AUTOMATIC PREDICTION OF MAINTENANCE INTERVENTION TYPES IN ROADS USING MACHINE LEARNING AND HISTORICAL RECORDS

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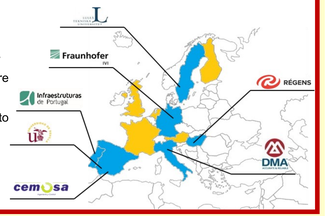
SCOPE

1

- This research is part of an European Horizon 2020 Project named **INFRALERT** and focuses on a specific issue within this project.
- **INFRALERT** is formed by 7 partners from 6 EU countries.
- Main goals:
  - Improving linear transport infrastructure efficiency/ capacity **at reduced budget and land availability**.
  - **Optimise the performance** of existing infrastructure **to enhance its capacity** to meet society needs.
  - To develop an **expert based information system** to support and automate infrastructure management.
  - From **measurements to maintenance**.
  - Suitable for linear infrastructure and applied in particular to **roads and railways**.

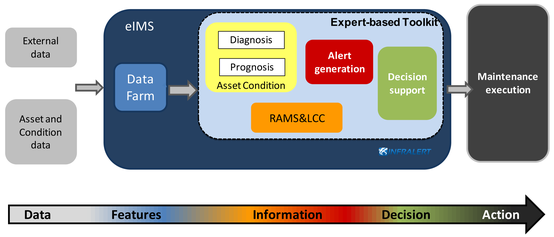


INFRALERT

2

INFRALERT is about **Intelligent Maintenance Planning for Linear Transport Infrastructures.**

A **modular architecture** consisting of several **plug-in modules** in a common framework: the *expert-based* Infrastructure management System (**eIMS**).



ALERT GENERATION TOOLKIT

In this research the **methodologies and algorithms** that define the Alert Generation expert-based toolkit have been developed.

Main objectives of this research:

- To **infer alerts** (where maintenance will be needed) for assets based on the **state conditions**.
- To prescribe a **level of severity** to all alerts.
- To **prioritise all alerts** according to their level of severity.
- To **recommend** the k-most probable **maintenance interventions** for each alert.
- To **learn from the new information** provided by the Maintenance Manager.

PROPOSED METHODOLOGY

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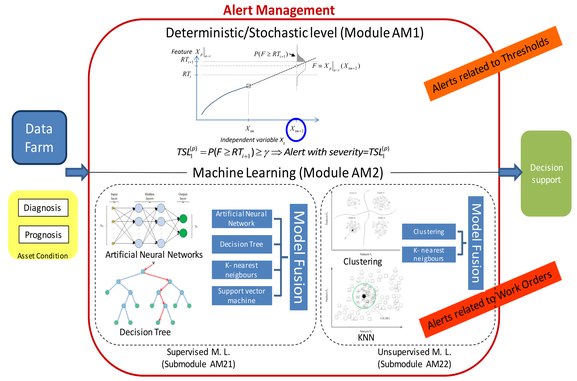


The proposed methodology infers **two types of alerts**.

Alert Related to Thresholds (Module AM1)

These Alerts are triggered by the **deviation of the predicted condition** of the assets from the **Standards**.

The **outputs** of this module are:

- A **specific feature** exceeds the prescribed threshold limit.
- **Technical severity levels** (TSL), an objective value to prioritise alerts regarding the asset predicted condition.

These kind of alerts are important since thresholds are very well defined in the regulations

Alert Related to Work Orders (Module AM2)

These Alerts are inferred by **correlating** the **historical maintenance interventions** with **measurements** carried out in the infrastructure network.

The **outputs** of this module are:

- **Alert triggered** (an intervention maintenance is required).
- **Global Technical Severity Level** (GTSL), an objective value to prioritise alerts.
- **K-Most probable intervention** to perform on the asset.
- **Probability** for each forecasted intervention listed to **be required**.

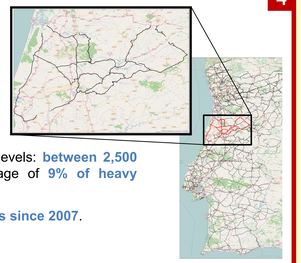
These alerts are important when maintenance depends on the subjective criteria of the Maintenance Manager.

REAL CASE and RESULTS

4

The pilot comprises **539 km** of roads in **Portugal**.

It includes a **rich variety of road categories** (principal itineraries, supplementary itineraries, national roads, regional roads and other roads) **classified** according to **travel speed, traffic volume, traffic mix and strategic importance**.



The pilot case presents heterogeneity in traffic levels: **between 2,500 and 10,000 vehicles per day**, with an average of **9% of heavy vehicles**.

Historical database stores **maintenance activities since 2007**.

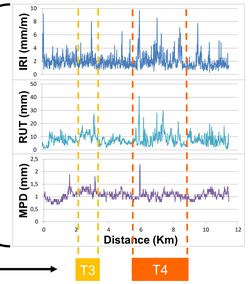
VARIABLES

Asset Properties

- Traffic flow
- Road category (motorway, arterial road, …).
- Heavy vehicle traffic.
- Road type (Rigid or flexible pavement, …).
- …

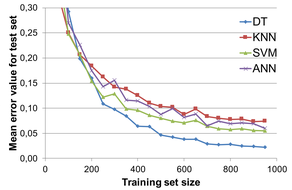
Measurements

Maintenance Interventions



MACHINE LEARNING MODELS

- **Outlier detection** and **data cleaning** have been carried out previous to the training.
- The road network has been split in **same size sections** in order to compare with sections on other roads and with itself in different periods.
- **All maintenance interventions are represented in the testing set**. The number of records of each maintenance intervention type are sufficient to **prevent bias**.
- The **mean error value** for all models, when they are **predicting alerts**, is low from a minimum of 500 records.
- The **k-most probable maintenance** types are predicted using a multiplicity of **features, variables** and **assets' condition**.



