Pavement rehabilitation in the XXI century

Jorge Pais

University of Minho

Pavement design

Mechanistic-Empirical Pavement Design Guide (MEPDG)

Differences to the previous method

incremental damage (monthly basis)

distresses

rutting in the subgrade

fatigue cracking

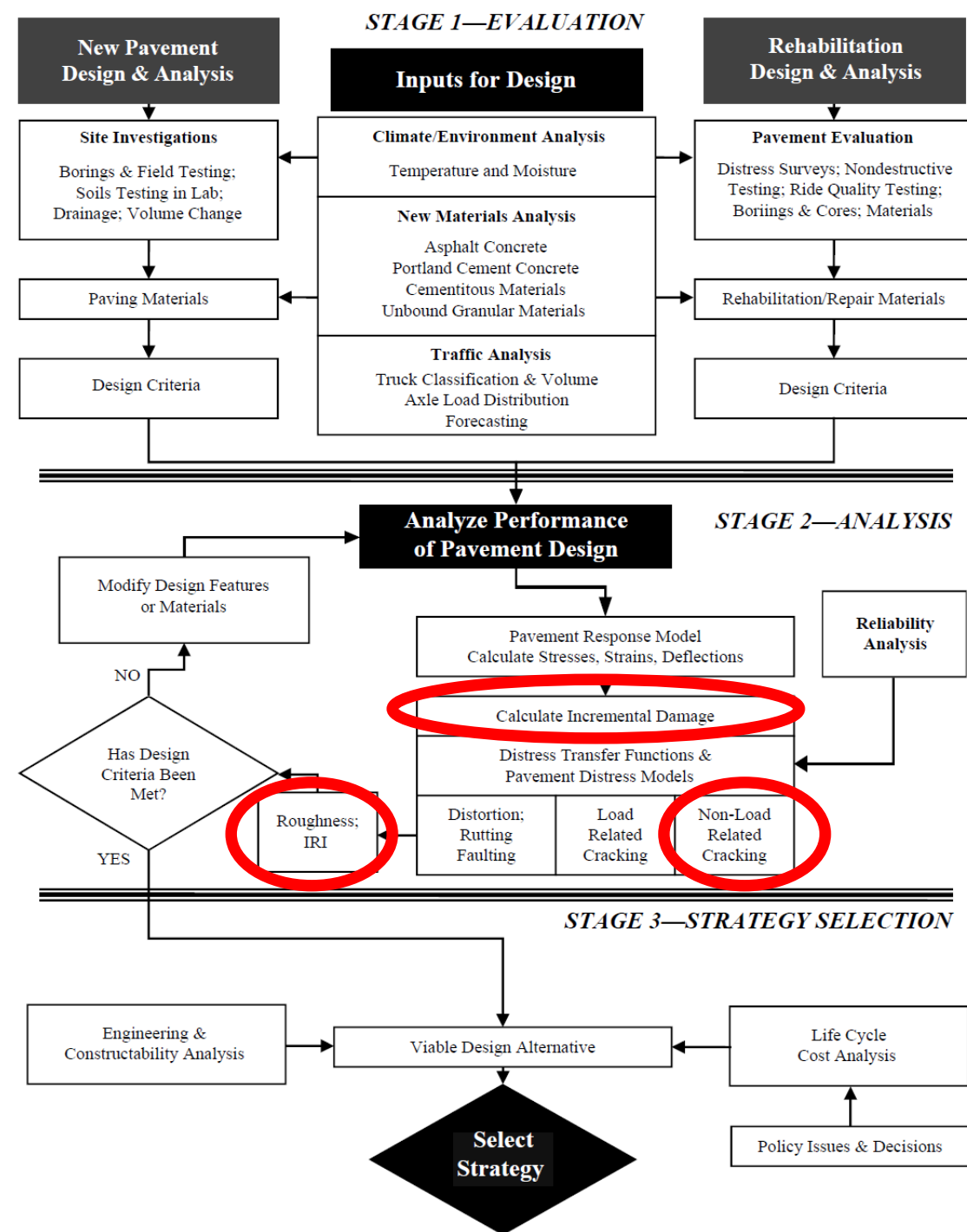**New**

rutting in granular layers

rutting in asphalt layers

longitudinal cracking

roughness

non-load related cracking

models can be calibrated by the user

models calibrated from LTPP database

STAGE 1—EVALUATION

New Pavement Design & Analysis

Inputs for Design

Rehabilitation Design & Analysis

Site Investigations — Borings & Field Testing; Soils Testing in Lab; Drainage; Volume Change

Climate/Environment Analysis — Temperature and Moisture

Pavement Evaluation — Distress Surveys; Nondestructive Testing; Ride Quality Testing; Borings & Cores; Materials

New Materials Analysis — Asphalt Concrete, Portland Cement Concrete, Cementitous Materials, Unbound Granular Materials

Paving Materials

Rehabilitation/Repair Materials

Traffic Analysis — Truck Classification & Volume, Axle Load Distribution, Forecasting

Design Criteria

Design Criteria

Analyze Performance of Pavement Design — STAGE 2—ANALYSIS

Modify Design Features or Materials

Pavement Response Model — Calculate Stresses, Strains, Deflections

Reliability Analysis

NO

Has Design Criteria Been Met?

Calculate Incremental Damage

Distress Transfer Functions & Pavement Distress Models

Roughness; IRI

Distortion; Rutting Faulting

Load Related Cracking

Non-Load Related Cracking

YES

STAGE 3—STRATEGY SELECTION

Engineering & Constructability Analysis

Viable Design Alternative

Life Cycle Cost Analysis

Select Strategy

Policy Issues & Decisions

3

Bitumen

Bitumen is a mixture of many thousands of dissimilar hydrocarbon molecules, which may contain small amounts of hetero atoms like nitrogen (≤ 2%), oxygen (≤ 2%), sulphur (≤ 6%),....
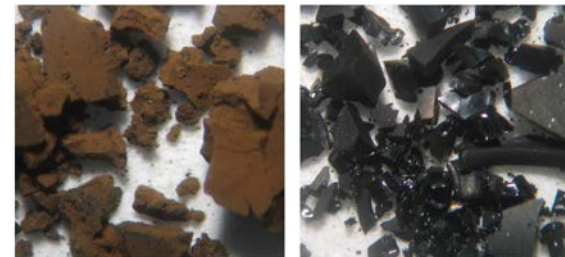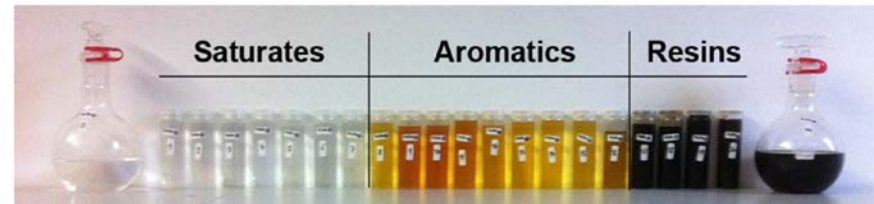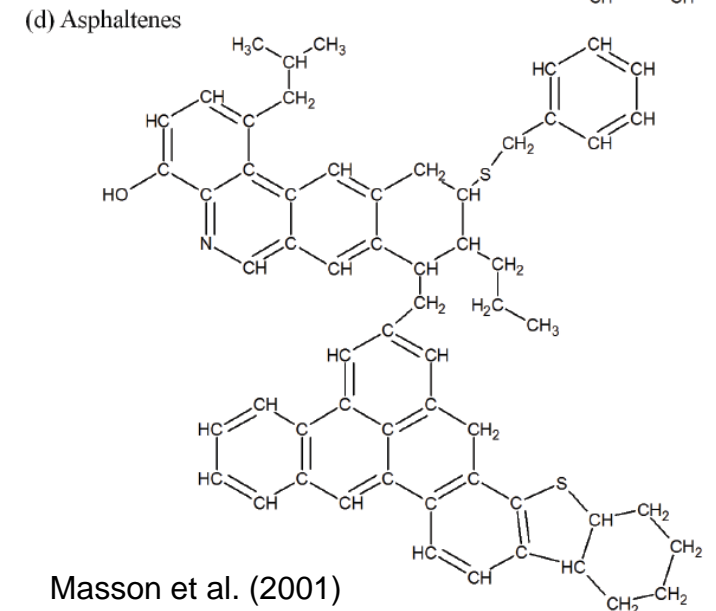
SARA

Maltenes
  Saturates
  Aromatics
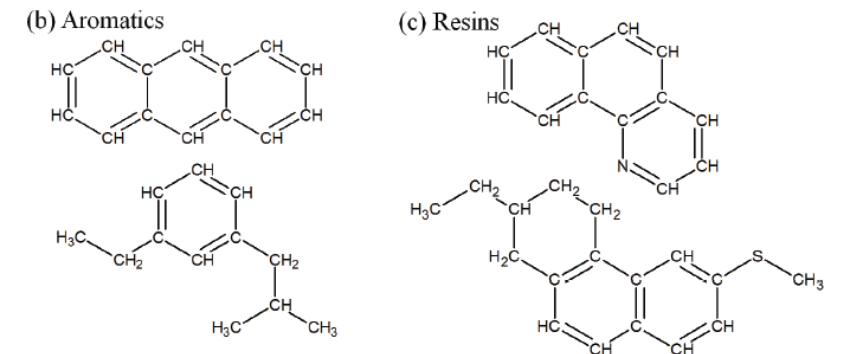 Resins
Asphaltenes

Eberhardsteiner et al. (2014)

Buckley (2006)

(a) Saturates

Paraffin

Isoparaffin (branched)

Naphtene

(b) Aromatics

(c) Resins

(d) Asphaltenes

Masson et al. (2001)

4
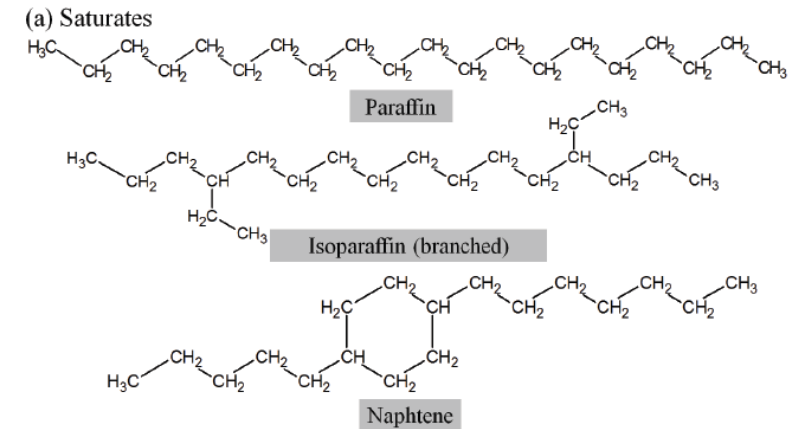
Bitumen

Atomic Force Microscope (AFM)

