



Alert management

2nd INFRA ALERT Open Workshop 17.04.2018

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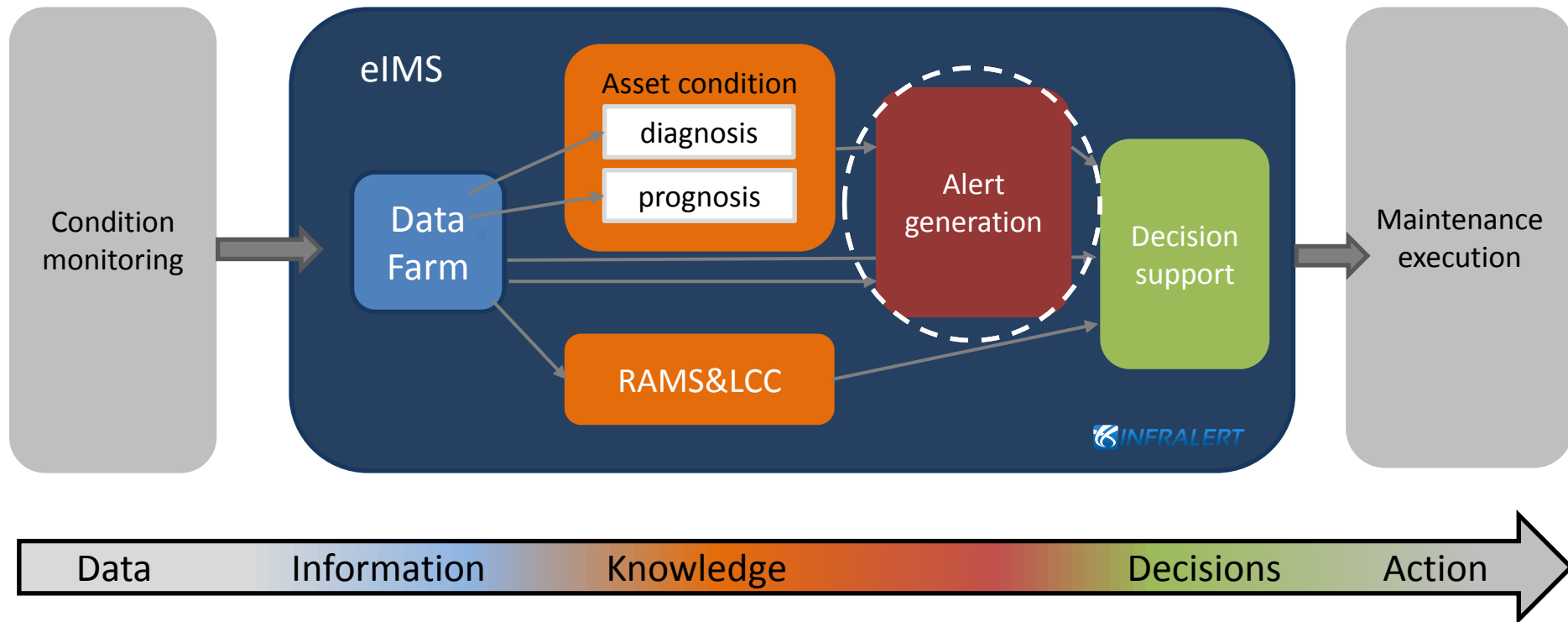


University of Sevilla

- General Overview & Objectives
- Methodological scheme
 - Relevant information
 - Machine Learning
 - Prediction stage
- Road Use Case
 - Historical Data
 - Machine Learning predictions
- Rail Use Case
 - Historical Data
 - Machine Learning predictions
- Conclusions



General Overview & Objectives



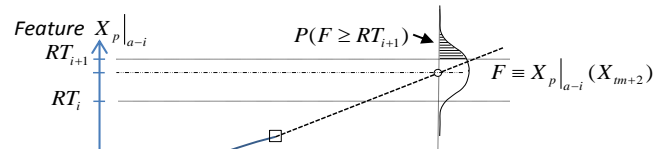
Objectives

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



Alert Management

Deterministic/Stochastic level (Module AM1)



Alerts related to
estimated features

OUTPUTS MODULE AM2:

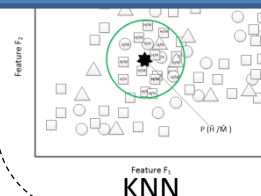
- Alerts: where maintenance is required (ALERT).
- Global Technical Severity Level (GTSL) of the alert.
- K-Most probable interventions to solve the alert.
- Probability of occurrence of the most probable interventions.

Decision support



Decision Tree

Support vector machine



KNN

Supervised M. L.
(Submodule AM21)

Unsupervised M. L.
(Submodule AM22)

