Aleksander Zborowski, PhD. Eng.

DIGITALIZATION AUTOMATION & ARTIFICIAL INTELLIGENCE

AN OPPORTUNITY FOR TECHNOLOGICAL ACCELERATION TOWARD SUSTAINABLE HIGHWAY ENGINEERING

DIGITALIZATION ARTIFICIAL INTELLIGENCE & AUTOMATION

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TPA

01 SUSTAINABLE HIGHWAY ENGINEERING

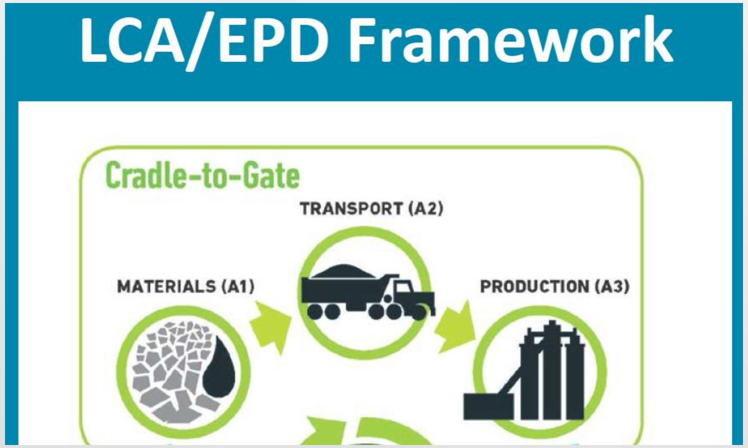
SUSTAINABLE HIGHWAY ENGINEERING

CHALLENGES

- EXTENTION OF LIFECYCLE
- REDUCTION OF ENVIRONMENTAL IMPACT
- CIRCULARITY
- ADAPTATION TO CLIMATE CHANGE – RESILIENT INFRASTRUCTURE