These structures look like bees showing lower regions as dark stripes and higher as brighter, from the false colour code of AFM data. Because of the appearance of these elliptical domains in AFM topography image, they are best known as 'bee- structure'.
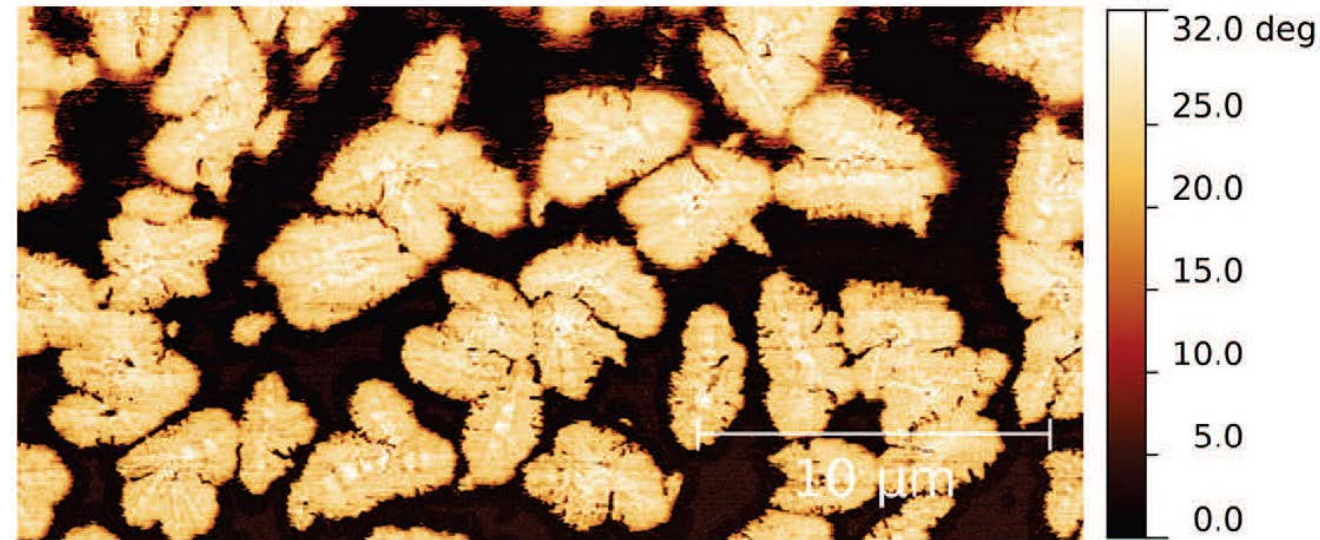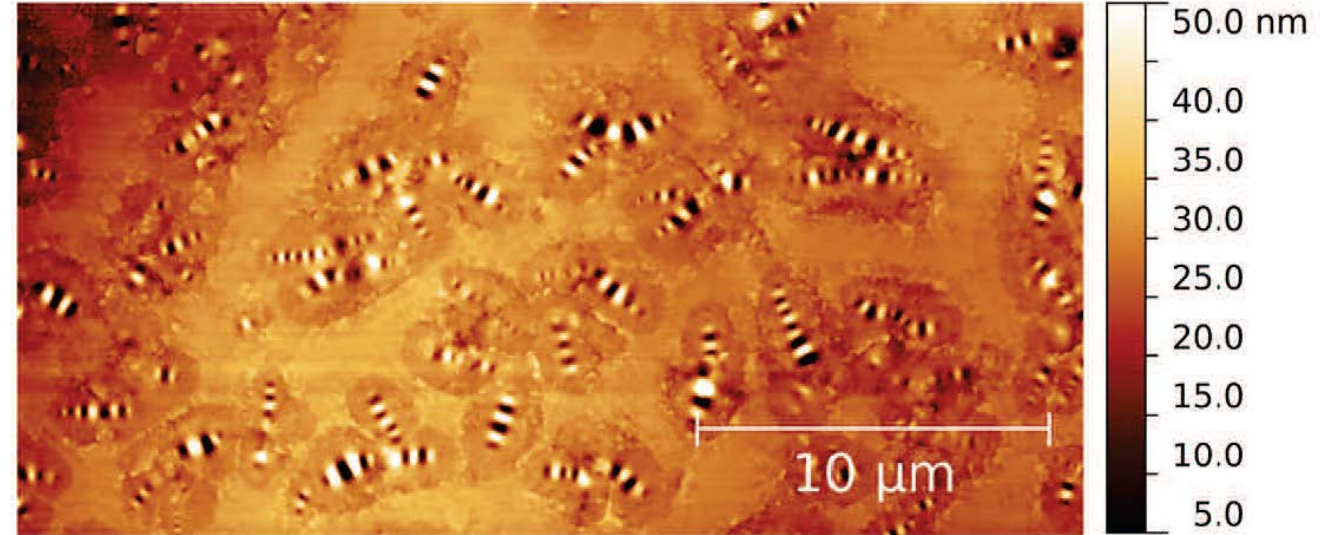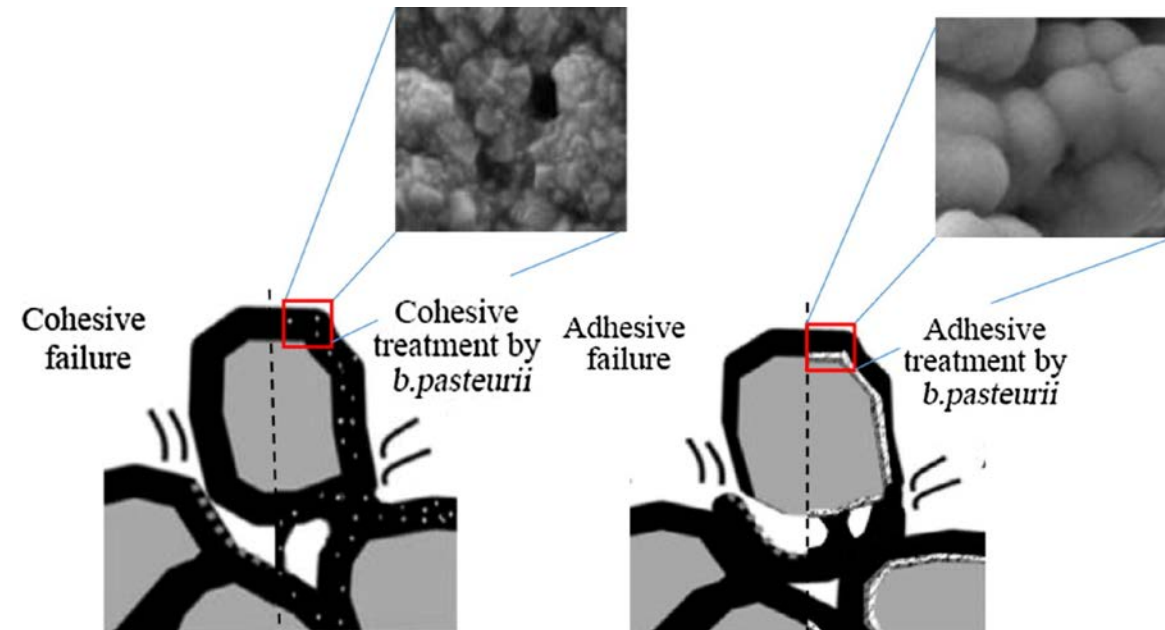
Nahar (2016)
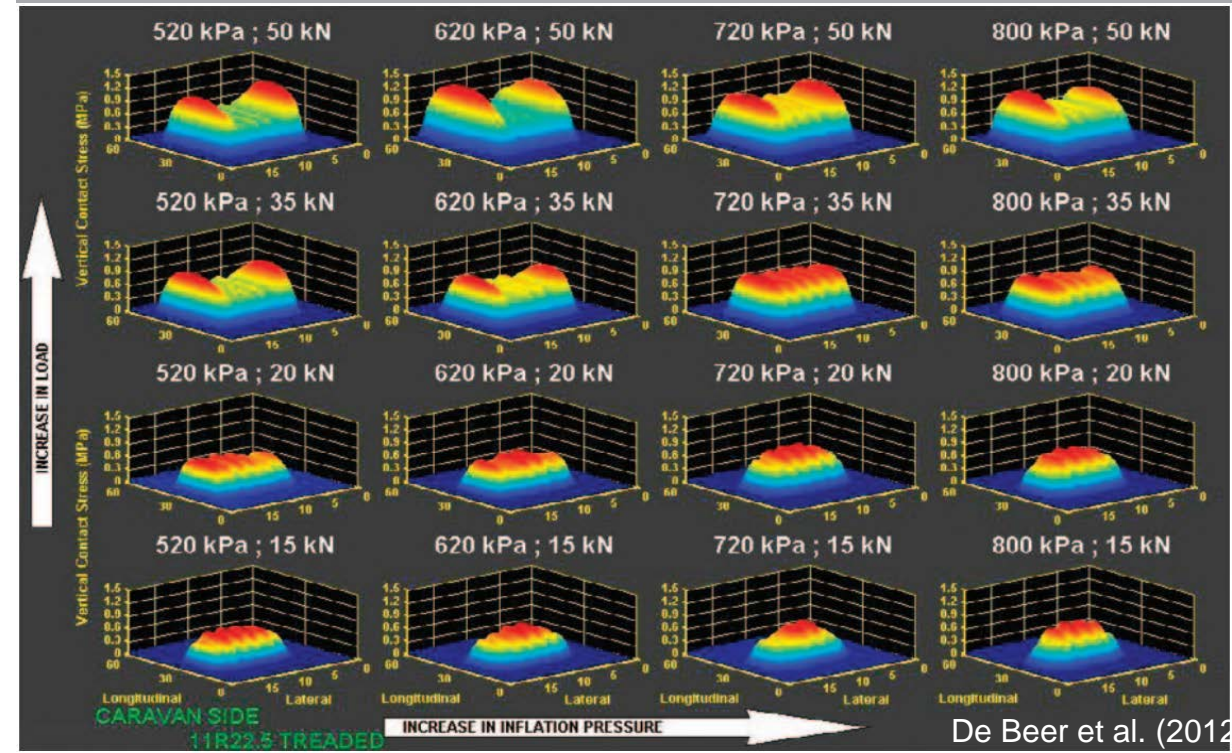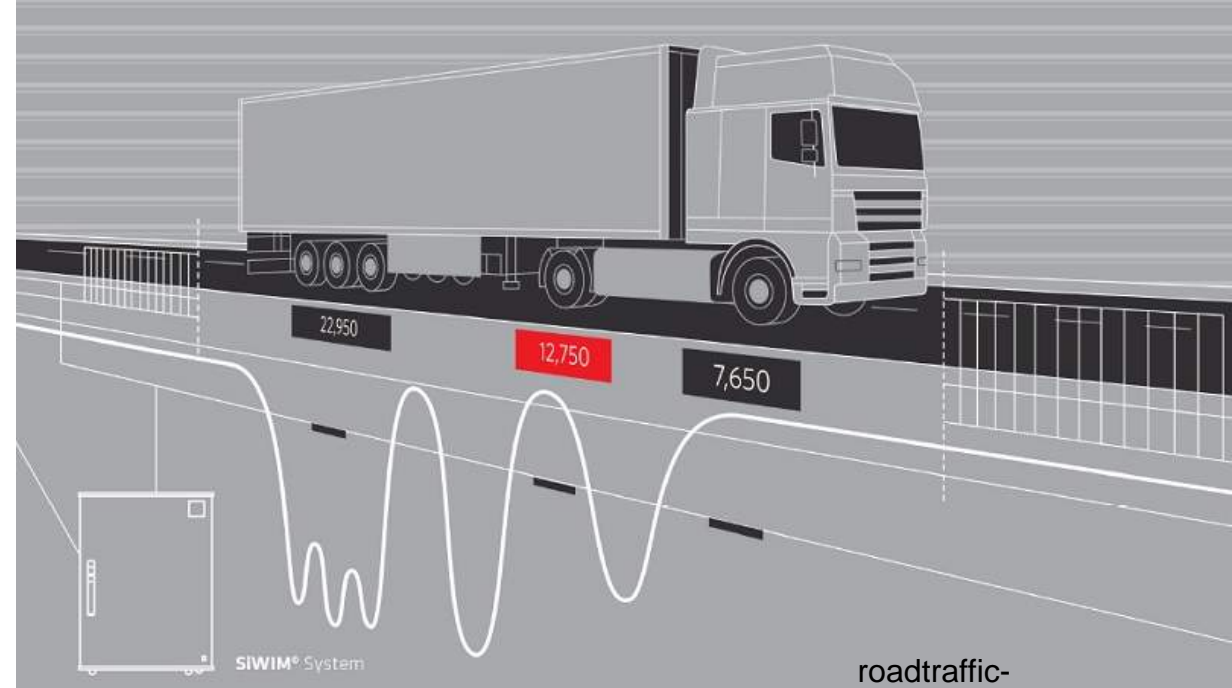
Environment

