Sustainability evaluation in asset management platforms

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SIIV Academy - ADVANCEMENTS IN ROAD ENGINEERING TOWARDS GREEN AND DIGITAL TRANSITION

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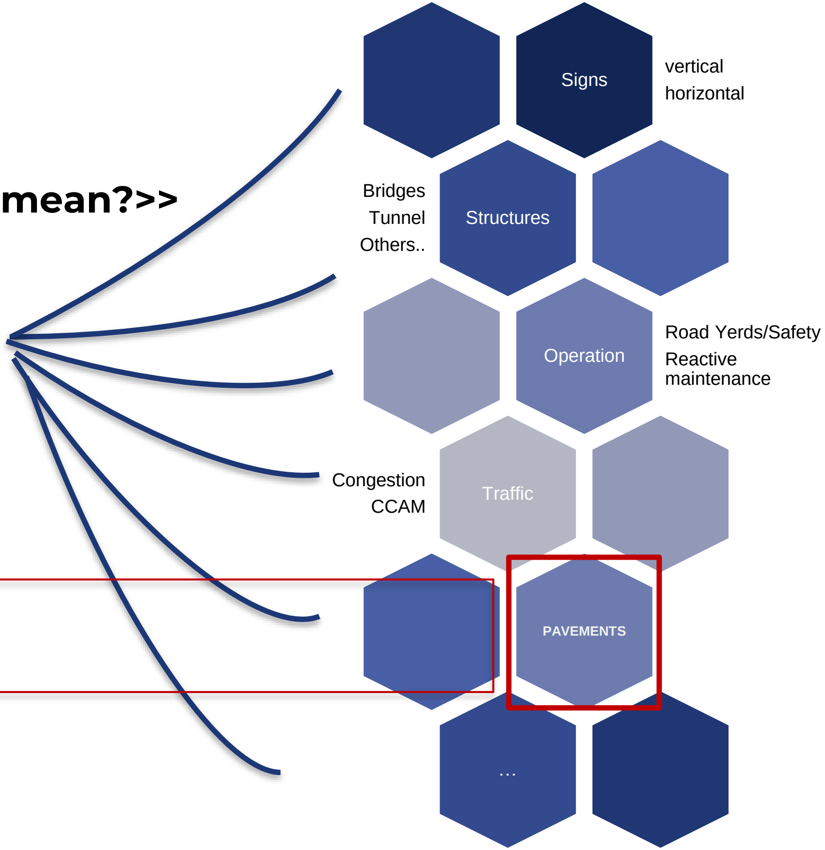
Sustainability evaluation in asset management platforms

[Open Question]

<<What does "asset management platform" mean?>>

"an asset management platform is a **powerful tool** that allows businesses to efficiently track, manage, and optimize their **assets**."

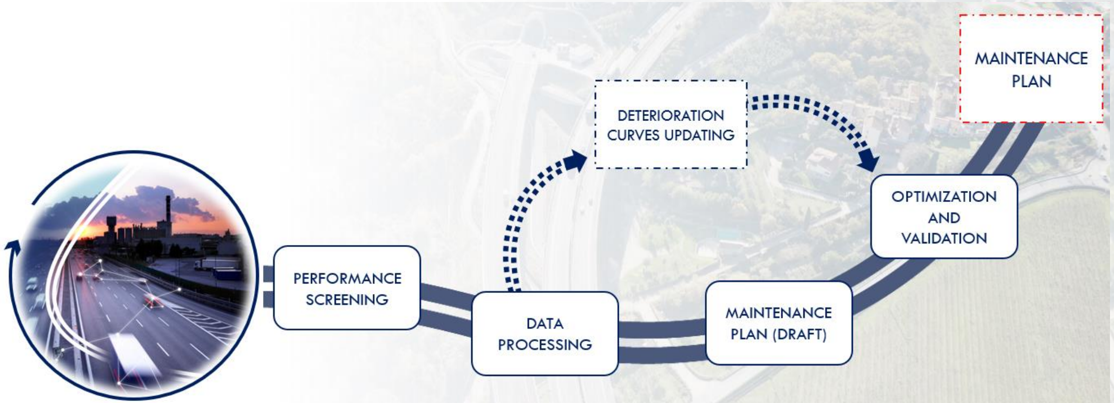


E-PMS

Evolutive **P**avement **M**anagment **S**ystem

E-PMS:
Evolutive Pavement Management System

ASPI E-PMS is an innovative and strategic tool developed by MOVYON Tech the Future with the technical supervision of UNIVERSITÀ POLITECNICA DELLE MARCHE which is already in use to define and validate optimized maintenance plans.



Monitoring
High-performance vehicles to collect performance data on the slow lane;

Knowledge
20-years data collection used to define procedures and «local» decay curves

Flexibility
Decay curves can be updated to consider significant variations of traffic spectra, weather conditions and construction characteristics in each traffic section;

Sustainability
Enviromental Asphalt Rating (EAR) intrducted to evaluate different maintenance strategies;

Evolutive **[work in progress...]**
Real time analysis of data from connected vehicles, fleet of vehicles, embedded sensors

E-PMS:

Evolutive Pavement Management System

Performance Screening

Maintenance plan definition process

PERFORMANCE SCREENING

SKID RESISTANCE - ROUGHNESS

SUMMS
(Survey Machine for Macrotexture and Skid)

- *Side Force Coefficient (CAT - Coefficiente di Aderenza Trasversale)*
- *MPD (Mean Profile Depth)*
- *IRI (International Roughness Index)*
- Measures under traffic
- Measurement pitch: 10 metres

BEARING CAPACITY

TSD
(Traffic Speed Deflectometer)

- ΔV (Deflection velocity of the road surface) -> deflections (micron) -> ***SCI300 (Surface Curvature Index)***
- Measures under traffic
- Measurement pitch: 10 metres
- Thickness measurement by Georadar

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E-PMS:

Evolutive Pavement Management System

Performance Screening

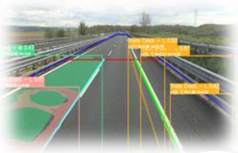
E-PMS innovations

DATA ACQUISITION
V2I Connection

Real time analysis ⟷ ⟷ **E-PMS** ⟷ **Maintenance plan**

✓ Automatic deteriorations analysis

These algorithms allow the identification of distress through a Real-Time analysis of the pavment. The images come from ASPI fleet of vehicles moving on the network.