Alerts related to Work Orders

Data Farm

Diagnosis

Prognosis

Asset Condition

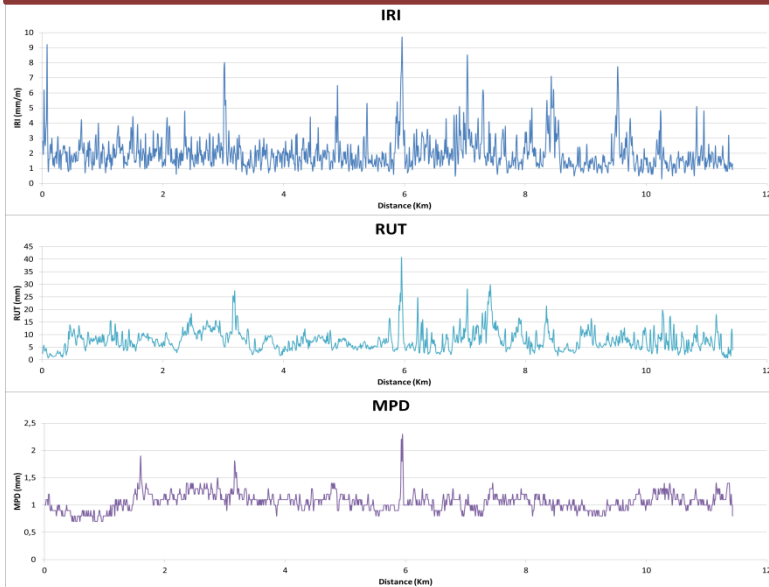


Methodological scheme.

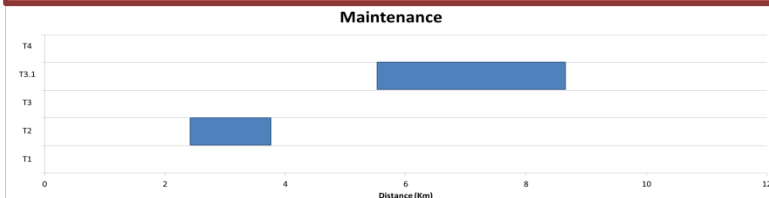
Relevant information for machine learning training stage



Measurements



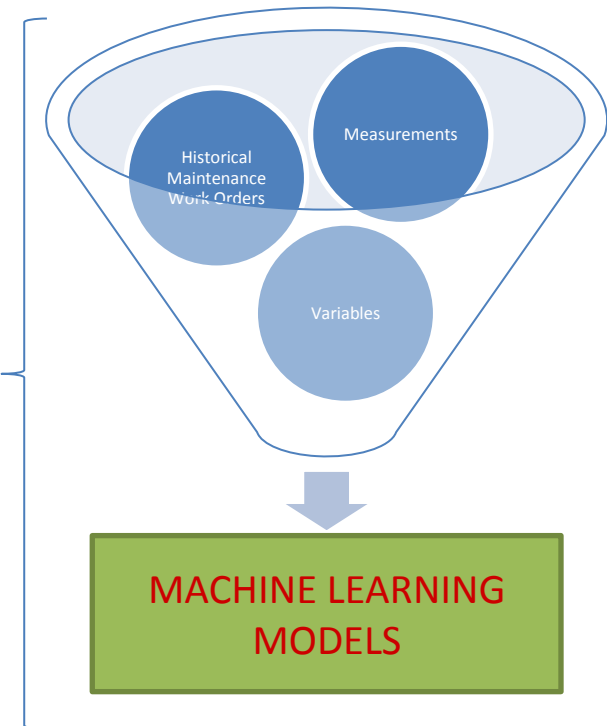
Maintenance Work Orders



External + Internal Infrastructure Variables

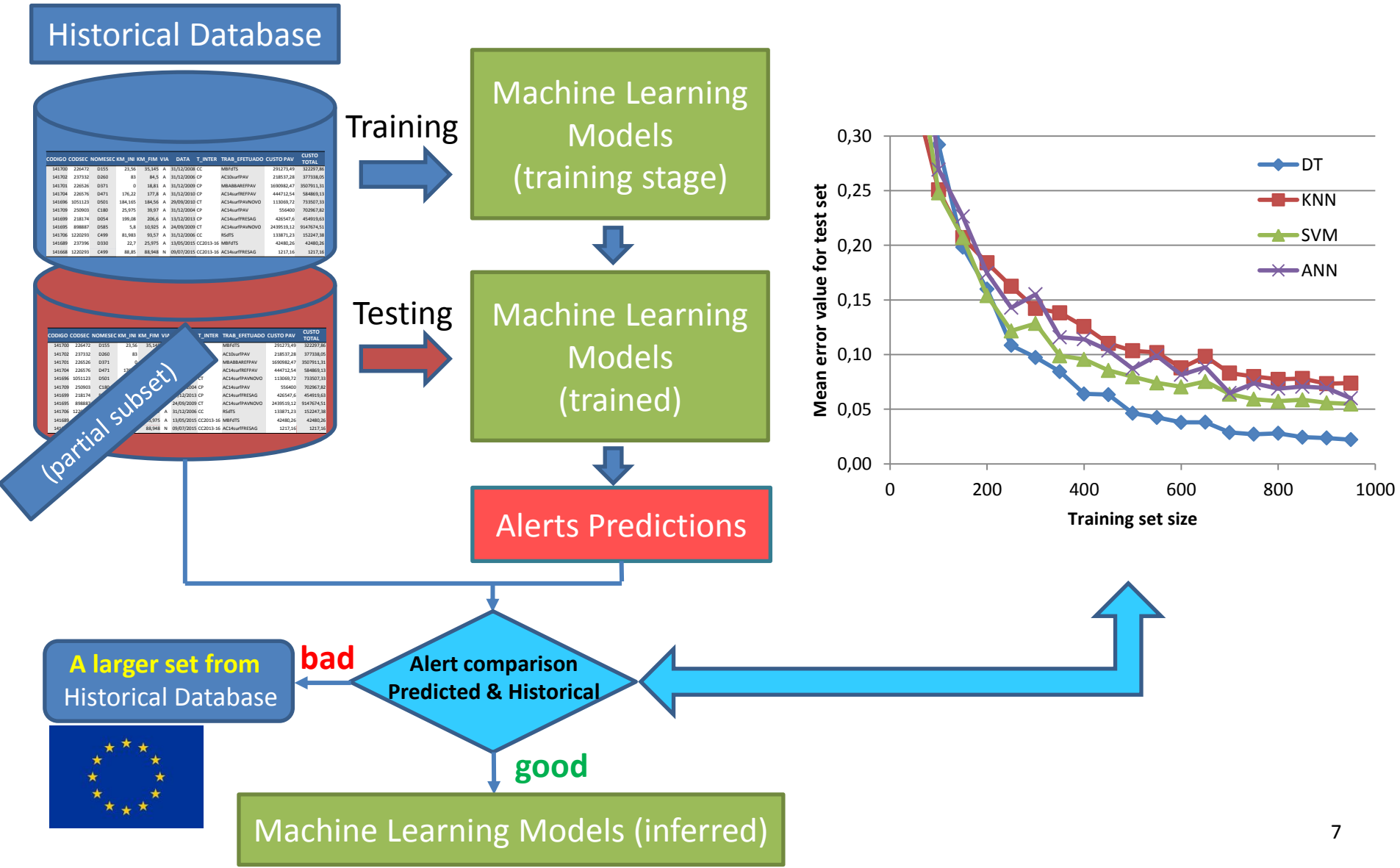
- Traffic flow
- Road category (motorway, arterial road, ...).
- Heavy vehicle traffic.
- Road type (Rigid pavement, flexible pavement,...).
- ...