Photo-thermal environment
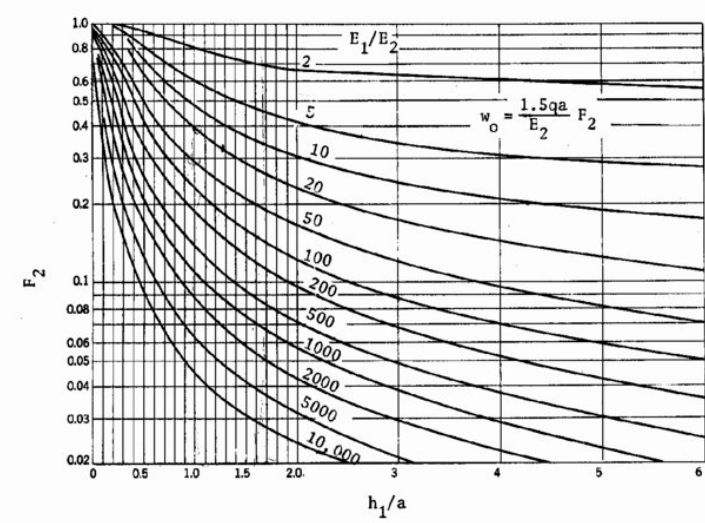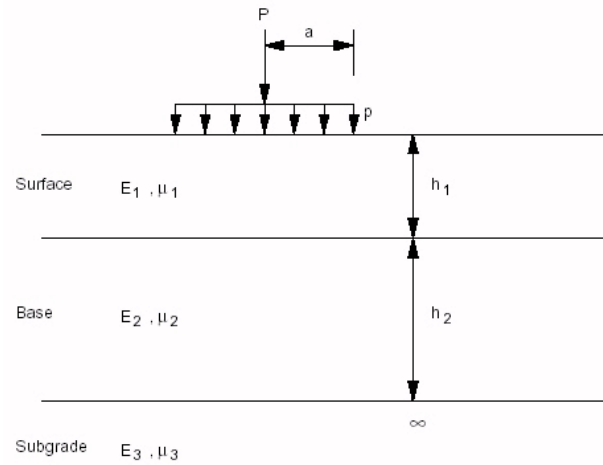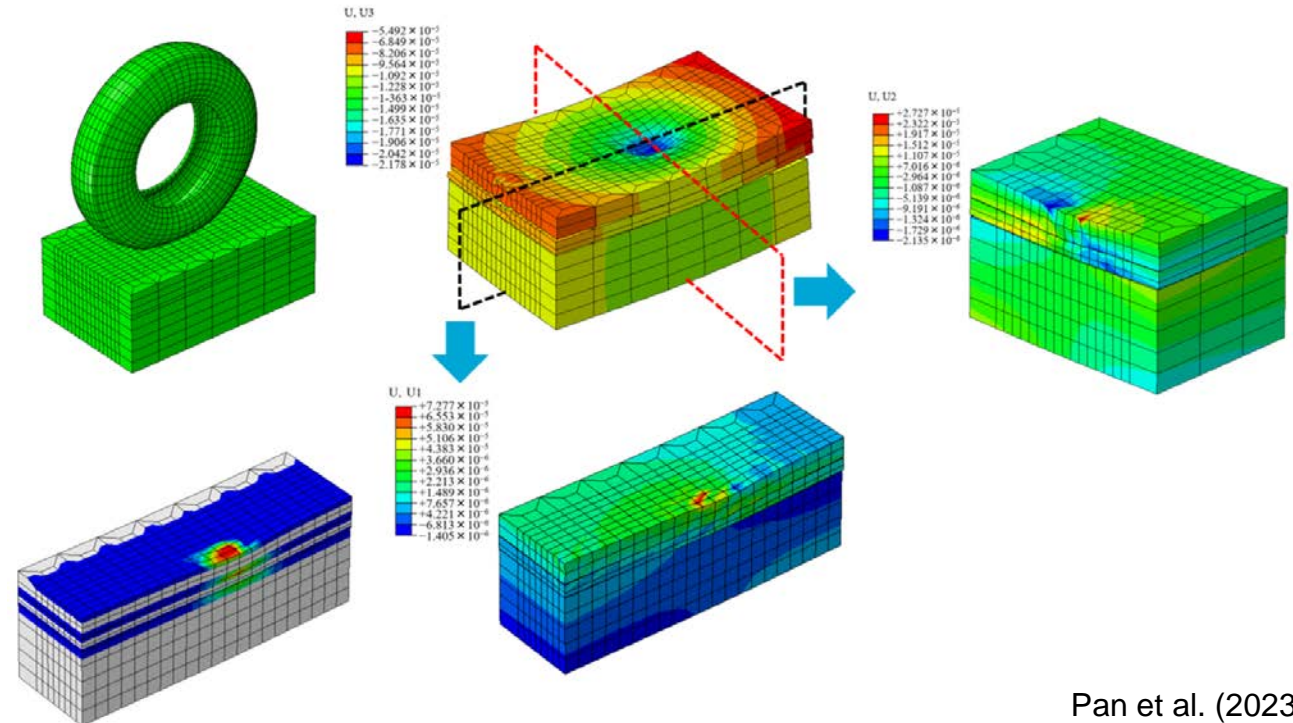
Water

Moisture
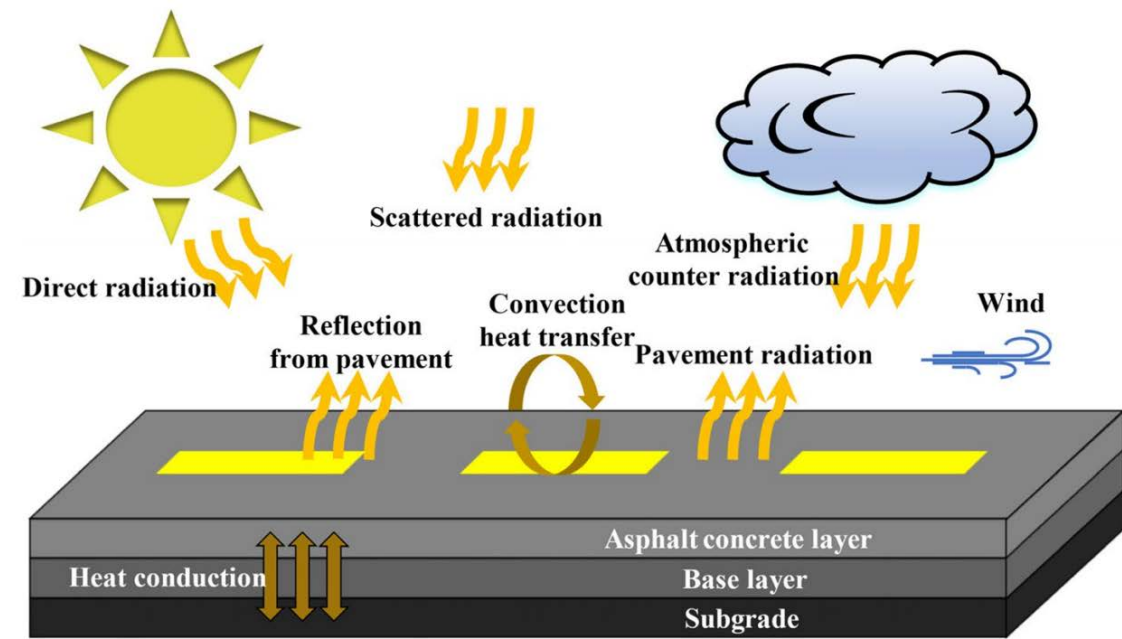
Gong et al. (2022)

Dovom et al. (2019)

Traffic

- Loads
- Speed
- Contact pressure

- Weigh-In-Motion (WIM) systems
- Stress-In-Motion (SIM) systems

roadtraffic-

De Beer et al. (2012)