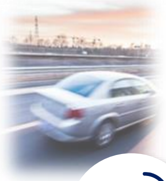
✓ Embedded Sensors

A monitoring technology, integrated into the pavement, capable of acquiring "undisturbed" measurements of the main physical characteristics inside the bounded layers (ex. temperature, humidity).

PATENT PENDING

✓ Smart Tyres

The interaction between the vehicle and the pavement takes place through the tire, and this technology is used to make very fast acquisition on the fastest lanes.



E-PMS:

Evolutive Pavement Management System

Data Processing

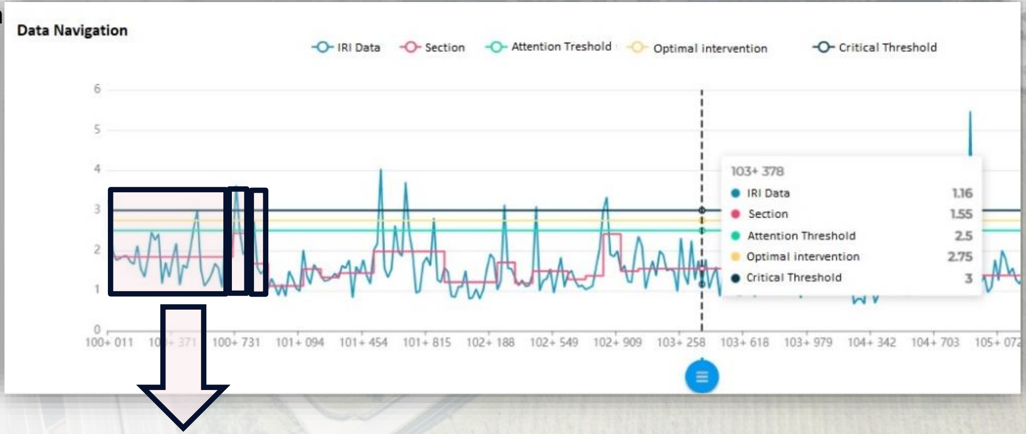
Traffic Data Homogeneous sections

- customised procedure to normalise the traffic effects
- a study of traffic spectra to define updated Load Equivalent Factors (LEF)
- traffic data available from tolling system **(close network)**
- The platform creates homogeneous sections for each parameter (IRI, CAT, SCI300)
- Bridges have been considered as independent homogeneous sections
- The process adopted in the E-PMS starts from a preliminary clustering in function of the traffic. These data are subsequently analysed through a statistical process

LEF (ESAL/vehic)	Motorway Type
5,11	4 lanes – high traffic
5,06	3 lanes – high traffic
4,94	3 lanes – medium traffic
3,95	2 lanes – low traffic

1st lane	2nd lane	Motorway Type
68%	**32%**	4 lanes – high traffic
83%	**17%**	3 lanes – high traffic
86%	**14%**	3 lanes – medium traffic
97%	**3%**	2 lanes – low traffic

DATA PROCESSING



Definition of homogeneous sections

E-PMS:

Evolutive Pavement Management System

Data Processing

Deterioration curves

DATA PROCESSING

- Prediction models and deterioration curves represent a crucial aspect of any Pavement Management System due to many combined influences of traffic, environment, pavement structure and maintenance strategies adopted;
- For this reason, parametric deterioration curves have been implemented within the E-PMS;
- This allows to customize the platform by setting different parameters in each traffic-section of the entire network.

[1] **Skid Resistance**	$CAT_{20,5-mis} = \boldsymbol{A} - \boldsymbol{B}\ \ln(t)$
[2] Roughness	$\theta_i = \boldsymbol{a} \cdot \left(SCI300_{r,50}\right)^{\boldsymbol{b}}$
[3] Bearing Capacity	$\varepsilon^r_{t,max} = \boldsymbol{a} \cdot \left(SCI300_{r,85}\right)^{\boldsymbol{b}}$ $E_r = \boldsymbol{c} \cdot \left(\varepsilon^r_{t,max}\right)^{\boldsymbol{d}}$ $N^r_{100} = 0{,}0795 \cdot \left(\frac{1}{\varepsilon^r_{t,max}}\right)^{3{,}291} \cdot \left(\frac{1}{E_r}\right)^{0{,}854}$

[1] Marchionna, A. P. (1994). Decadimento dell’aderenza sulle pavimentazioni autostradali. Autostrade.

[2] Regression curve obtained from field data.

[3] F. Canestrari, L. I. (2022). Assessing the remaining structural life of motorway pavements at the network level from Traffic Speed Deflectometer measurements. submitted to International Journal of Pavement Engineering.