Machine Learning



Methodological scheme.

Machine Learning training stage



Methodological scheme.

Machine Learning training stage (accuracy)



PPV: Right Predictions per maintenance type (Positive Predicted value)

FDR: Wrong Predictions per maintenance type (False discovery rate)

PPV
FDR

*Predicted
Maintenance Type*

Maint. Type	Description
T0	No maintenance requested
T1	Do nothing
T2	Microsurfacing, Surface dressing
T3	Thin Hot-Mix Asphalt overlay (< 5 cm)
T3.1	Surface milling + Thin Hot-Mix Asphalt (≥ 5 cm)
T4	Thick Hot-Mix Asphalt (> 5 cm) with/without milling

T0 No Alert	14.7 %	0 %	0 %	0.6 %	0 %	0 %	95.8 % 4.2 %
T1	0 %	14.1 %	0 %	0.6 %	0 %	0 %	95.7 % 4.3 %
T2	0 %	1.9 %	15.4 %	0 %	0 %	0 %	88.9 % 11.1 %
T3	0.6 %	0 %	0.6 %	16.7 %	1.9 %	0 %	83.9 % 16.1 %
T3.1	0 %	0 %	1.3 %	0 %	14.7 %	0 %	92.0 % 8.0 %
T4	0 %	0 %	0.6 %	0.6 %	1.3 %	14.1 %	84.6 % 15.4 %
	95.8 % 4.2 %	88.0 % 12.0 %	85.7 % 14.3 %	89.7 % 10.3 %	82.1 % 17.9 %	100 % 0.0 %	89.7 % 10.3 %
	T0 No Alert	T1	T2	T3	T3.1	T4	ACC ERR