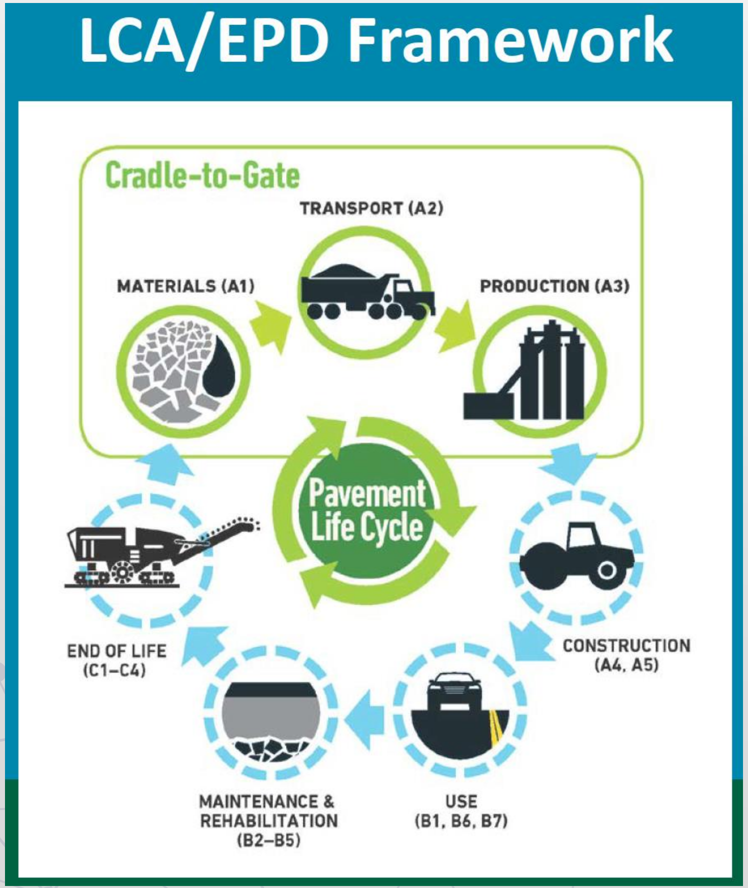
COST AND ENVIRONMENTAL IMPACT OF INFRASTRUCTURE CONTRACTS

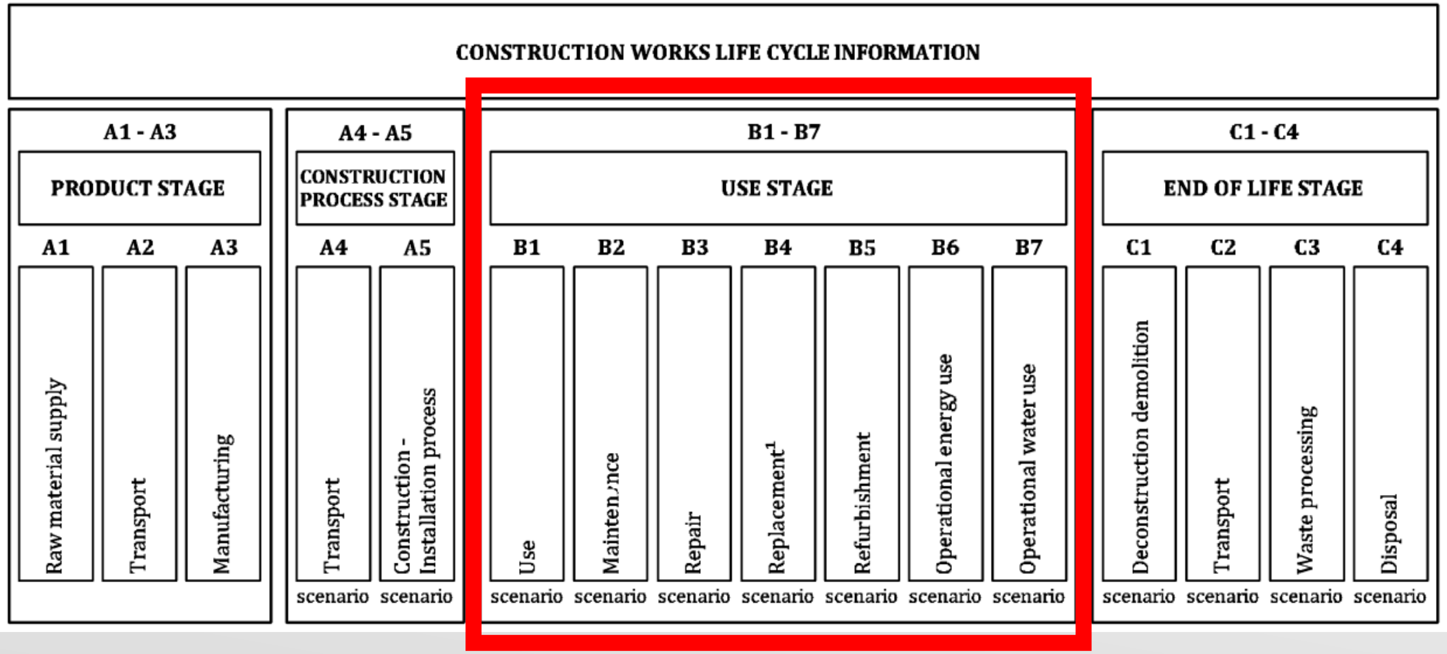
CRADLE-TO-GATE ANALYSES ARE NECESSARY BUT NOT SUFFICIENT



COST AND ENVIRONMENTAL IMPACT OF INFRASTRUCTURE CONTRACTS

ONLY FULL LIFE CYCLE ASSESSMENTS ARE CORRECT





- 20-50 years of exploitation
- Maintanance, repairs, rehabilitations
- Traffic delay cost

A RECIPE FOR DURABLE, COST-EFFECTIVE AND SUSTAINABLE HIGHWAY ENGINEERING

OPTIMAL PAVEMENT STRUCTURE DESIGN

- ✓ Longevity of pavement construction achieved through careful mechanistic analysis
- ✓ Increased structural performance - less, but better quality
- ✓ Balanced development of all pavement layers

PROPER MATERIALS AND TECHNOLOGIES

- ✓ Materials better tailored to function and role in pavement
- ✓ Higher mechanical performance
- ✓ Innovative materials and technologies
- ✓ More use of local and recycled materials

HIGHER PRODUCTION AND CONSTRUCTION QUALITY

- ✓ Increased quality of production and workmanship through process automation and prediction of results
- ✓ Stricter adherence to the technological regime and recommendations through machine automation and process coordination