E-PMS:

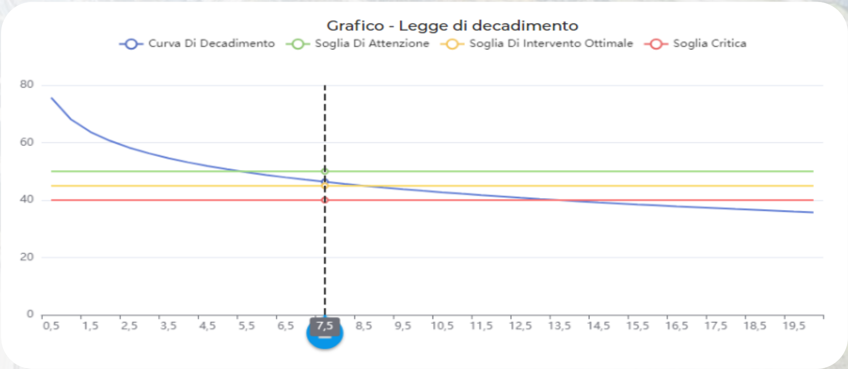
Evolutive Pavement Management System

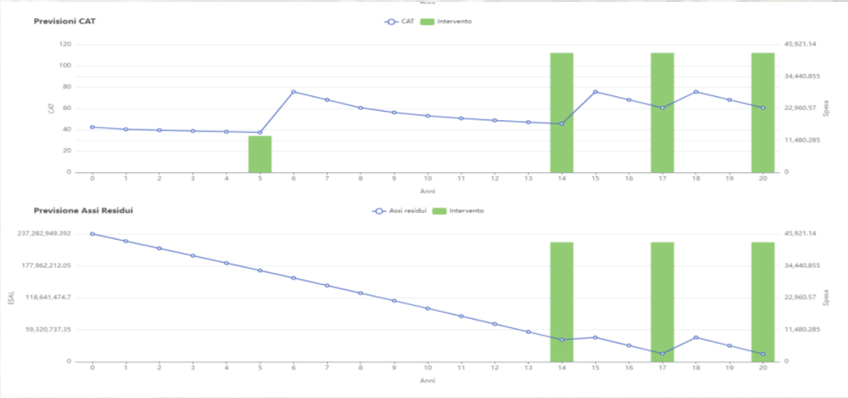
Data Processing

Deterioration curves

DATA PROCESSING

- An example of a homogeneous sections decay curve;
- The purpose of the decay curves is to estimate the residual service life for each hom.sec., therefore of the entire network;
- Thanks to the use of deterioration curves we can predict how often we need a maintenance activities;
- We can define a scenario according to the quality parameters (skid resistance and roughness);
- For each homogeneous section we can predict the maintenance for a short, medium and long period.



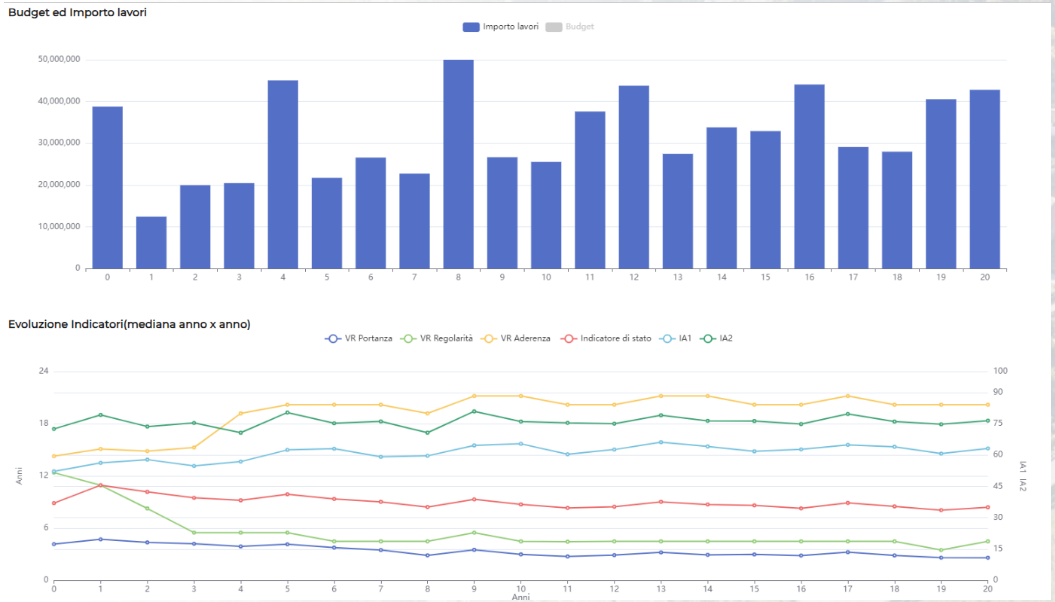


E-PMS:

Evolutive Pavement Management System

SCENARIO

Strategy



kpi: performance, economics…other

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E-PMS:

Evolutive Pavement Management System | **EAR Index Introduction**

Maintenance Plan
Maintenance plan definition and optimization

OPTIMIZATION AND VALIDATION

Bering capacity
- **Residual service life < trigger value** → Analysis of the adjacent sections (Fuzzy tolerance) → Verification of the distance between construction sites

Roughness
- **Residual service life < trigger value** → Structural anticipation →Analysis of the adjacent sections (Fuzzy tolerance) → Verification of the distance between construction sites

Skid Resistance
- **Residual service life < trigger value** → Analysis of the adjacent sections (Fuzzy tolerance) → Verification of the distance between construction sites

EAR
- **EAR (Environment Asphalt Rating)** → EAR is an innovative index for assessing the environmental impact of pavement maintenance operations on the motorway network

Materials and production processes as sustainable as possibile

PRODUCTION PHASE			REALIZATION PHASE	
Extraction of raw material	Transport to the production site	Production	Transport to the worksite	Realization
A1	A2	A3	A4	A5

A2

A4

Production

Realization

Environmental Asphalt Rating

Introduction: SUSTAINABLE DEVELOPMENT FACTORS IN PAVEMENT LIFE-CYCLE

Source: FHWA.