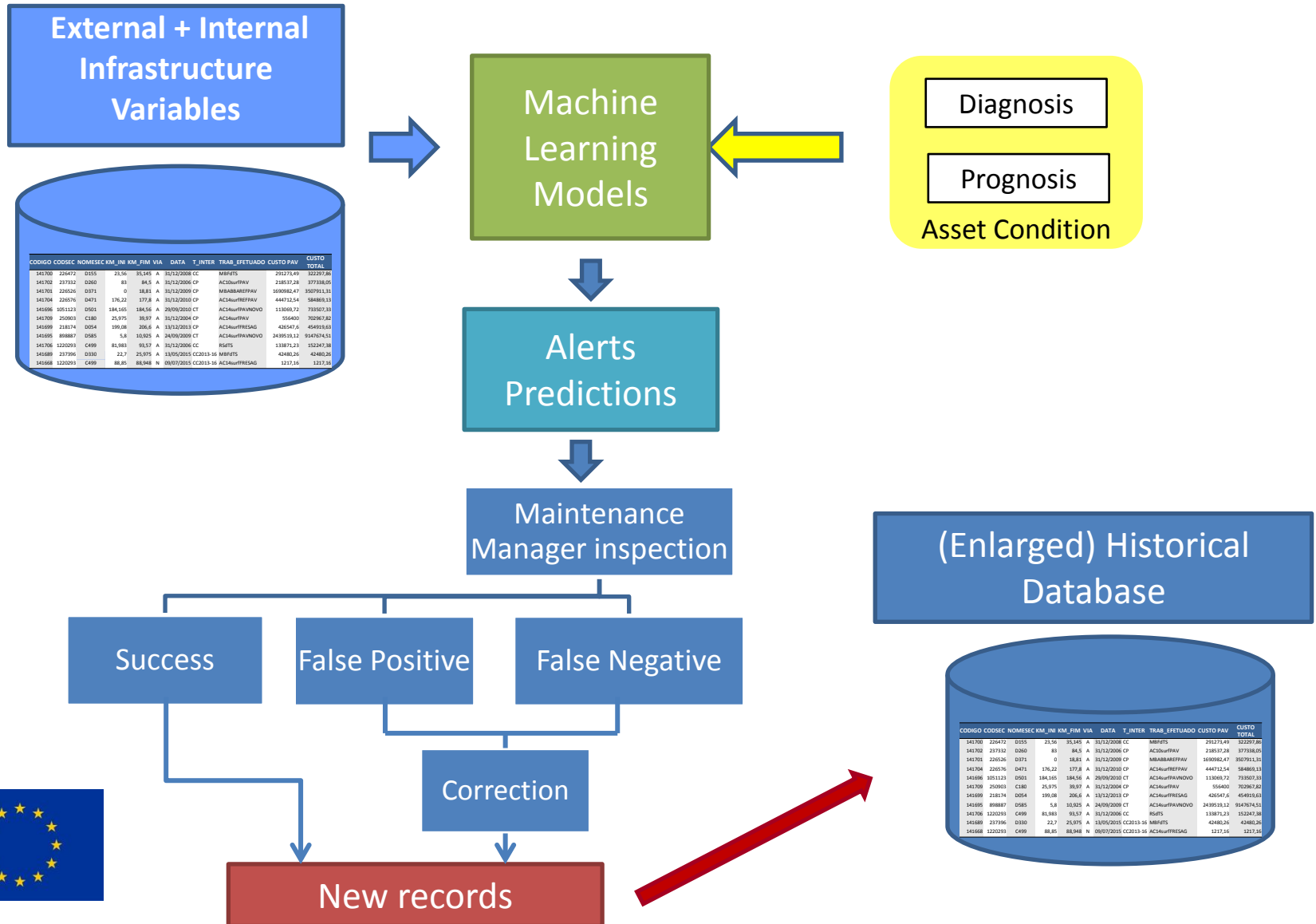
*Real
Maintenance Type (WO)*

ACC: Right Predictions (Accuracy rate)

ERR: Wrong Predictions (False discovery rate)

Methodological scheme.

Prediction stage + learning stage



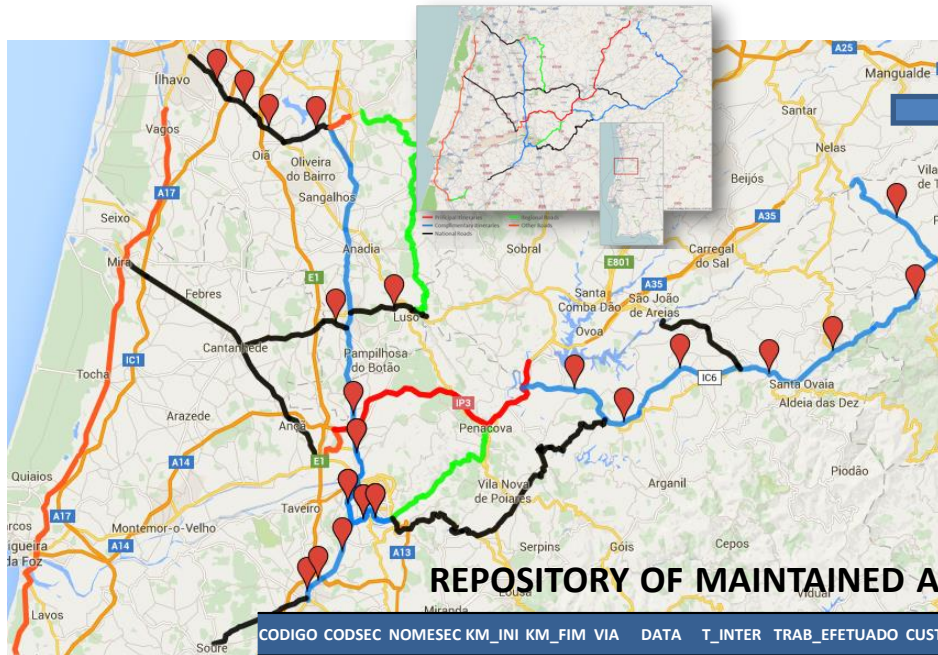
Road Use Case.

Historical Data



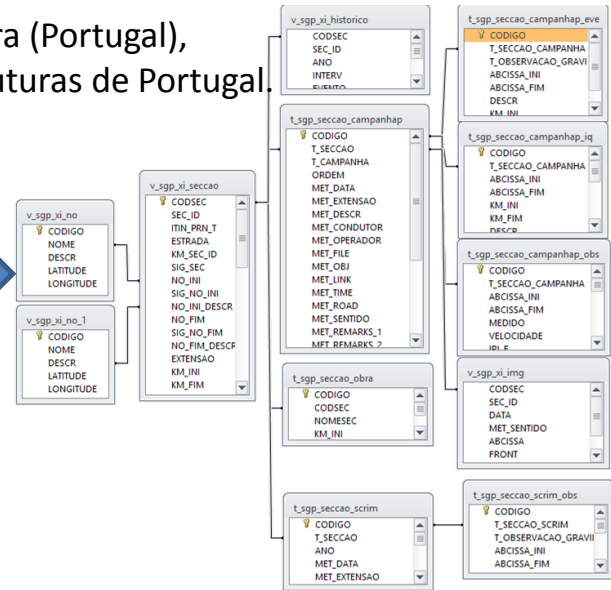
Road Demonstration in Portugal

Road network, Coimbra (Portugal), managed by Infraestruturas de Portugal.