RESULTS

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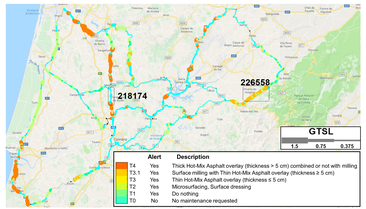
The methodology has been applied using predictions provided by the Asset Condition toolkit for a specific scenario. The figure shows the **Alerts**, the **most probable maintenance interventions** and the **severity level** (GTSL) of all assets of the pilot case in a graphical form.



VALIDATION

The methodology has been validated with **real data** provided by Infraestruturas de Portugal for the **period 2012-2016**. Two cases are shown.

- Road maintained in 2013: Alerts are no longer triggered.

Road ID			Global Technical Severity Level (GTSL)					Estimated Alert					Maintenance Intervention				
Section ID	Category	Section	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016	2012	2013	2014	2015
218174	2521	0	0,358	0,353	0,285	0,307	0,398	-	-	-	-	-	-	Maintained	-	-
218174	2521	0,5	0,367	0,645	0,287	0,32	0,342	-	-	-	-	-	-	Maintained	-	-
218174	2521	1	0,596	0,688	0,318	0,436	0,429	-	Alert	-	-	-	-	Maintained	-	-
218174	2521	1,5	0,737	0,653	0,448	0,656	0,601	Alert	Alert	-	-	-	-	Maintained	-	-
218174	2521	2	0,477	0,475	0,279	0,37	0,445	-	-	-	-	-	-	Maintained	-	-
218174	2521	2,5	1,144	1,052	0,187	0,212	0,227	Alert	Alert	-	-	-	-	Maintained	-	-
218174	2521	3	1,078	1,247	0,204	0,228	0,231	Alert	Alert	-	-	-	-	Maintained	-	-
218174	2521	3,5	0,801	1,051	0,268	0,346	0,407	Alert	Alert	-	-	-	-	Maintained	-	-
218174	2521	4	0,563	0,757	0,194	0,21	0,231	Alert	Alert	-	-	-	-	Maintained	-	-
218174	2521	4,5	0,338	0,585	0,157	0,174	0,187	-	Alert	-	-	-	-	Maintained	-	-
218174	2521	5	0,498	0,532	0,195	0,219	0,293	-	-	-	-	-	-	Maintained	-	-
218174	2521	5,5	0,969	0,56	0,169	0,188	0,2	Alert	-	-	-	-	-	Maintained	-	-
218174	2521	6	0,505	0,328	0,219	0,233	0,332	-	-	-	-	-	-	Maintained	-	-
218174	2521	6,5	0,377	0,288	0,208	0,224	0,232	-	-	-	-	-	-	Maintained	-	-
218174	2521	7	0,779	0,642	0,248	0,263	0,277	Alert	Alert	-	-	-	-	Maintained	-	-
218174	2521	7,5	0,481	0,925	0,718	1,044	1,056	-	Alert	Alert	Alert	Alert	-	-	-	-
218174	2521	8	0,313	0,979	0,804	1,024	0,862	-	Alert	Alert	Alert	Alert	-	-	-	-

- Road without maintenance: Alerts remain active in the time interval.

Road ID			Global Technical Severity Level (GTSL)					Estimated Alert					Maintenance Intervention				
Section ID	Category	Section	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016	2012	2013	2014	2015
226558	2522	0	1,228	0,991	0,967	0,643	1,1	Alert	Alert	Alert	-	Alert	-	-	-	-
226558	2522	0,5	1,145	1,161	1,067	0,945	0,864	Alert	Alert	Alert	Alert	Alert	-	-	-	-
226558	2522	1	1,194	1,301	1,226	1,165	1,361	Alert	Alert	Alert	Alert	Alert	-	-	-	-
226558	2522	1,5	1,22	1,27	1,252	1,217	1,276	Alert	Alert	Alert	Alert	Alert	-	-	-	-
226558	2522	2	0,625	1,113	1,066	1,103	1,154	-	Alert	Alert	Alert	Alert	-	-	-	-
226558	2522	2,5	0,991	1,261	1,147	1,182	1,292	Alert	Alert	Alert	Alert	Alert	-	-	-	-

CONCLUSIONS

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- Several **Machine Learning** models have been generated, implemented in a toolkit and proved to work for a real pilot case.
- The **quality of the stored information** relative to the maintenance interventions conducted in the past is of uttermost importance for a reliable prediction. The procedure to obtain the information relevant to the self-learning process of the models is described in the paper.
- The **predictions** of maintenance interventions can be **continuously improved** with the inferred information derived from positive/negative false estimates.
- This research is on going: a) additional data will be incorporate to the predicting model, b) a longer period of validation under the supervision of the maintenance manager is needed.

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