Sustainable Pavement Development

- **Planning & Design**
  - Cost-Benefit Analysis (CBA)
  - Life-Cycle Cost Analysis (LCCA)
  - Life-Cycle Assessment (LCA)
  - Multi-Criteria Decision Analysis (MCDA)
- **Construction & Rehabilitation**
  - Environmental Impact Assessment (EIA)
  - Social Life-Cycle Assessment (SLCA)
  - Waste Management Plan
- **Operation & Maintenance**
  - Pavement Management system (PMS)
  - Site Maintenance Plan
- **Tender phase – choice of suppliers**
  - Green Public Procurement (GPP)

Environmental Asphalt Rating

Definition

- The Environmental Asphalt Rating, hereinafter EAR, is an **ENVIRONMENTAL IMPACT INDEX** to be associated with asphalt concrete mixtures used as part of scheduled maintenance plans. This index has been defined with the **aim** of:

1- **UNEQUIVOCALLY QUANTIFY** THE POTENTIAL ENVIRONMENTAL IMPACT DUE TO DIFFERENT MAINTENANCE STRATEGIES;

2 - PROVIDE ASPI, AS A CONTRACTING AUTHORITY, WITH A **BENCHMARK FOR THE EVALUATION** OF TECHNICAL OFFERS AND THE ASSIGNMENT OF SCORES DURING THE TENDER PHASE;

3 - FULLY **MONITOR** AND ESTIMATE THE IMPACTS BASED ON THE OFFERS MADE BY THE WINNING CONTRACTORS.

4 - EVALUATE THE BENEFICIAL EFFECTS OF **NEW INTERVENTION TECHNOLOGIES** IN TERMS OF CIRCULAR ECONOMY AND ENVIRONMENTAL SUSTAINABILITY.

- The EAR indicator is a dimensionless number ranging from 0 (zero impact) to infinity
- The EAR is based on the Environmental Product Declaration (**EPD**) certification:

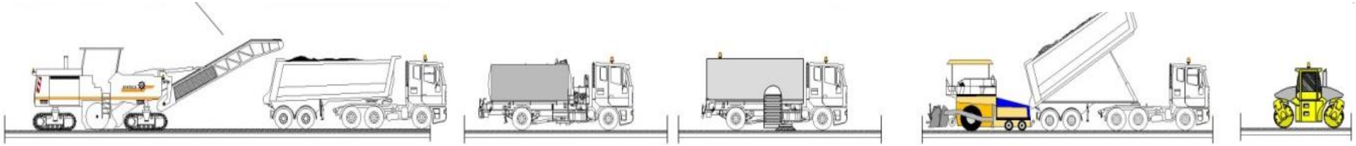
Product Category Rules **(PCR)** → TELL YOU HOW TO DO A → Life-Cycle Assessment **(LCA)** → WHICH GETS SUMMARIZED IN AN → Environmental Product Declaration **(EPD)**

Environmental Asphalt Rating

Definition

- The approach considered is the so-called **"cradle to the gate + other"**

PRODUCTION STEPS			CONSTRUCTION PHASES		USE PHASE							END-OF-LIFE PHASE				BENEFITS AND LOADS BEYOND THE BOUNDARIES OF THE SYSTEM
Extraction and supply of raw materials	Transport to the production site	Realization of the product	Transport to the construction site	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Energy consumption during use	Water consumption during use	Demolition	Transport of demolition waste	Waste treatment	Waste disposal	Potential for reuse - recovery - recycling
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D



Milling **Preparation of the laying surface** **Asphalt paving** **Compaction**

Environmental Asphalt Rating

Definition

- The approach considered is the so-called "**cradle to the gate + other**"

Environmental impact assessment of 1 tonne of asphalt

A1

A3

A5

B1 - D

TRANSPORT

A2

TRANSPORT

A4

PRODUCTION STEPS			CONSTRUCTION PHASES		USE PHASE							END-OF-LIFE PHASE				BENEFITS AND LOADS BEYOND THE BOUNDARIES OF THE SYSTEM
Extraction and supply of raw materials	Transport to the production site	Realization of the product	Transport to the construction site	Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Energy consumption during use	Water consumption during use	Demolition	Transport of demolition waste	Waste treatment	Waste disposal	Potential for reuse - recovery - recycling
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D

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Environmental Asphalt Rating

Drafting of the EPD

Drafting of the EPD

Parameter	Absloute value (v_m)	Weighting factor (w_f)	Normalization value (V_n)	Relative impact (I_f%)	Weighted value (v_w)
		Emissions - Category [A]			
GWP	$6.15 \cdot 10^{1}$	3.00	$8.86 \cdot 10^{1}$	69%	2.08
ODP	$6.70 \cdot 10^{-6}$	1.00	$5.12 \cdot 10^{-1}$	0%	0.00
AP	$3.25 \cdot 10^{-1}$	1.00	$4.35 \cdot 10^{-1}$	75%	0.75
POCP	$1.68 \cdot 10^{-2}$	1.00	$7.39 \cdot 10^{-2}$	23%	0.23
EP	$5.24 \cdot 10^{-2}$	1.00	$1.07 \cdot 10^{-1}$	49%	0.49
ADPE	$3.10 \cdot 10^{-5}$	1.00	$2.36 \cdot 10^{-4}$	13%	0.13
ADPF	$3.19 \cdot 10^{3}$	2.00	$3.39 \cdot 10^{3}$	94%	1.88
				Total for emissions - A =	55.59
		Use of resources - Category [B]			
PERE	$5.60 \cdot 10^{1}$	0.00	$5.39 \cdot 10^{2}$	-	-
PERM	$1.76 \cdot 10^{0}$	1.43	$6.40 \cdot 10^{1}$	3%	1.39
PERT	$5.78 \cdot 10^{1}$	1.43	$6.03 \cdot 10^{2}$	10%	1.29
PENRE	$7.80 \cdot 10^{2}$	0.00	$3.28 \cdot 10^{3}$	-	-
PENRM	$2.56 \cdot 10^{3}$	1.43	$2.78 \cdot 10^{3}$	92%	1.32
PENRT	$3.33 \cdot 10^{3}$	1.43	$5.75 \cdot 10^{3}$	58%	0.83
SM	$1.57 \cdot 10^{-1}$	1.43	$4.34 \cdot 10^{2}$	0%	1.43
RSF	$7.76 \cdot 10^{-4}$	1.43	$1.91 \cdot 10^{0}$	0%	1.43
NRSF	$1.15 \cdot 10^{-2}$	1.43	$1.13 \cdot 10^{2}$	0%	0.00
FW	$2.16 \cdot 10^{0}$	0.00	$2.45 \cdot 10^{0}$	-	-
				Total use of resources - B =	76.80
		Output flows and waste - Category [C]			
HWD	$3.32 \cdot 10^{-3}$	1.00	$6.43 \cdot 10^{-1}$	1%	0.01
NHWD	$9.21 \cdot 10^{0}$	1.00	$1.98 \cdot 10^{9}$	0%	0.00
RWD	$0.00 \cdot 10^{0}$	1.00	$1.91 \cdot 10^{-2}$	0%	0.00
CRU	$0.00 \cdot 10^{0}$	0.00	0.00	-	-
MFR	$4.64 \cdot 10^{-2}$	2.50	$6.70 \cdot 10^{-1}$	7%	2.33
MER	$0.00 \cdot 10^{0}$	2.50	$3.40 \cdot 10^{-1}$	0%	2.50
EEE	$0.00 \cdot 10^{0}$	2.00	$3.40 \cdot 10^{0}$	0%	2.00
EET	$0.00 \cdot 10^{0}$	0.00	$0.00 \cdot 10^{0}$	-	-
				Total output flows and waste - C =	68.32
				EAR =	62.17