REPOSITORY OF MAINTAINED ASSET

CODIGO	CODSEC	NOMESEC	KM_INI	KM_FIM	VIA	DATA	T_INTER	TRAB_EFETUADO	CUSTO PAV	CUSTO TOTAL
141700	226472	D155	23,56	35,145	A	31/12/2008	CC	MBFdTS	291273,49	322297,86
141702	237332	D260	83	84,5	A	31/12/2006	CP	AC10surfPAV	218537,28	377338,05
141701	226526	D371	0	18,81	A	31/12/2009	CP	MBABBAREPAV	1690982,47	3507911,31
141704	226576	D471	176,22	177,8	A	31/12/2010	CP	AC14surfREFPAV	444712,54	584869,13
141696	1051123	D501	184,165	184,56	A	29/09/2010	CT	AC14surfPAVNOVO	113069,72	733507,33
141709	250903	C180	25,975	39,97	A	31/12/2004	CP	AC14surfPAV	556400	702967,82
141699	218174	D054	199,08	206,6	A	13/12/2013	CP	AC14surfFRESAG	426547,6	454919,63
141695	898887	D585	5,8	10,925	A	24/09/2009	CT	AC14surfPAVNOVO	2439519,12	9147674,51
141706	1220293	C499	81,983	93,57	A	31/12/2006	CC	RSdTS	133871,23	152247,38
141689	237396	D330	22,7	25,975	A	13/05/2015	CC2013-16	MBFdTS	42480,26	42480,26
141668	1220293	C499	88,85	88,948	N	09/07/2015	CC2013-16	AC14surfFRESAG	1217,16	1217,16



Historical Database

CODIGO	CODSEC	NOMESEC	KM_INI	KM_FIM	VIA	DATA	T_INTER	TRAB_EFETUADO	CUSTO PAV	CUSTO TOTAL
141700	226472	D155	23,56	35,145	A	31/12/2008	CC	MBFdTS	291273,49	322297,86
141702	237332	D260	83	84,5	A	31/12/2006	CP	AC10surfPAV	218537,28	377338,05
141701	226526	D371	0	18,81	A	31/12/2009	CP	MBABBAREPAV	1690982,47	3507911,31
141704	226576	D471	176,22	177,8	A	31/12/2010	CP	AC14surfREFPAV	444712,54	584869,13
141696	1051123	D501	184,165	184,56	A	29/09/2010	CT	AC14surfPAVNOVO	113069,72	733507,33
141709	250903	C180	25,975	39,97	A	31/12/2004	CP	AC14surfPAV	556400	702967,82
141699	218174	D054	199,08	206,6	A	13/12/2013	CP	AC14surfFRESAG	426547,6	454919,63
141695	898887	D585	5,8	10,925	A	24/09/2009	CT	AC14surfPAVNOVO	2439519,12	9147674,51
141706	1220293	C499	81,983	93,57	A	31/12/2006	CC	RSdTS	133871,23	152247,38
141689	237396	D330	22,7	25,975	A	13/05/2015	CC2013-16	MBFdTS	42480,26	42480,26
141668	1220293	C499	88,85	88,948	N	09/07/2015	CC2013-16	AC14surfFRESAG	1217,16	1217,16

Road Use Case.

Machine learning Predictions (I)

CODIGO	CODSEC	NOMESEC	KM_INI	KM_FIM	VIA	DATA	T_INTER	TRAB_EFETUADO	CUSTO_PAV	CUSTO_TOTAL
141700	226472	D155	23,56	35,545	A	31/12/2008	CC	MBFRTS	201273,49	322297,86
141702	237332	D260	81	84,5	A	31/12/2008	CP	AC10urFFAV	218537,28	377338,05
141701	226526	D371	0	18,81	A	31/12/2009	CP	MBABAREFFAV	160982,47	350791,131
141704	226576	D471	176,22	177,8	A	31/12/2010	CP	AC14urFFAV	444712,54	584869,13
141696	1051123	D501	184,165	184,56	A	29/09/2010	CT	AC14urFFAVNOVO	113060,72	733507,33
141709	250903	C180	25,975	39,97	A	31/12/2004	CP	AC14urFFAV	556400	702967,82
141699	218174	D054	199,08	206,6	A	13/12/2013	CP	AC14urFFRESAG	426547,6	454919,63
141695	898887	D585	5,8	10,925	A	24/09/2009	CT	AC14urFFAVNOVO	2439519,12	9147674,51
141706	1220293	C499	81,983	93,57	A	31/12/2008	CC	RS6TS	133871,23	152247,38
141689	237396	D330	22,7	25,975	A	13/05/2015	CC2013-16	MBFRTS	42480,26	42480,26
141688	1220293	C499	88,85	88,948	N	09/07/2015	CC2013-16	AC14urFFRESAG	1217,16	1217,16

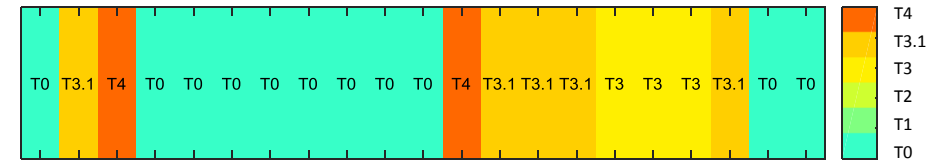
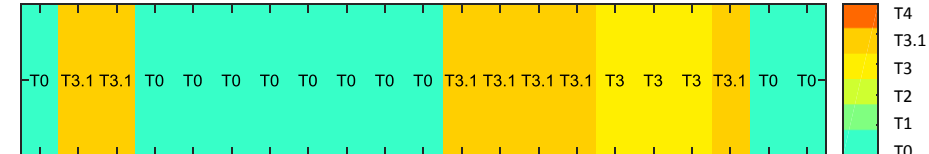