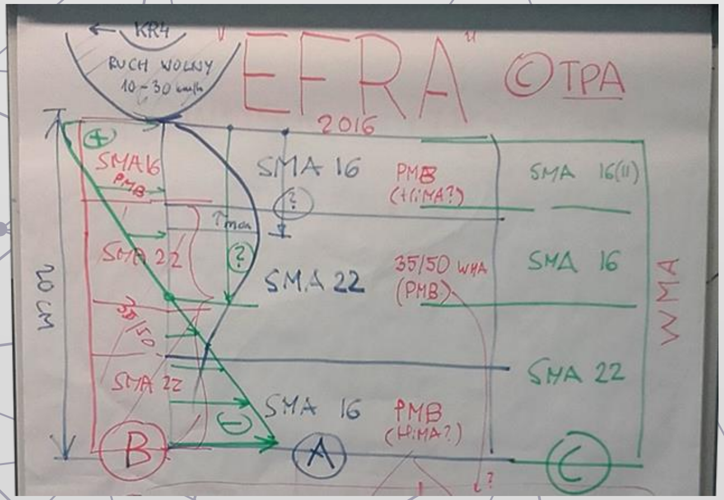
We have already done a lot on this issue as an industry, academia and administration but we need to accelerate the validation and implementation of new solutions