Chiola D, Cirimele V, Tozzo C,
An index for assessing the environmental impact of pavement maintenance operations on the motorway network: the Environmental Asphalt Rating, submitted to MDPI 2023.

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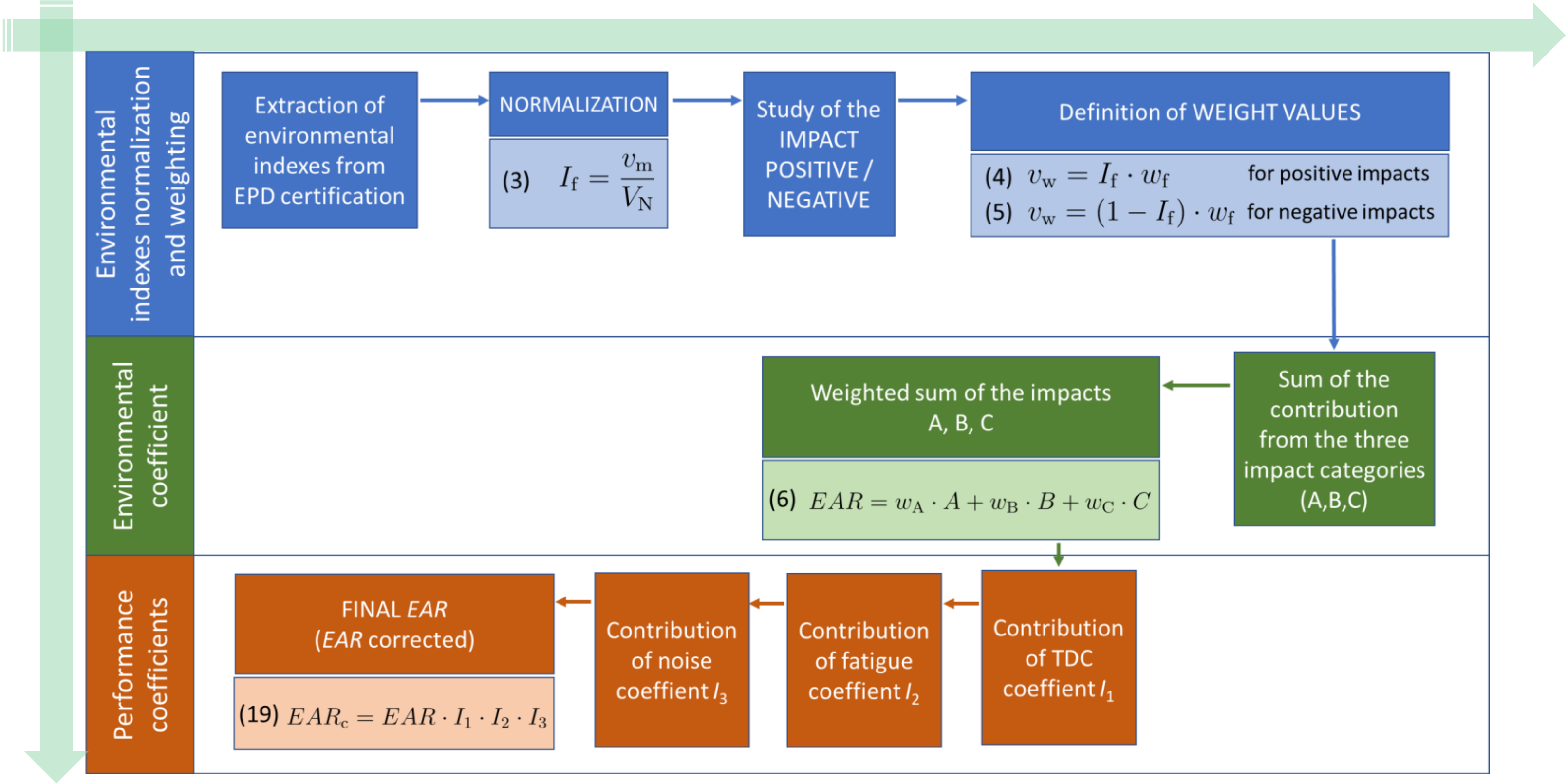
Environmental Asphalt Rating