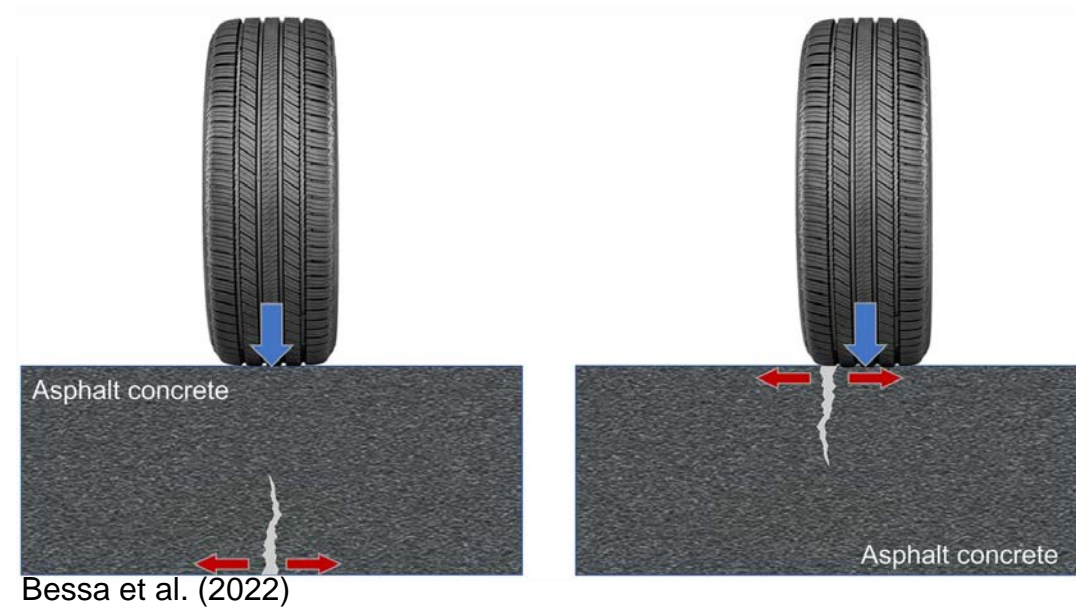# Modelling

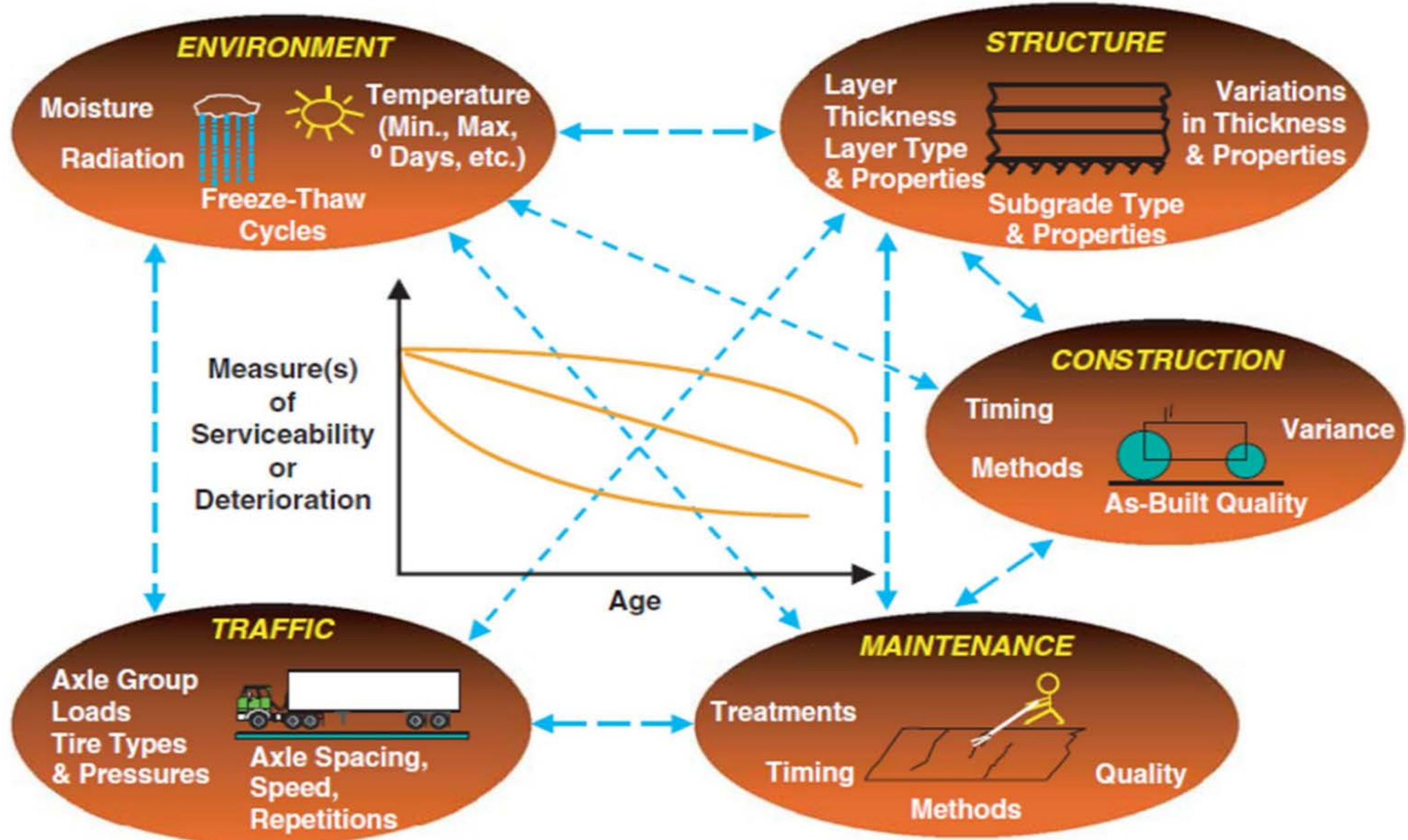From Burmister to FEM
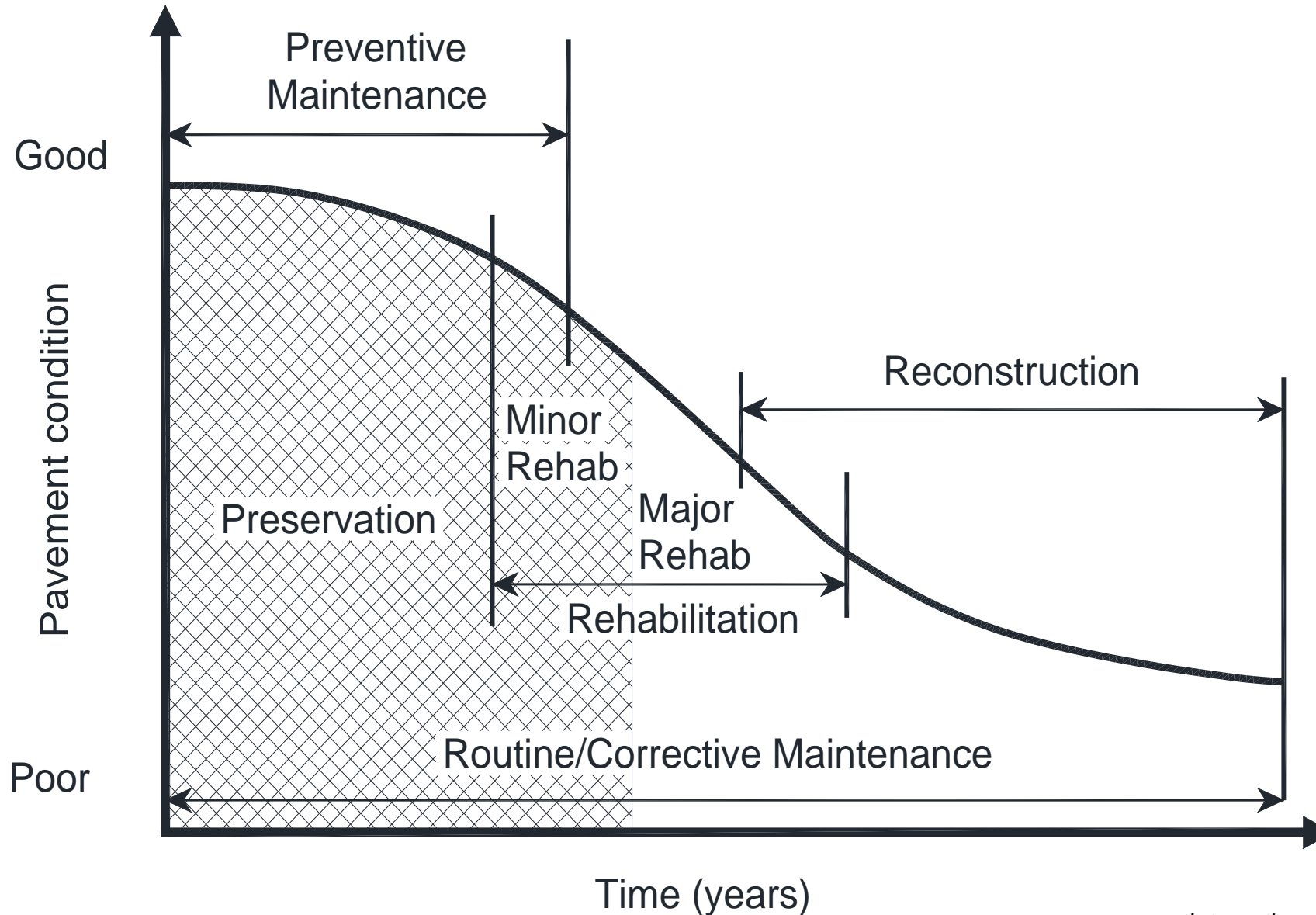

Pan et al. (2023)

however

Cracking in pavements

- Longitudinal cracking
- Fatigue cracking
- Block cracking
- Transverse cracking
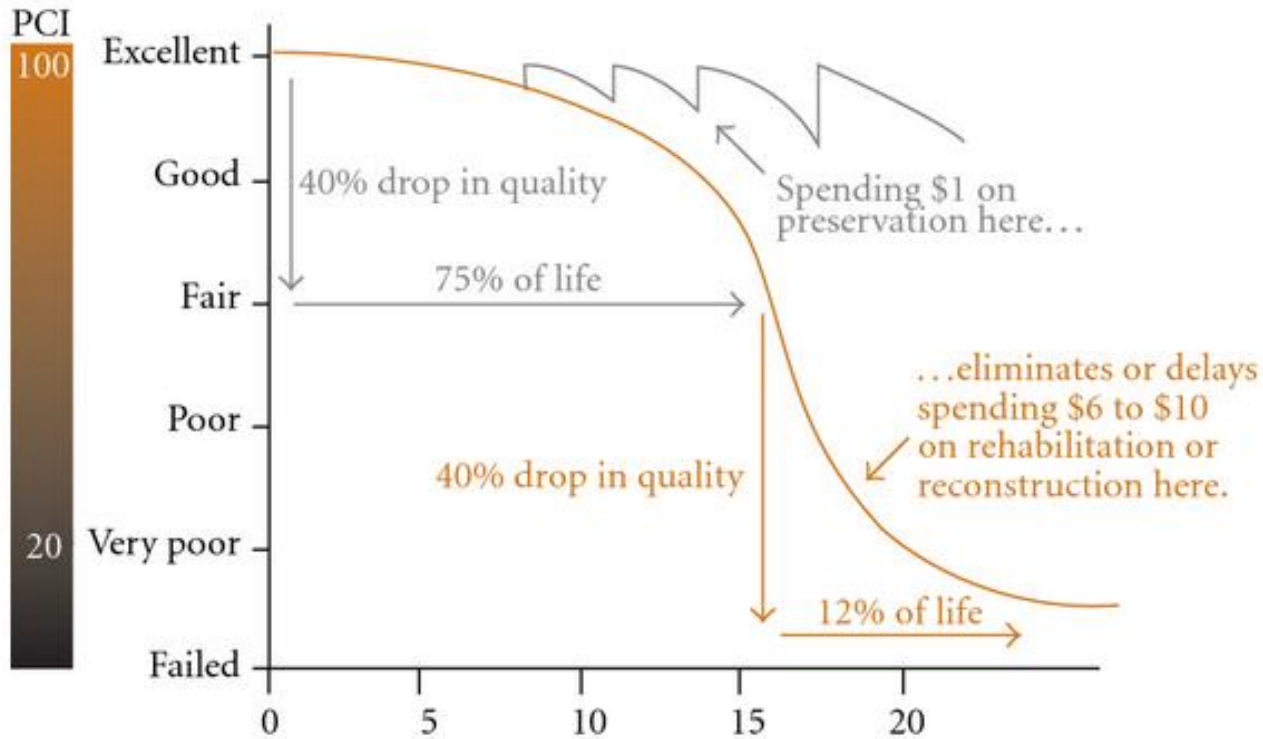- Reflection cracking
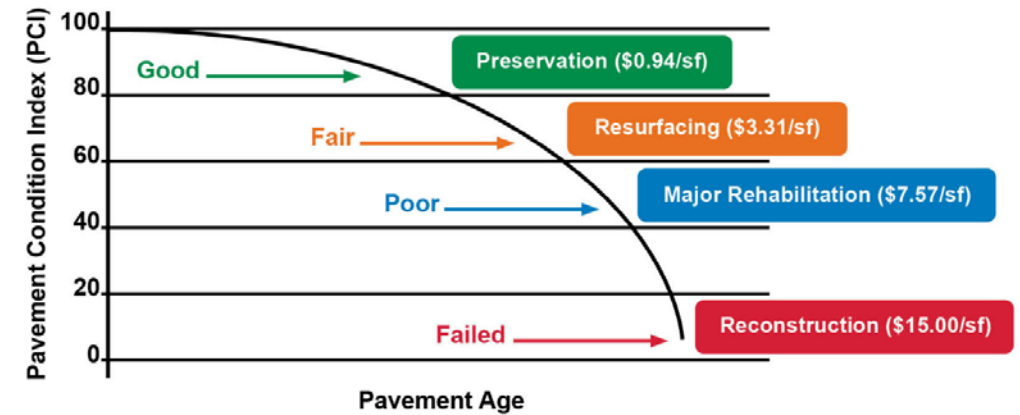- Slippage cracking
- Edge cracking

Bessa et al. (2022)

fixasphalt.com

Factors influencing pavement performance

Younos et al.