- ✓ Model validation (predicting capabilities) using road features measured

Maintenance type Work Orders 2014

CODSEC	NETCLASS	KM_INI	KM_END	CT	IRI	RUT	Real WO
226512	2521	120,54	121,041	15,28	2,70	2,63	T0
226512	2521	121,041	121,541	1,79	2,24	2,30	T0
226512	2521	121,551	122,051	53,62	2,87	3,90	T3.1
226512	2521	122,061	122,561	41,67	2,53	4,13	T3.1
226512	2521	122,571	123,071	65,71	4,96	4,73	T4
226512	2521	123,081	123,581	46,15	4,20	6,29	T4
226512	2521	123,591	124,091	28,38	3,23	4,91	T3
226512	2521	124,101	124,601	28,79	3,78	5,35	T3
226512	2521	124,611	125,111	42,67	2,72	3,82	T3.1
226512	2521	125,121	125,621	52,54	4,60	6,68	T4

Real WO



Segments of 0.5km [from - to]

Predicted WO

Predicted WO

Real Work Orders vs.
Predicted Work Orders
Model Accuracy ~ 90%

Models trained

Artificial Neural
Network

Decision Tress

K- nearest
neighbours

Support vector
machine

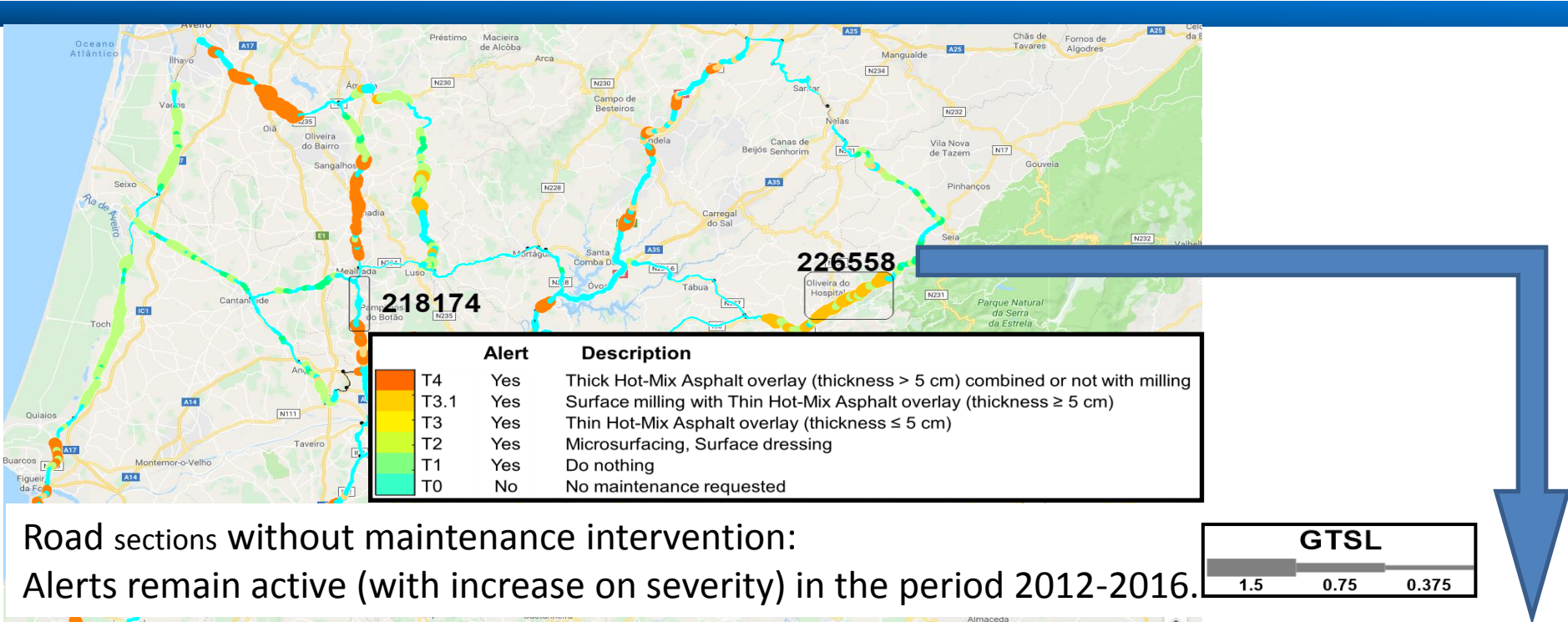
Model Fusion

Table 1. Description of maintenance types

M	Alert	Description
T0	No	No maintenance requested
T1	Yes	Do nothing
T2	Yes	Microsurfacing, Surface dressing
T3	Yes	Thin Hot-Mix Asphalt overlay (thickness ≤ 5 cm)
T3.1	Yes	Surface milling with Thin Hot-Mix Asphalt overlay (thickness ≥ 5 cm)
T4	Yes	Thick Hot-Mix Asphalt overlay (thickness > 5 cm) combined or not with milling

Road Use Case.

Machine learning Predictions (II)



Road sections without maintenance intervention:

Alerts remain active (with increase on severity) in the period 2012-2016.