Calculation process



Environmental Asphalt Rating

Drafting of the EPD

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EEE	$0.00 \cdot 10^0$	2.00	$3.40 \cdot 10^0$	0%	2.00
EET	$0.00 \cdot 10^0$	0.00	$0.00 \cdot 10^0$	-	-
				Total output flows and waste - C =	68.32
				EAR =	62.17

$$EAR = 0.65\,A + 0.25\,B + 0.1\,C$$

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Environmental Asphalt Rating

Performance Corrections

Finally, the EAR index, calculated as described above, must be adjusted based on the expected performance in terms of residual service life, which is evaluated based on the pre-qualification values (grain size, binder quality, binder %, voids %, ITS…):

- For open graded mixtures, an approach based on the top-down cracking evolution model was used:

$$\mathrm{TDC(N)} = \mathrm{TDC_{max}}\, e^{-\left(\frac{a}{n}\right)^{B}}$$

$$a = 1{,}008 - 0{,}071 \cdot (\text{età c.b.})$$

$$B = 0{,}716 - 0.220 \cdot \mathrm{ITS}$$

- For dense graded mixtures, an estimation of fatigue axes is performed according to the Asphalt Institute report (NCHRP 1-37):

$$\log E^{*} = 3.750063 + 0.02932\rho_{200} - 0.001767(\rho_{200})^{2} - 0.002841\rho_{4} - 0.058097V_{a} - 0.802208\left(\frac{V_{beff}}{V_{beff}+V_{a}}\right) + \frac{3.871977 - 0.0021\rho_{4} + 0.003958\rho_{38} - 0.000017(\rho_{38})^{2} + 0.005470\rho_{34}}{1+e^{(-0.603313-0.313351\log(f)-0.393532\log(\eta))}}$$

Environmental Asphalt Rating

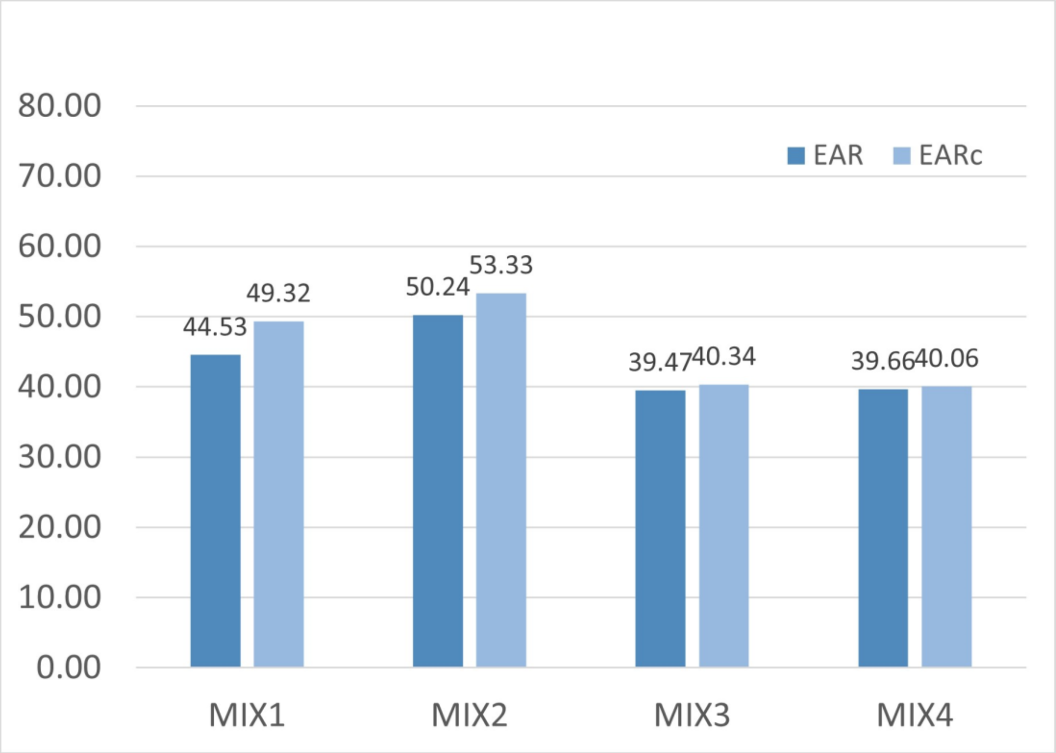
Performance Corrections

For surface mixtures only, emissions are also considered from the noise point of view, calculated using the following model:

$$CPXL = a_1 + a_2 \cdot Log\left(\frac{S}{S_0}\right) + \left[a_3 + a_4 \cdot Log\left(\frac{S}{S_0}\right)\right] \cdot \frac{D_{95}}{D_F} + \left[a_5 + a_6 \cdot Log\left(\frac{S}{S_0}\right)\right] \cdot \frac{V_A}{VMA}$$

Environmental Asphalt Rating

Results



Environmental Asphalt Rating

Latest revision of the method

Most recently, the EAR index calculation procedure has been updated considering the latest developments in LCA methods, practices and standards.

- ✓ Consideration of the updated version of Environmental Performance Indicators (Version 2.0).
- ✓ Consideration of an updated set of weighting and normalization factors, based on a much larger and publicly available library, to obtain a well-founded and shareable estimation of the EAR index.