Maintenance, rehabilitation and reconstruction

pavementinteractive.org

Pavement maintenance strategy vs LCCA

Galehouse et al. (2003)

Cost Comparison of Options

- **Preventative Preservation**...........................$50,000/lane mile
- **Rehabilitation**..$400,000/lane mile
- **Reconstruction**...$800,000/lane mile

https://www.honolulu.gov/dfmroad/pavement-preservation-program.html

13

Mill & HMA overlay

forconstructionpros.com

Mill and Overlay (otherwise known as Mill and Fill) is the process of grinding off the top layer of existing asphalt pavement by means of a large milling machine and replacing this layer with a new HMA.

Typical depth of milling is between 1" and 2", depending on the condition of the existing riding surface, depth of available curb reveal and depth of existing asphalt pavement.

A leveling course may applied prior to the final surface to resolve rutting, depressions or other roadway profile issues.
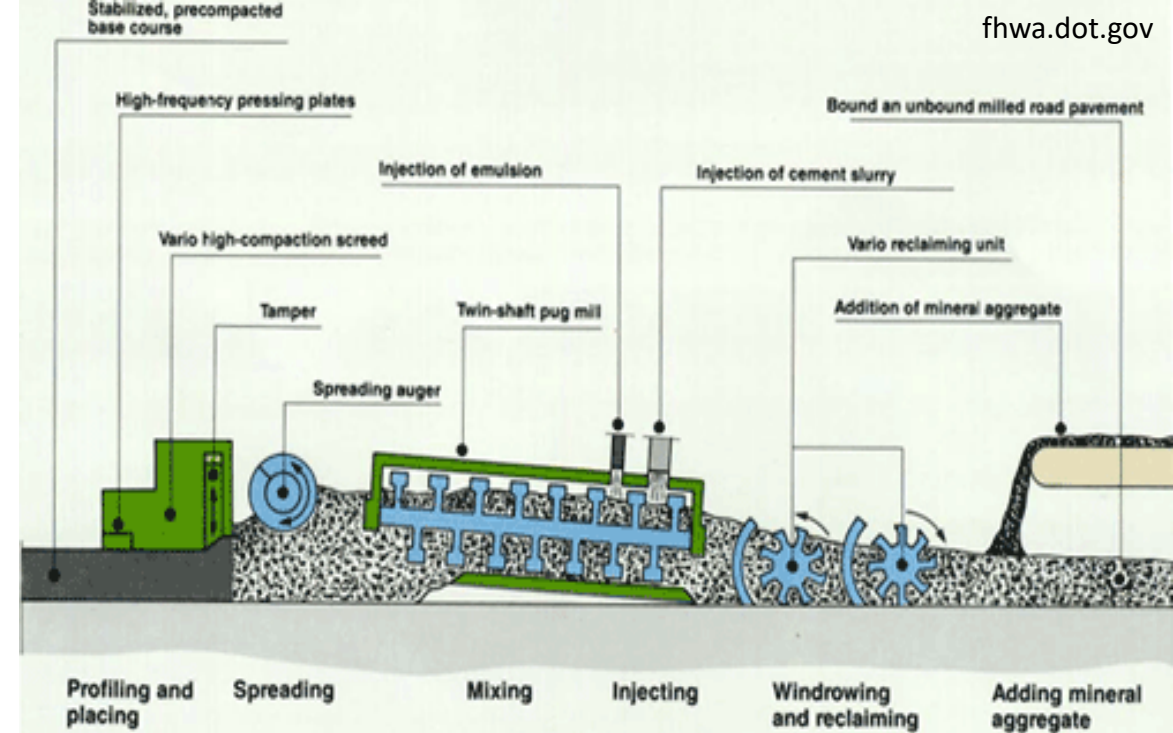

forta-fi.com

14

In-place recycling & overlay
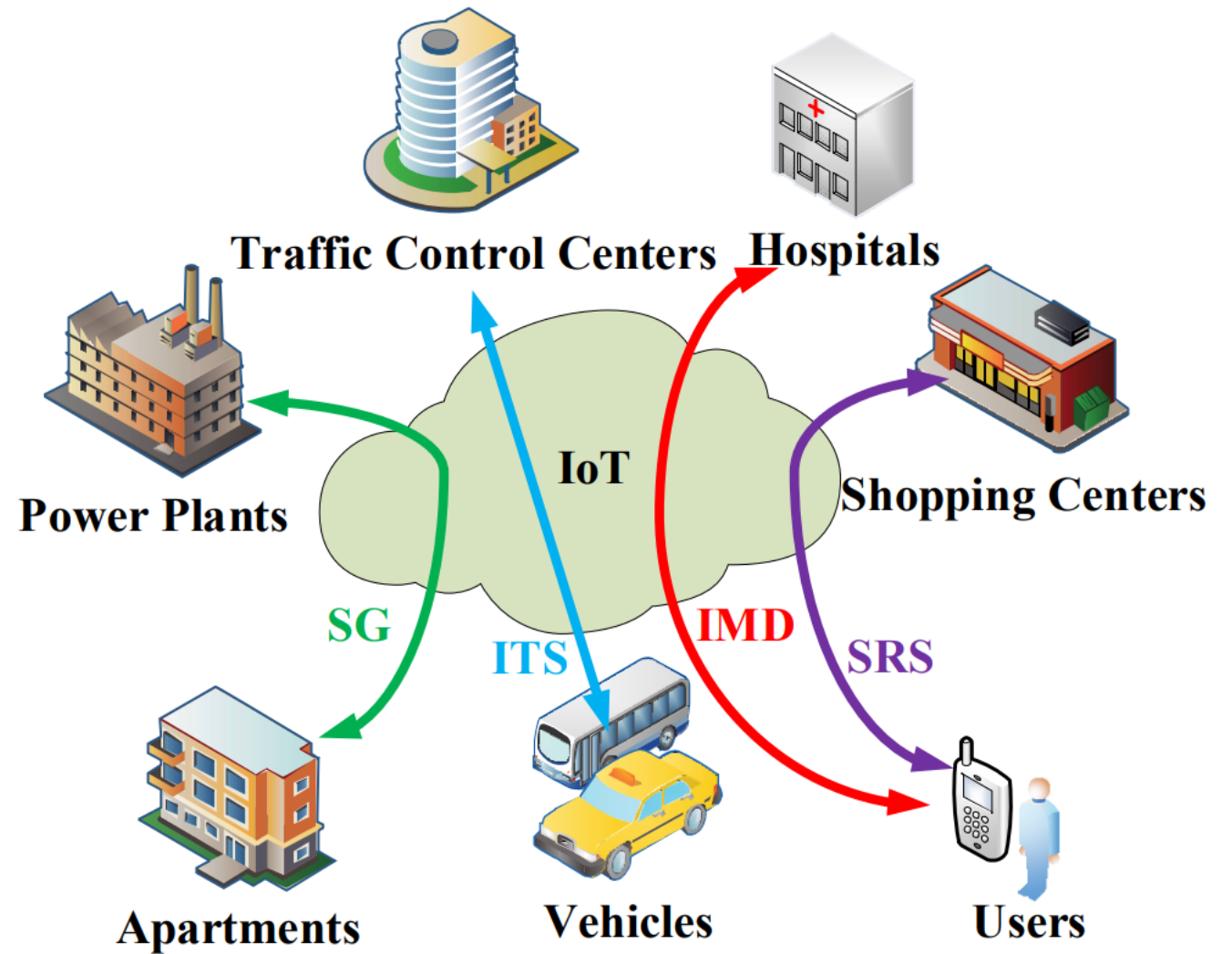
Cold or hot in-place recycling

- Existing pavement materials are reused in place
- Reclaimed asphalt pavement (RAP) material is obtained by milling
- Virgin aggregate and recycling agent are added
- recycling restores old pavement
  - profile
  - eliminate wheel ruts
  - restore the crown and cross slope, and
  - eliminate pothole and irregularities
  - scarcity of materials

So, what the pavement rehabilitation in the XXI century should be ?