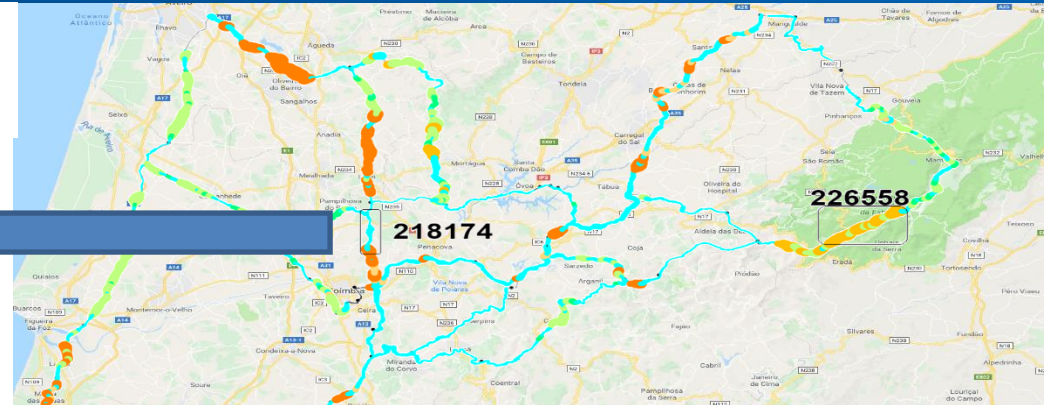
Road ID: 226558, Category: 2522														
Section	Global Technical Severity Level					Estimated Alert					Maintenance Intervention			
	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016	2012	2013	2014	2015
0	1,228	0,991	0,967	0,649	1,1	Alert	Alert	Alert	-	Alert	-	-	-	-
0,5	1,145	1,161	1,067	0,945	0,864	Alert	Alert	Alert	Alert	Alert	-	-	-	-
1	1,194	1,301	1,226	1,165	1,361	Alert	Alert	Alert	Alert	Alert	-	-	-	-
1,5	1,22	1,27	1,252	1,217	1,276	Alert	Alert	Alert	Alert	Alert	-	-	-	-
2	0,625	1,113	1,066	1,103	1,154	-	Alert	Alert	Alert	Alert	-	-	-	-
2,5	0,991	1,261	1,147	1,182	1,292	Alert	Alert	Alert	Alert	Alert	-	-	-	-

Road Use Case.

Machine learning Predictions (III)



Road sections maintained in 2013:
Alerts are no longer triggered in 2014-2016.



Road ID: 218174, Category: 2521														
	Global Technical Severity Level					Estimated Alert					Maintenance Intervention			
Section	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016	2012	2013	2014	2015
0	0,358	0,353	0,285	0,307	0,398	-	-	-	-	-	-	Maintained	-	-
0,5	0,367	0,645	0,287	0,32	0,342	-	-	-	-	-	-	Maintained	-	-
1	0,596	0,688	0,318	0,436	0,429	-	Alert	-	-	-	-	Maintained	-	-
1,5	0,737	0,653	0,448	0,656	0,601	Alert	Alert	-	-	-	-	Maintained	-	-
2	0,477	0,475	0,279	0,37	0,445	-	-	-	-	-	-	Maintained	-	-
2,5	1,144	1,052	0,187	0,212	0,227	Alert	Alert	-	-	-	-	Maintained	-	-
3	1,078	1,247	0,204	0,228	0,231	Alert	Alert	-	-	-	-	Maintained	-	-
3,5	0,801	1,051	0,268	0,346	0,407	Alert	Alert	-	-	-	-	Maintained	-	-
4	0,563	0,757	0,194	0,21	0,231	Alert	Alert	-	-	-	-	Maintained	-	-
4,5	0,338	0,585	0,157	0,174	0,187	-	Alert	-	-	-	-	Maintained	-	-
5	0,498	0,532	0,195	0,219	0,293	-	-	-	-	-	-	Maintained	-	-
5,5	0,969	0,56	0,169	0,188	0,2	Alert	-	-	-	-	-	Maintained	-	-
6	0,505	0,328	0,219	0,233	0,332	-	-	-	-	-	-	Maintained	-	-

Rail Use Case. Historical Data



Rail Demonstration in Sweden

Rail Demonstration at Railway corridor,
Iron Ore Line in Malmbannan in northern
Sweden, managed by Trafikverket.



Historical Database

CODIGO	CDSECC	NOMESEC	KM_INI	KM_FIM	VIA	DATA	T_INTER	TRAB	EFTUADO	CUSTO_PAV	CUSTO_TOTLA
141300	220472	0535	23,56	35,145	A	31/12/2008	CC	MBFITS	201277,49	322292,24	
141301	220472	0540	81	84,5	A	31/12/2008	CP	AC34uPRFV	238557,28	377336,09	
141302	220472	0571	0	18,83	A	31/12/2008	CP	MBABABREFAV	160098,47	307921,33	
141304	220576	0471	176,22	177,8	A	31/12/2008	CP	AC34uPRFV	444712,54	584889,13	
141306	205123	0501	184,165	184,56	A	29/09/2002	CT	AC34uPRVNOVO	113669,72	731007,33	
141309	202603	C385	25,475	39,57	A	31/12/2008	CP	AC34uPRV	556400	702067,32	
141309	218124	0504	199,08	206,6	A	13/12/2003	CP	AC34uPRFV	426247,5	454919,63	
141305	888887	0585	5,8	10,925	A	24/09/2008	CT	AC34uPRVNOVO	2499519,12	9142674,51	
141306	1220231	C491	81,863	93,57	A	31/12/2008	CC	MBFITS	133871,23	112347,38	
141309	237396	0302	22,7	25,975	A	13/09/2005	CC2003-16	MBFITS	42480,26	42480,26	
141308	1220231	C491	88,85	88,88	N	09/07/2005	CC2003-16	AC34uPRFV	1217,16	1217,16	