References:

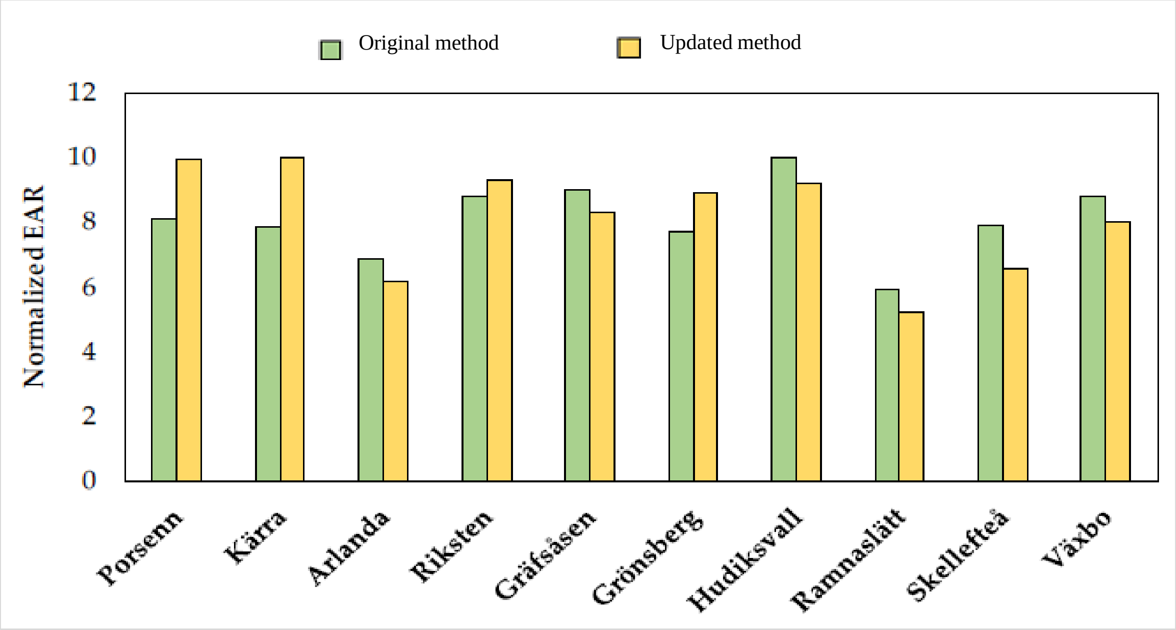
- EN 15804:2012+A2:2019/AC:2021
- Sala S., Cerutti A.K., Pant R.; *Development of a weighting approach for the Environmental Footprint;* Publications Office of the European Union; Luxembourg, 2018.

Indicator	Weighting Factor w_f	Normalization Factor V_n	Normalization Factor Unit of Measurement
Core environmental indicators (A)			
GWP, Total	2.11×10^{-01}	$8.10 \times 10^{+03}$	kg CO_2 eq.
ODP	6.31×10^{-02}	5.36×10^{-02}	kg CFC11 eq.
AP	6.20×10^{-02}	$5.56 \times 10^{+01}$	mol H^+ eq.
EP, freshwater	2.80×10^{-02}	$1.61 \times 10^{+00}$	kg P eq.
EP, marine	2.96×10^{-02}	$1.95 \times 10^{+01}$	kg N eq.
EP, terrestrial	3.71×10^{-02}	$1.77 \times 10^{+02}$	mol N eq.
POCP	4.78×10^{-02}	$4.06 \times 10^{+01}$	kg NMVOC eq.
ADPE	7.55×10^{-02}	6.37×10^{-02}	kg Sb eq.
ADPF	8.32×10^{-02}	$6.50 \times 10^{+04}$	MJ
WDP	8.51×10^{-02}	$1.15 \times 10^{+04}$	m^3
Use of resources (B)			
PERE	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	MJ
PERM	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	MJ
PERT	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	MJ
PENRE	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	MJ
PENRM	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	MJ
PENRT	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	MJ
SM	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	kg
RSF	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	MJ
NRSF	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	MJ
FW	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	m^3
Output flows and waste (C)			
HWD	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	kg
NHWD	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	kg
RWD	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	kg
CRU	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	kg
MFR	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	kg
MER	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	kg
EE	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	MJ

Tozzo C., Chiola D., Pierani M., Urbano L., Ricci R., Susani S.
Improving the EAR Index for flexible pavement and a preliminary definition of an Environmental Index (ECR) for rigid pavement.
MDPI 2024.

Environmental Asphalt Rating

Latest revision of the method: results



Comparison of EAR values calculated with original and updated method (no performance corrections applied).

Note: To efficiently compare the two methods, a second normalization to the EAR values is applied, dividing the EAR value of each mixture by the maximum EAR value obtained from the entire set of mixtures. This is conducted separately for the set of EAR values obtained with the original method and for the set of EAR values obtained with the updated method.