Internet of Things (IoT)

Traffic Control Centers · Hospitals

Power Plants · IoT · Shopping Centers

SG · ITS · IMD · SRS

Apartments · Vehicles · Users

Guo et al. (2018)

Digital twin

xenomatix.com
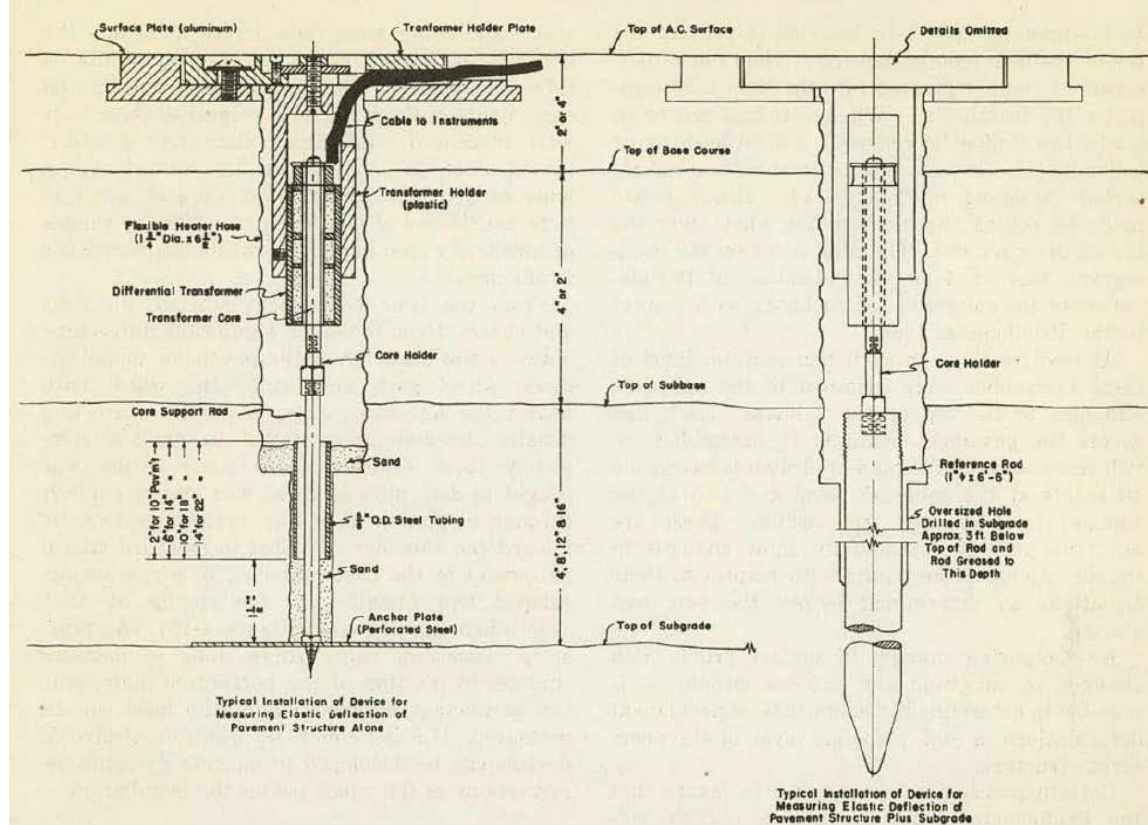
WASHO road test (1950-1951)

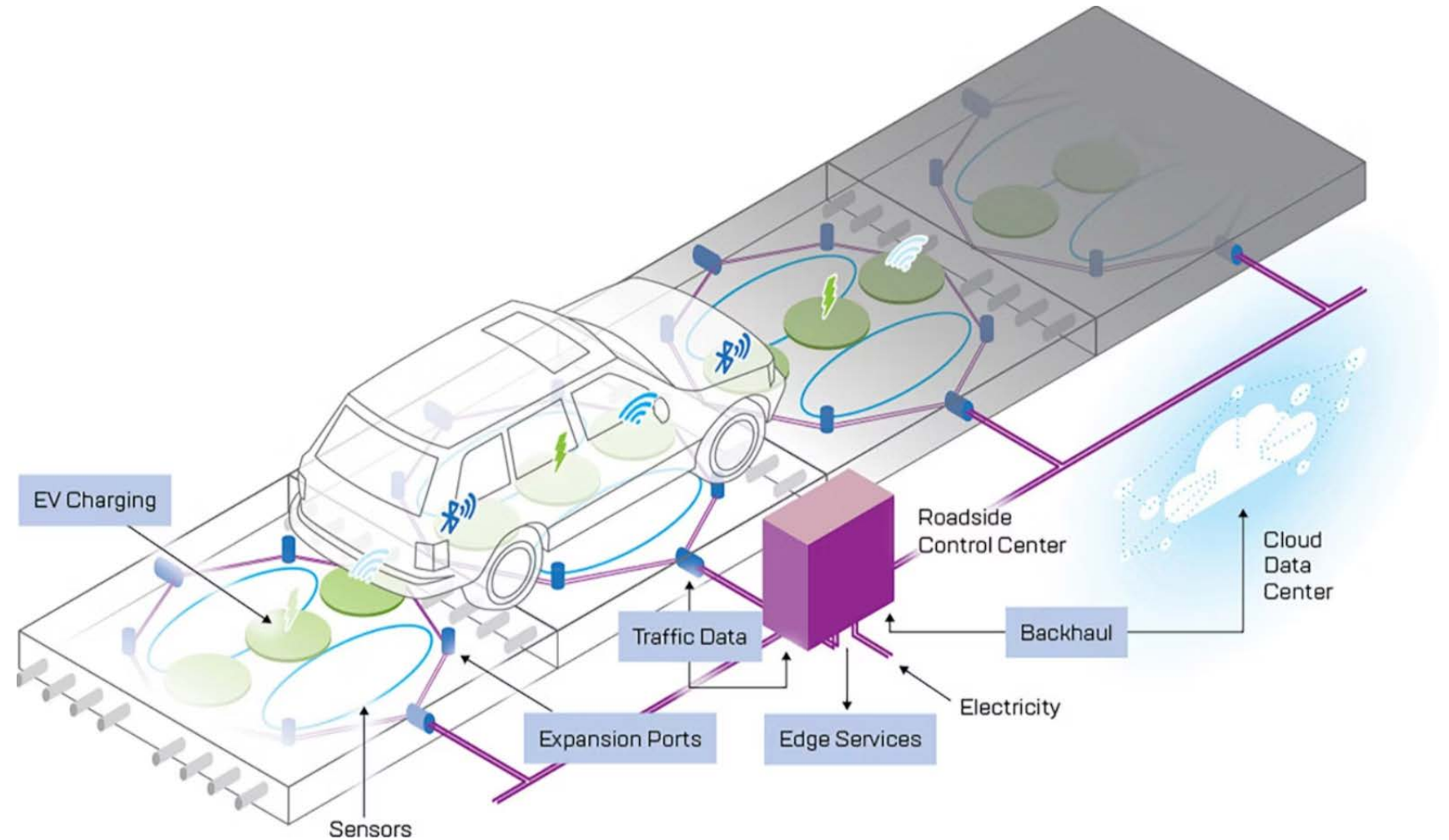First application of sensors in a road pavement

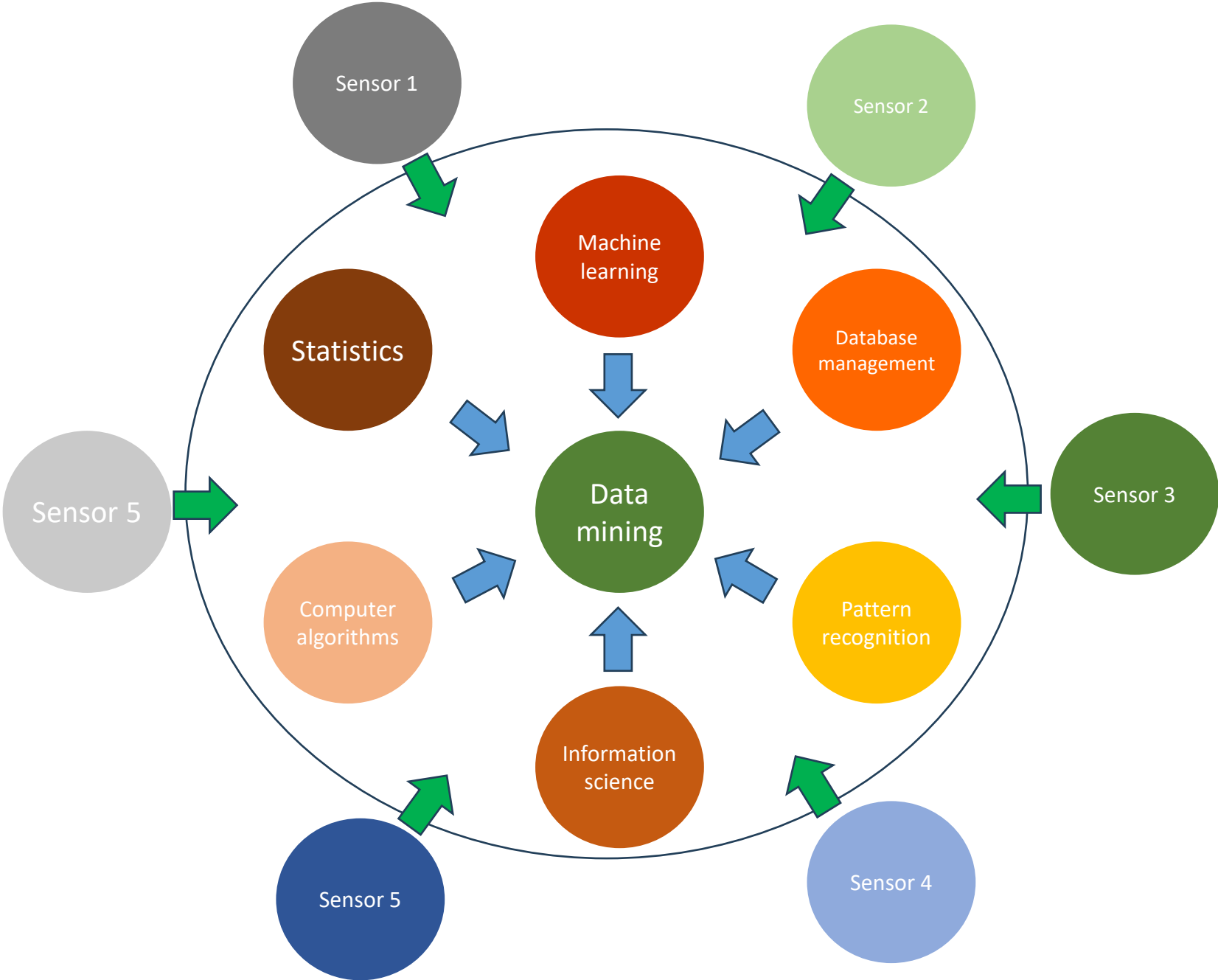Measurement of:

      strains

      deformations

      stresses

Use of intelligent sensors
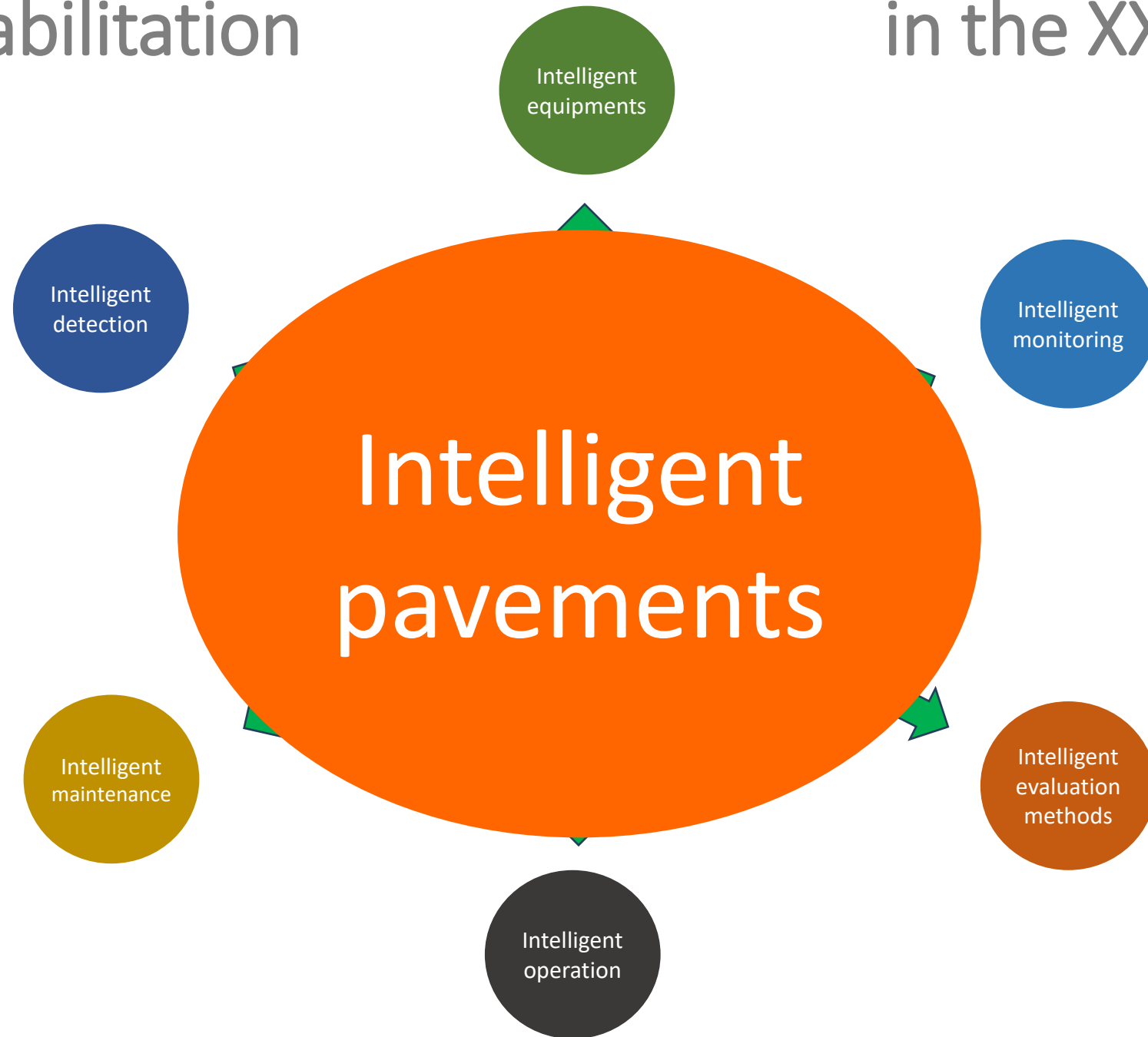

EV Charging

Roadside Control Center

Cloud Data Center

Traffic Data

Backhaul

Electricity

Expansion Ports

Edge Services

Sensors

forconstructionpros.com

Data mining and Artificial intelligence

Intelligent equipments

Intelligent detection

Intelligent monitoring

Intelligent pavements

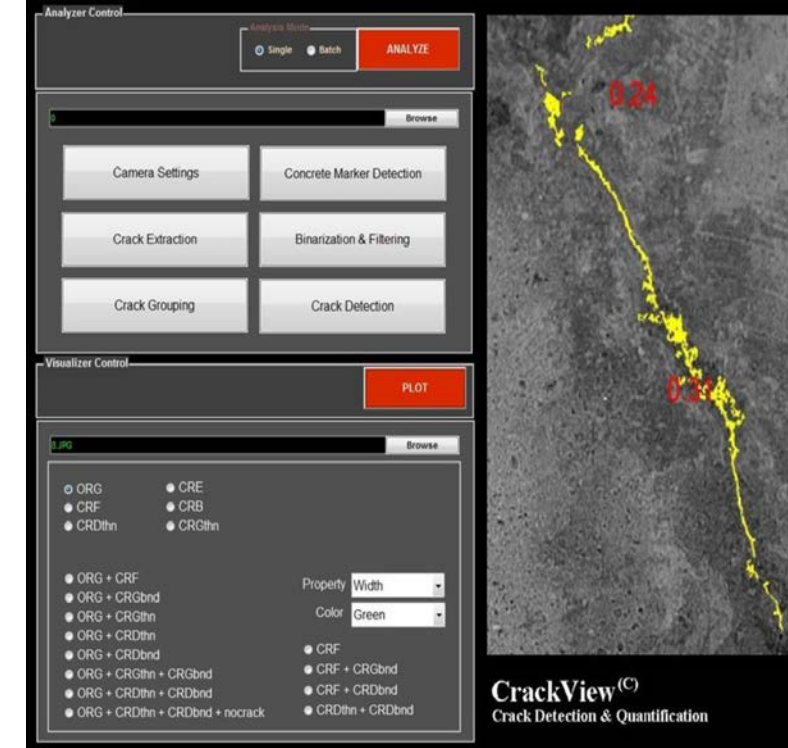Intelligent maintenance

Intelligent evaluation methods

Intelligent operation

Intelligent monitoring

- Unmanned Aerial Vehicles and Digital Image Processing

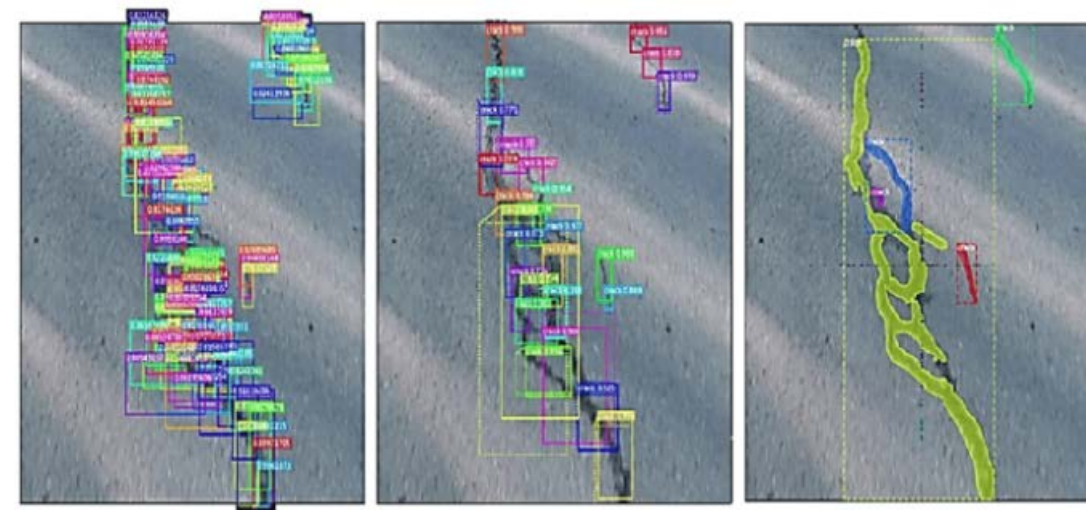Jong-Woo Kim et al. (2015)

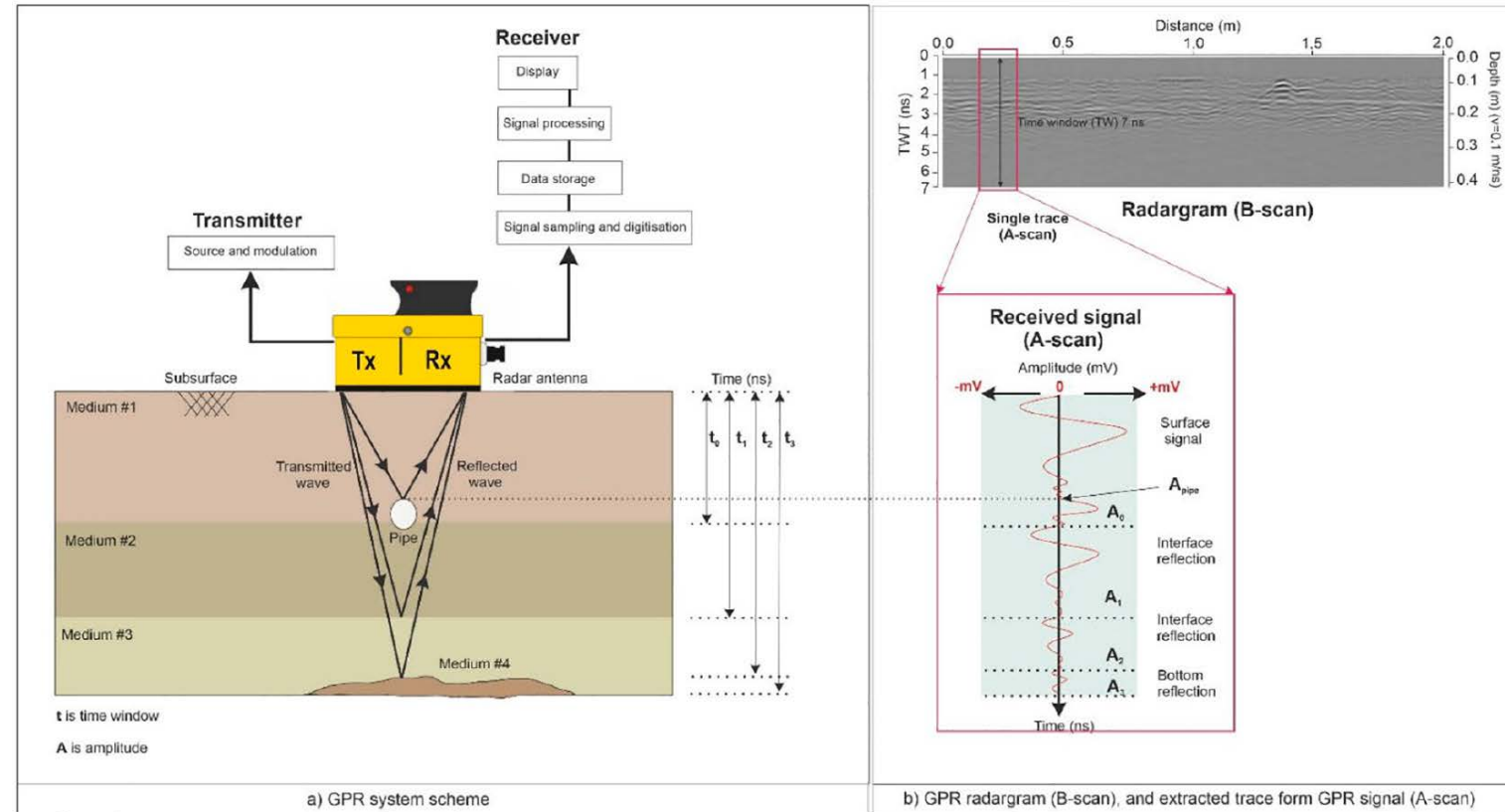Phantom 2 DJI S1000 3DR IRIS 3DR RTF X8 AiBotix X6

Types of drones

Jong-Woo Kim et al. (2015)

Intelligent detection

Moradi and Assaf (2023)

- Ground Penetrating Radar (GPR)

a) GPR system scheme

b) GPR radargram (B-scan), and extracted trace form GPR signal (A-scan)

Rasol et al. (2022)

Intelligent equipments

- Equipment that automatically:
  - Cut the pavement
  - Clear all surfaces
  - Apply bitumen
  - Apply asphalt mix
  - Compact the mix

alenizpaving.com

en.wikipedia.org

Intelligent maintenance

- The next-generation of pavement maintenance and rehabilitation

- Multi-objective optimization

Deterministic optimization

Sustainable concept   Precise decision

- **Purpose**: sustainable and precise pavement decision-making
- **Requirement**: affluent objectives, advanced predictive models, and multi-indicator decision process