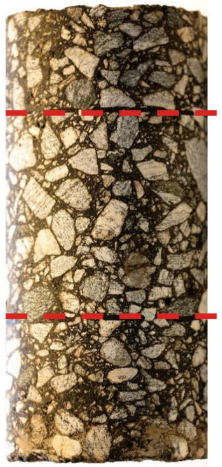
Just a few examples…

HIGH-PERFORMANCE PAVEMENTS 2015-2019

FLEXIBLE PERPETUAL PAVEMENT

FULL SMA Heavy Duty Pavement EFRA – LOTOS





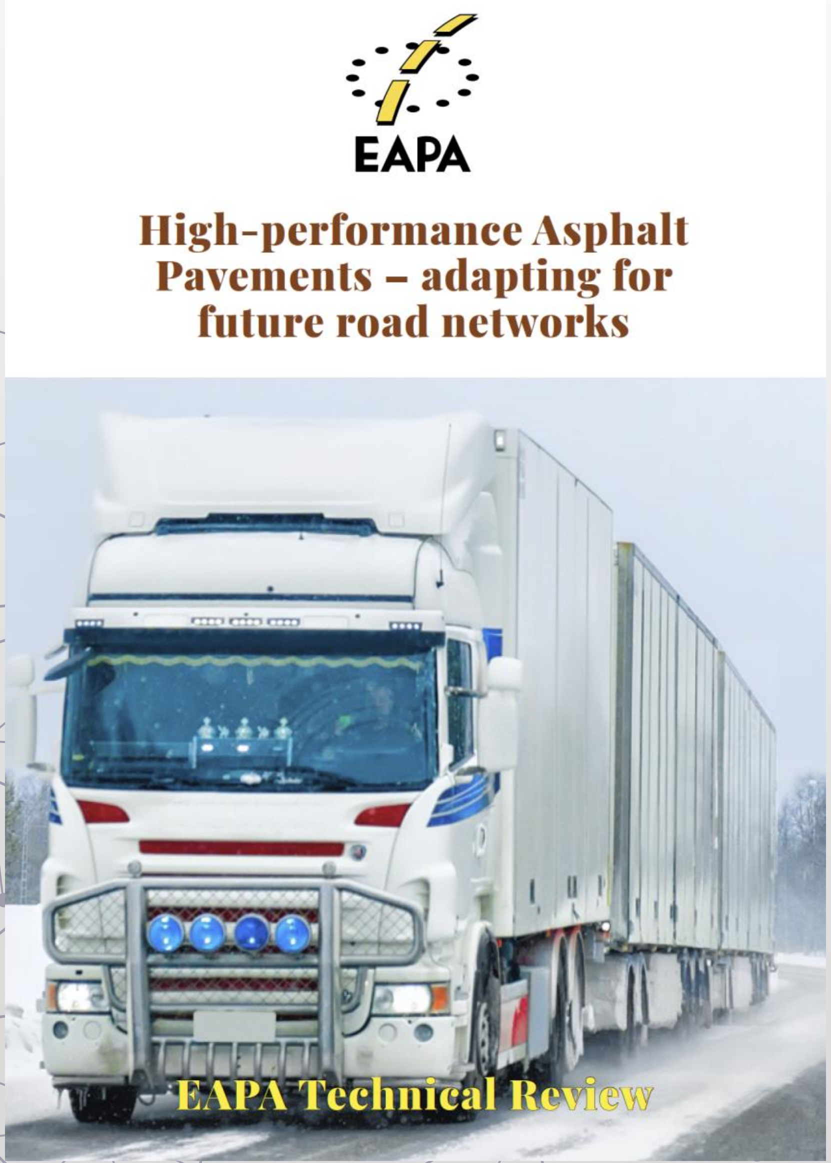
SMA 16 HiMA 45/80-80
5 CM

SMA 22 W HiMA 25/55-80
9 CM

SMA 16 P HiMA 45/80-80
6 CM

2019

HIGH-PERFORMANCE PAVEMENTS 2022



3.5 New concepts for pavement structures

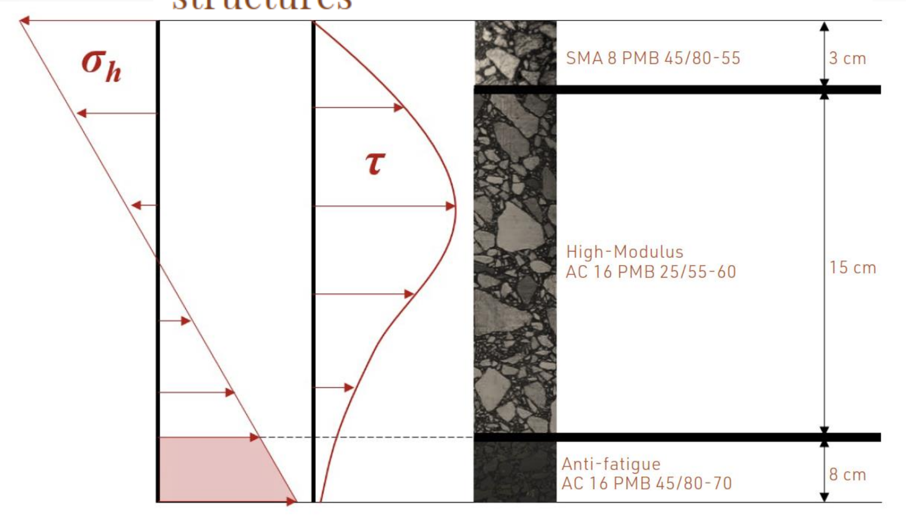


Figure 6. New pavement structure configuration incorporating anti-fatigue layer

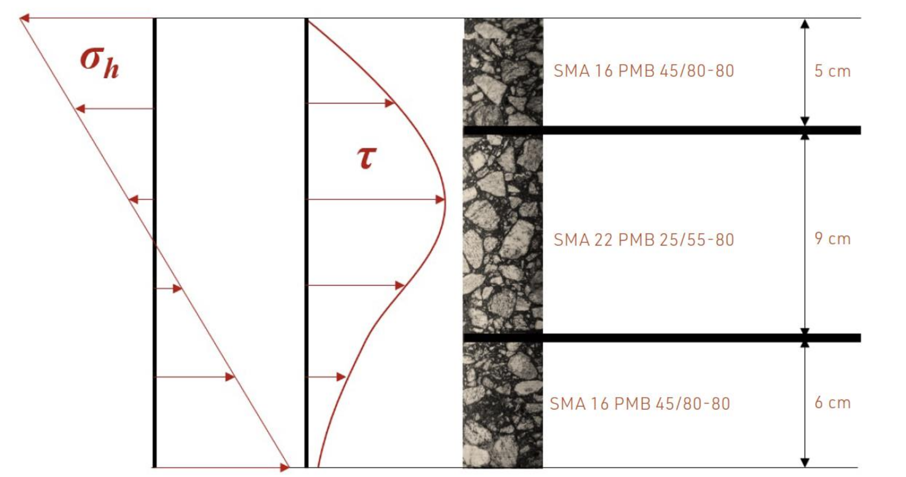
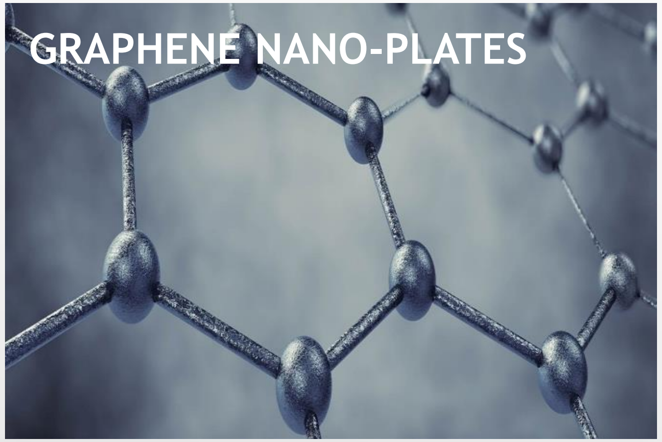