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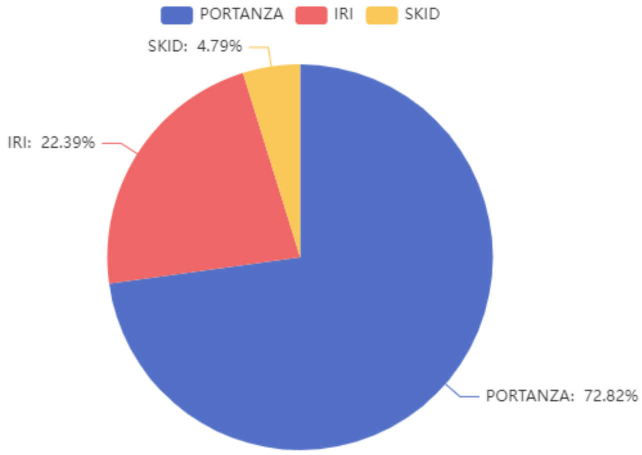
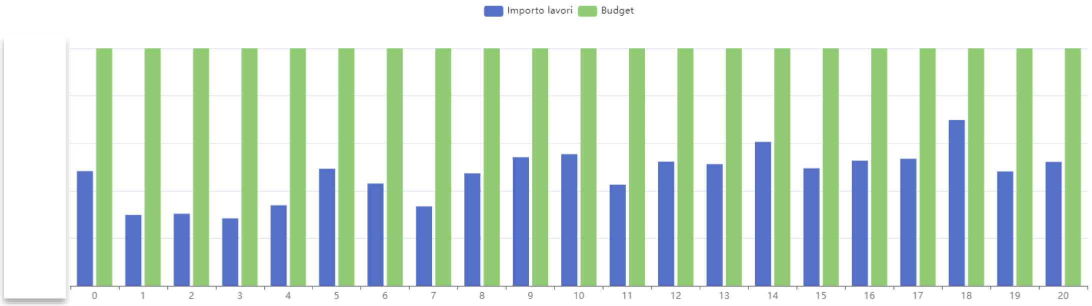
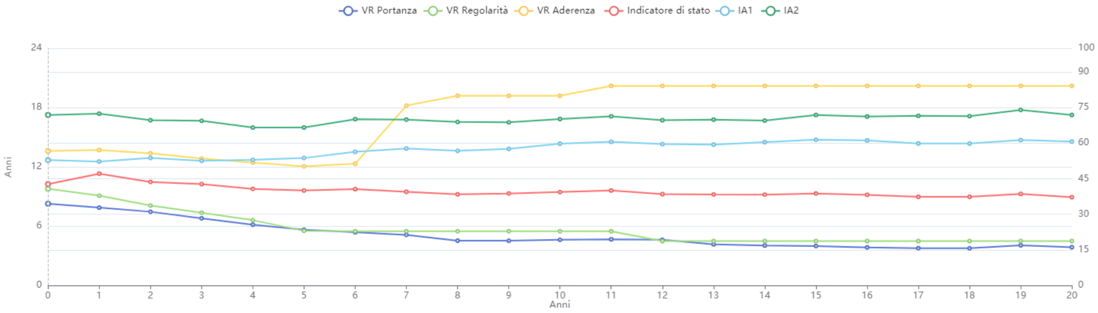
EXAMPLES: Geocomposite

Scenario 1: default boundary conditions + Geocomposite to restore bearing Capacity on the 20% of the Network*







EAR = 14.974.299,11

* the Scenario is just a demonstration of the tool and all the data and the graphs reported in this slide are not referred to a real case.

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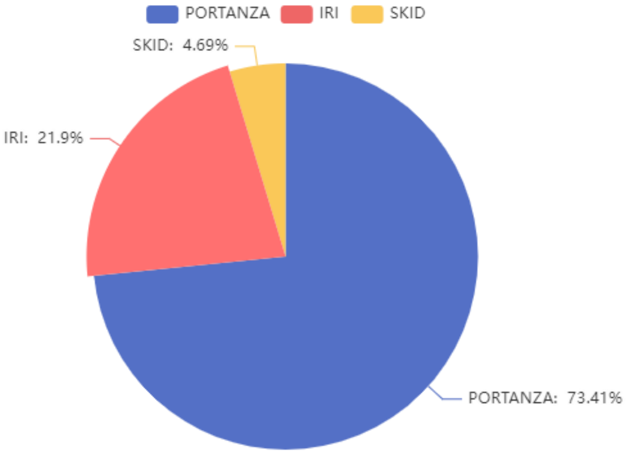
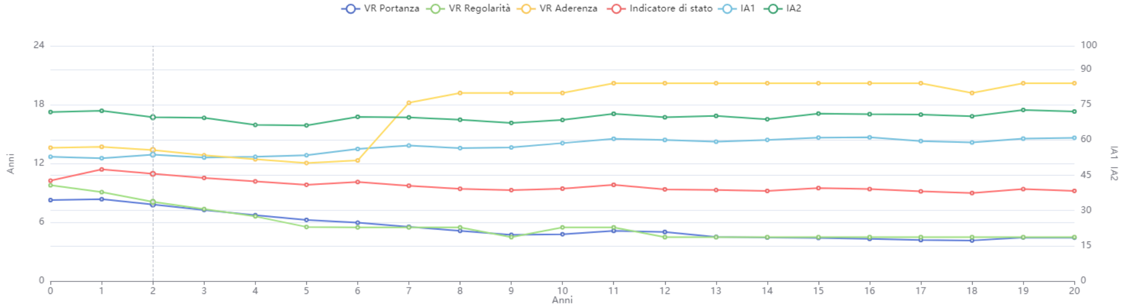
EXAMPLES: Geocomposite

Scenario 2: default boundary conditions + Geocomposite to restore bearing Capacity on the 50% of the Network*



EAR = 14.283.487,82



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* the Scenario is just a demonstration of the tool and all the data and the graphs reported in this slide are not referred to a real case.

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EXAMPLES: Geocomposite
Comparison Between SCENARIO 1* (20% Geocomposite to restore Bearing Capacity) **and SCENARIO 2*** (50% Geocomposite to restore Bearing Capacity)

Scenario 1

- 20y-Budget: 100%
- Global indicator @10th year: 9,4y
- Global indicator @20th year: 8,9y
- EAR 20y: 14,974 M

Scenario 2

- 20y-Budget: 98%
- Global indicator @10th year: 9,4y
- Global indicator @20th year: 9,2y
- EAR 20y: 14,283 M

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* the Scenarios are just a demonstration of the tool and all the data reported in this slide are not referred to a real case.

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CONCLUSIONS

a) AS shown, Asset Management Platforms are spreading to manage different components of the asset

b) A merging process of different asset management platforms is running to analyse every aspect of the Asset by using one single Territorial-scale Digital Twin,

c) PMS platforms are used to **support** decision-makers by generating 20-years scenarios

d) Comparison between different strategies can be made in terms of economic aspects, Global-Performance and **Sustainability**

e) The ASPI|Movyon E-PMS allows sustainability assessment through the **EAR** Index, which is one of the first examples of sustainability analysis integrated in a PMS

f) The challenge is to develop new procedures to track the whole process, from tender phase to the execution.

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Thank you.

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