Uncertainty optimization

Risk and uncertainty of infrastructure

- **Agency view**: better understand the decision-making
- **Approach**: more reasonable uncertainty representation methods, and multiple uncertainties effects
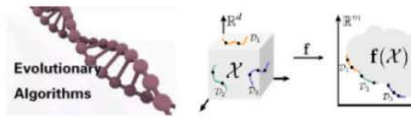
MODAT for PMMS

User interaction decision-making with AI

- **Function**: full of MOO models and multiple algorithms
- **Design**: interaction interfaces, and AI to integrated information and optimization

New optimization algorithm

Evolutionary Algorithms

More novel algorithm for MOO problems

- **Purpose**: suitable for more complex MOO problem
- **Requirement**: demand-oriented to improve optimization algorithms

New modeling

Multiple facilities and M&R activities

- **Extension**: oriented transportation infrastructure network
- **Requirement**: joint optimization for multiple facilities and multiple M&R activities

Chen and Zheng (2021)

Intelligent evaluation methods

- Linear viscoelastic continuum damage (LVECD)

Constitutive law for viscoelasticity

$$\sigma = \int_o^t E(t-\tau)\frac{d\varepsilon}{d\tau}d\tau$$
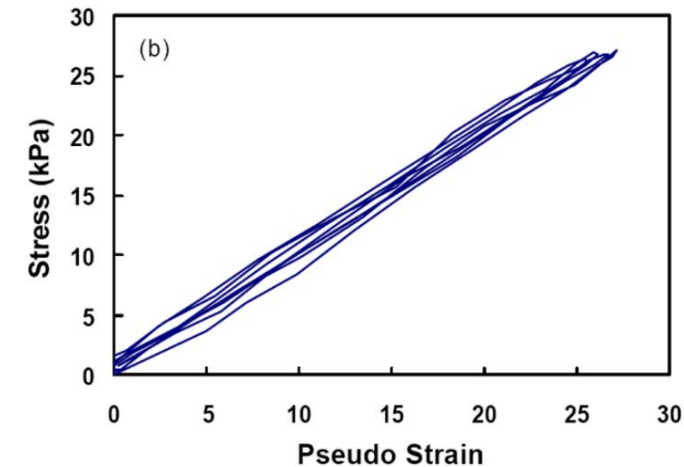
Elastic-viscoelastic correspondence principle
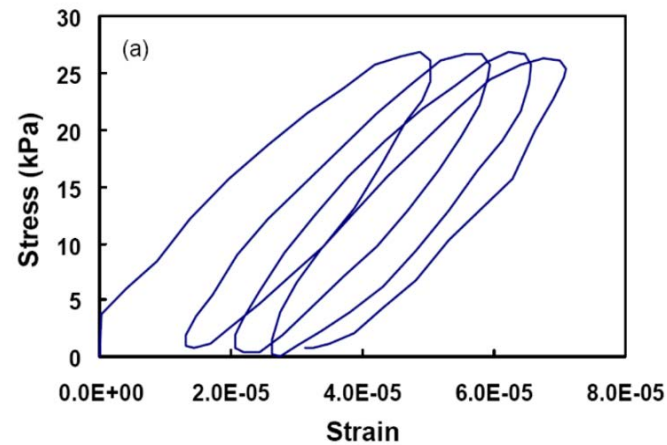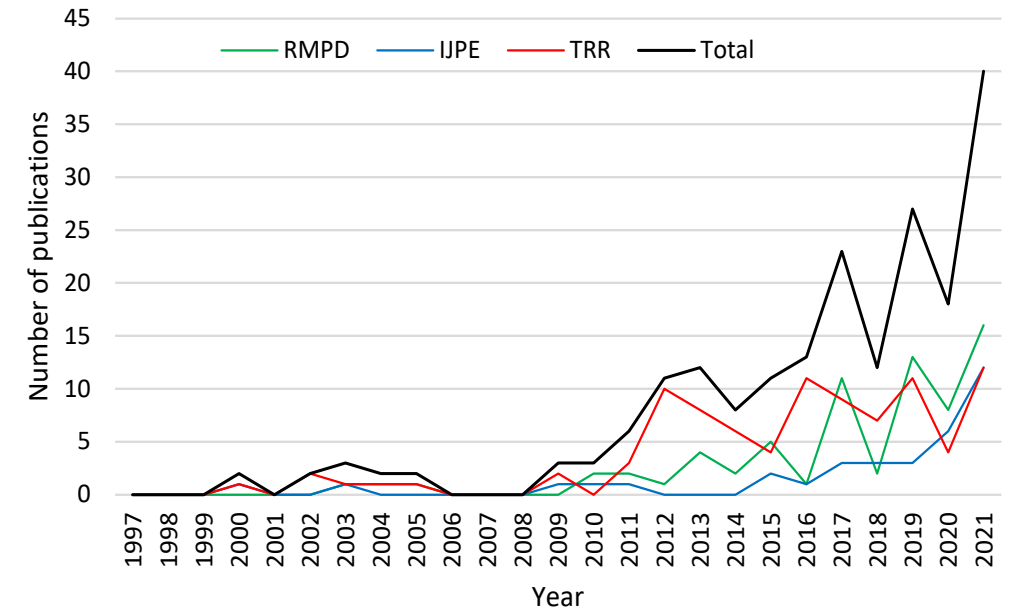
$$\varepsilon_{ij}^R = \frac{1}{E_R}\int_o^t E(t-\tau)\frac{\partial \varepsilon_{ij}}{\partial \tau}d\tau$$

$$\sigma_{ij}^R = E_R\int_o^t D(t-\tau)\frac{\partial \sigma_{ij}}{\partial \tau}d\tau$$

Using the definition of pseudo-strain
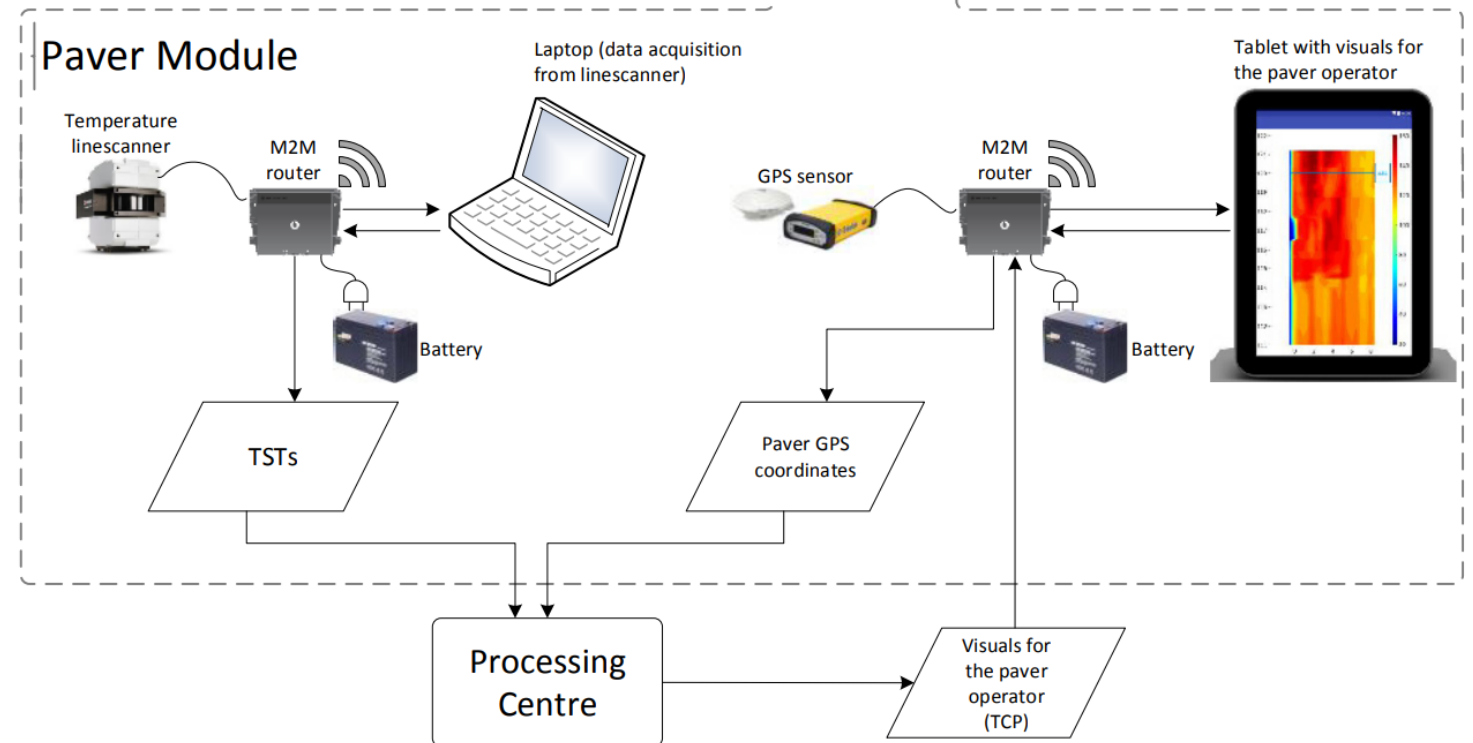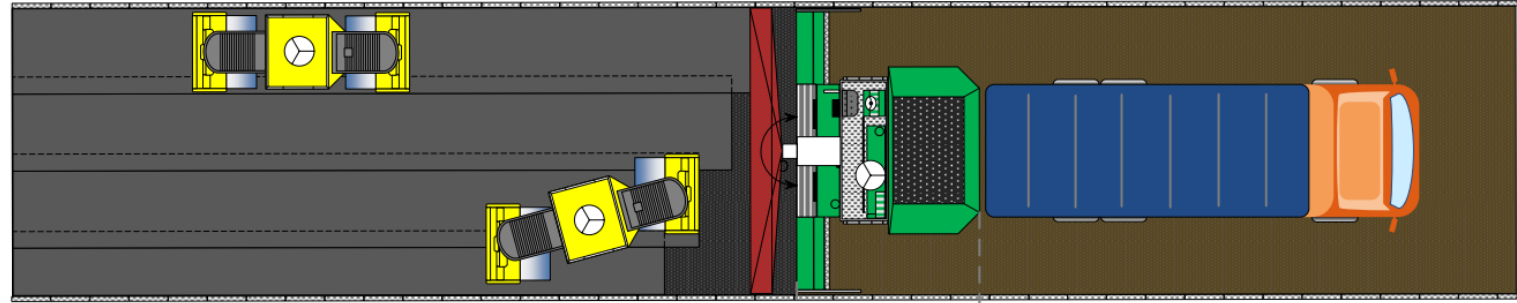
$$\sigma = E_R \cdot \varepsilon^R$$

$$\varepsilon^R = \frac{1}{E_R}\int_o^t E(t-\tau)\frac{\partial \varepsilon}{\partial \tau}d\tau$$

Intelligent construction operation

- Guidance to pavers and rollers
- Temperature control
- Number of passages

Makarov et al. (2019)

So, what the pavement rehabilitation in the XXI century should be ?

thank you

Pavement rehabilitation in the XXI century

Jorge Pais

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