Figure 7. Triple-SMA pavement structure configuration

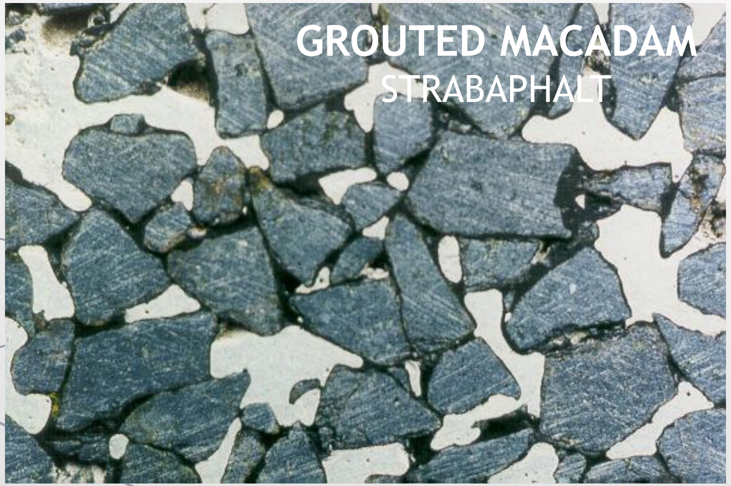
PROPER MATERIALS AND TECHNOLOGIES

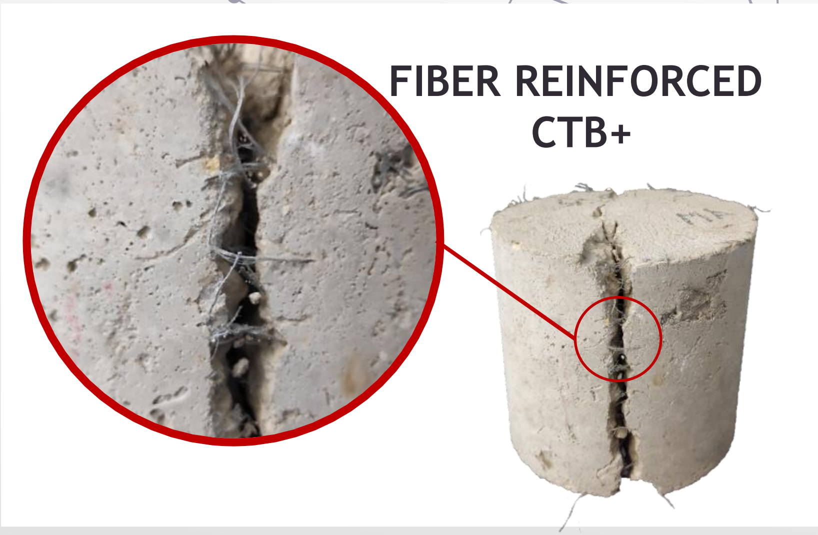
INNOVATIVE, HIGH-PERFORMANCE, TAILOR-MADE MATERIALS



PROPER MATERIALS AND TECHNOLOGIES

INNOVATIVE, HIGH-PERFORMANCE, TAILOR-MADE MATERIALS