Training

Testing

Machine Learning
Models
(training stage)

Machine Learning
Models

Measurements

PREDICTED ALERTS

Track	KM_Start	KM_End	GTSL					Estimated Alerts				
			2008	2009	2010	2011	2012	2008	2009	2010	2011	2012
2	280,5	280,7	0,34	0,39	0,41	0,23	0,28	Alert	Alert	Alert	-	Alert
2	280,7	280,9	0,44	0,47	0,47	0,33	0,46	Alert	Alert	Alert	Alert	Alert
2	280,9	281,1	0,41	0,46	0,46	0,34	0,38	Alert	Alert	Alert	Alert	Alert
2	281,1	281,3	0,57	0,62	0,65	0,37	0,47	Alert	Alert	Alert	-	Alert
2	281,3	281,5	0,39	0,40	0,44	0,38	0,42	Alert	Alert	Alert	Alert	Alert



Rail Use Case.

Machine learning Predictions (I)



Alert	Bad conditions but Do Nothing
Alert	Maintenance Intervent. required

Track	KM_Start	KM_End	GTSL					Estimated Alerts				
			2008	2009	2010	2011	2012	2008	2009	2010	2011	2012
2	254,9	255,1	0,40	0,42	0,45	0,46	0,46	Alert	Alert	Alert	Alert	Alert
2	255,1	255,3	0,41	0,46	0,48	0,52	0,58	Alert	Alert	Alert	Alert	Alert
2	255,3	255,5	0,40	0,44	0,46	0,49	0,53	Alert	Alert	Alert	Alert	Alert
2	255,5	255,7	0,45	0,37	0,40	0,44	0,44	Alert	Alert	Alert	Alert	Alert
2	255,7	255,9	0,37	0,34	0,38	0,40	0,40	Alert	-	Alert	Alert	Alert

Track	Km_Start	Km_End	Intervention	2008	2009	2010	2011	2012
2	254,9	255,1	Do Nothing	33	20	15	11	13
			Tamping	37	48	53	54	52
			Ballast Regulation	30	33	33	35	35
2	255,1	255,3	Do Nothing	25	9	3	2	0
			Tamping	43	55	54	55	65
			Ballast Regulation	32	36	43	43	36
2	255,3	255,5	Do Nothing	68	45	49	29	19
			Tamping	25	45	41	61	72
			Ballast Regulation	7	10	11	10	10
2	255,5	255,7	Do Nothing	30	62	59	48	54
			Tamping	50	19	21	30	27
			Ballast Regulation	20	19	19	22	19
2	255,7	255,9	Do Nothing	74	0	59	63	67
			Tamping	17	0	21	21	15
			Ballast Regulation	9	0	19	17	18



Rail Use Case.

Machine learning Predictions (II)



Track	KM_Start	KM_End	GTSL					Estimated Alerts				
			2008	2009	2010	2011	2012	2008	2009	2010	2011	2012
2	280,5	280,7	0,34	0,39	0,41	0,23	0,28	Alert	Alert	Alert	-	Alert
2	280,7	280,9	0,44	0,47	0,47	0,33	0,46	Alert	Alert	Alert	Alert	Alert
2	280,9	281,1	0,41	0,46	0,46	0,34	0,38	Alert	Alert	Alert	Alert	Alert
2	281,1	281,3	0,57	0,62	0,65	0,37	0,47	Alert	Alert	Alert	-	Alert
2	281,3	281,5	0,39	0,40	0,44	0,38	0,42	Alert	Alert	Alert	Alert	Alert

Alert	Bad conditions but Do Nothing
Alert	Maintenance Intervent. required

Track	Km_Start	Km_End	Intervention	2008	2009	2010	2011	2012
2	280,5	280,7	Do Nothing	75	27	19	0	78
			Tamping	16	42	49	0	15
			Ballast Regulation	9	32	32	0	7
2	280,7	280,9	Do Nothing	3	3	3	76	6
			Tamping	60	60	60	17	56
			Ballast Regulation	37	37	37	7	38
2	280,9	281,1	Do Nothing	46	6	8	79	64
			Tamping	30	57	54	12	20
			Ballast Regulation	24	37	38	9	17
2	281,1	281,3	Do Nothing	3	1	0	0	49
			Tamping	89	92	87	0	41
			Ballast Regulation	8	8	13	0	11
2	281,3	281,5	Do Nothing	68	50	21	67	50
			Tamping	20	31	60	18	43
			Ballast Regulation	12	19	20	15	7

Maintenance Inspection

Date:
26/09/2010

Asset type:
Switch&crossing

Intervention Hint:
Excess of ballast

Suggested Intervention:
Ballast regulation



- Several **Machine Learning** models have been generated, implemented in a toolkit and **proved to work** for two real pilot cases: a **Road network** in Portugal and two **Railway lines** in Sweden .
- The **quality of the stored information** relative to the maintenance interventions conducted in the past is of **utmost importance** for a reliable prediction. The procedure to obtain the information relevant to the self-learning process is based in Machine Learning algorithms.
- The **predictions** of maintenance interventions can be **continuously improved** with the inferred **information** derived from positive/negative **false estimates**.
- Further research: a) to **incorporate additional data** for improving prediction capabilities, b) **longer validation periods**





www.infralert.eu



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