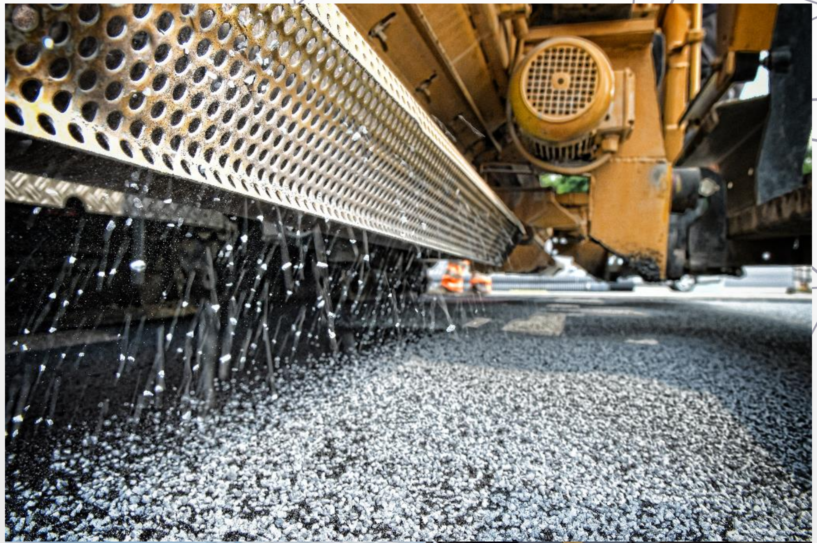




SUPERIOR CONSTRUCTION TECHNOLOGIES

KOMPAKTASPHALT

SPREADER INTEGRATED WITH PAVER



ADVANCED LAB AND FIELD TESTS FOR QC

E* Dynamic Stiffness Modulus, SVECD

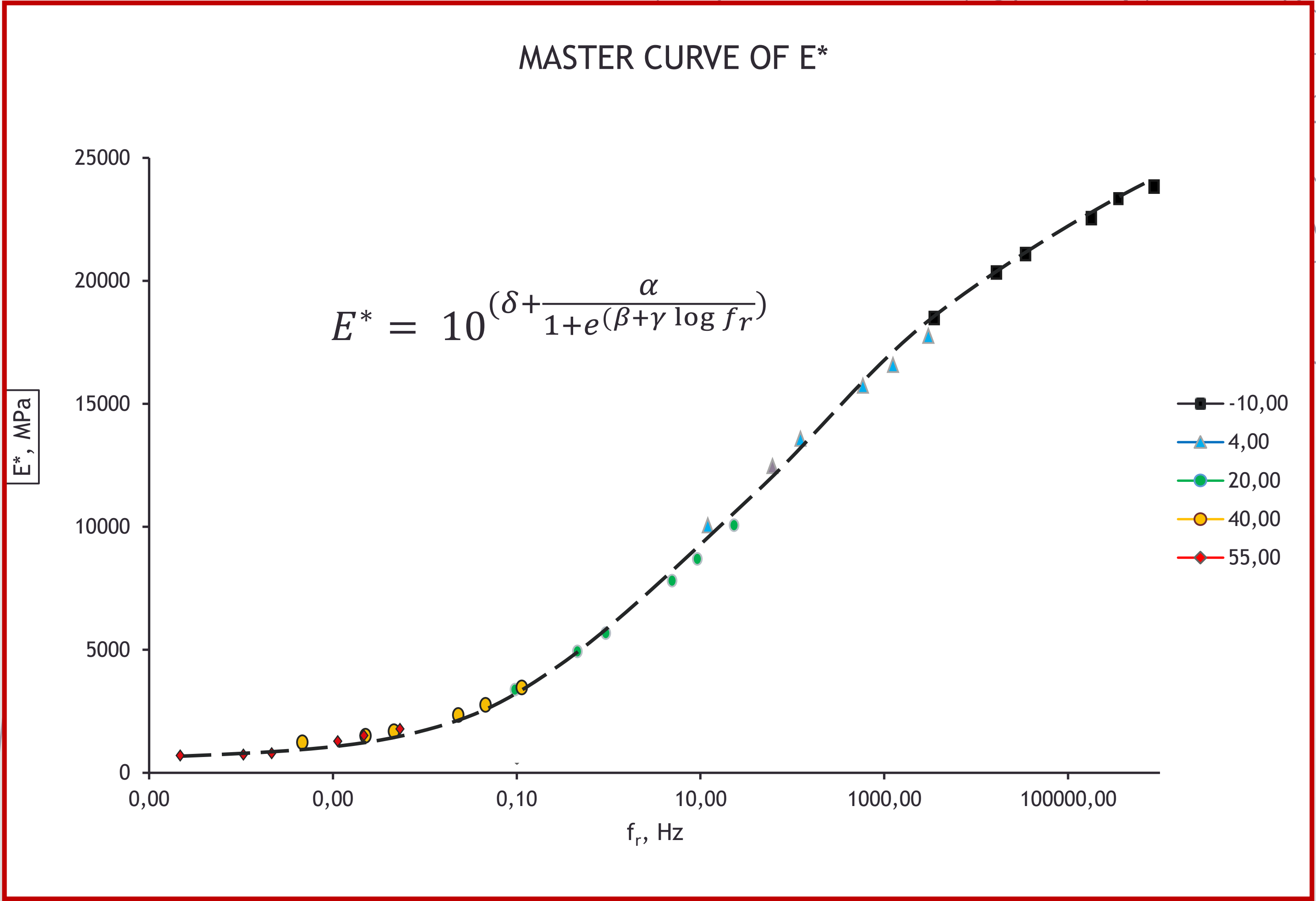
DSR for G*, MSCR, LAS

PQI –nondestructive layer compaction

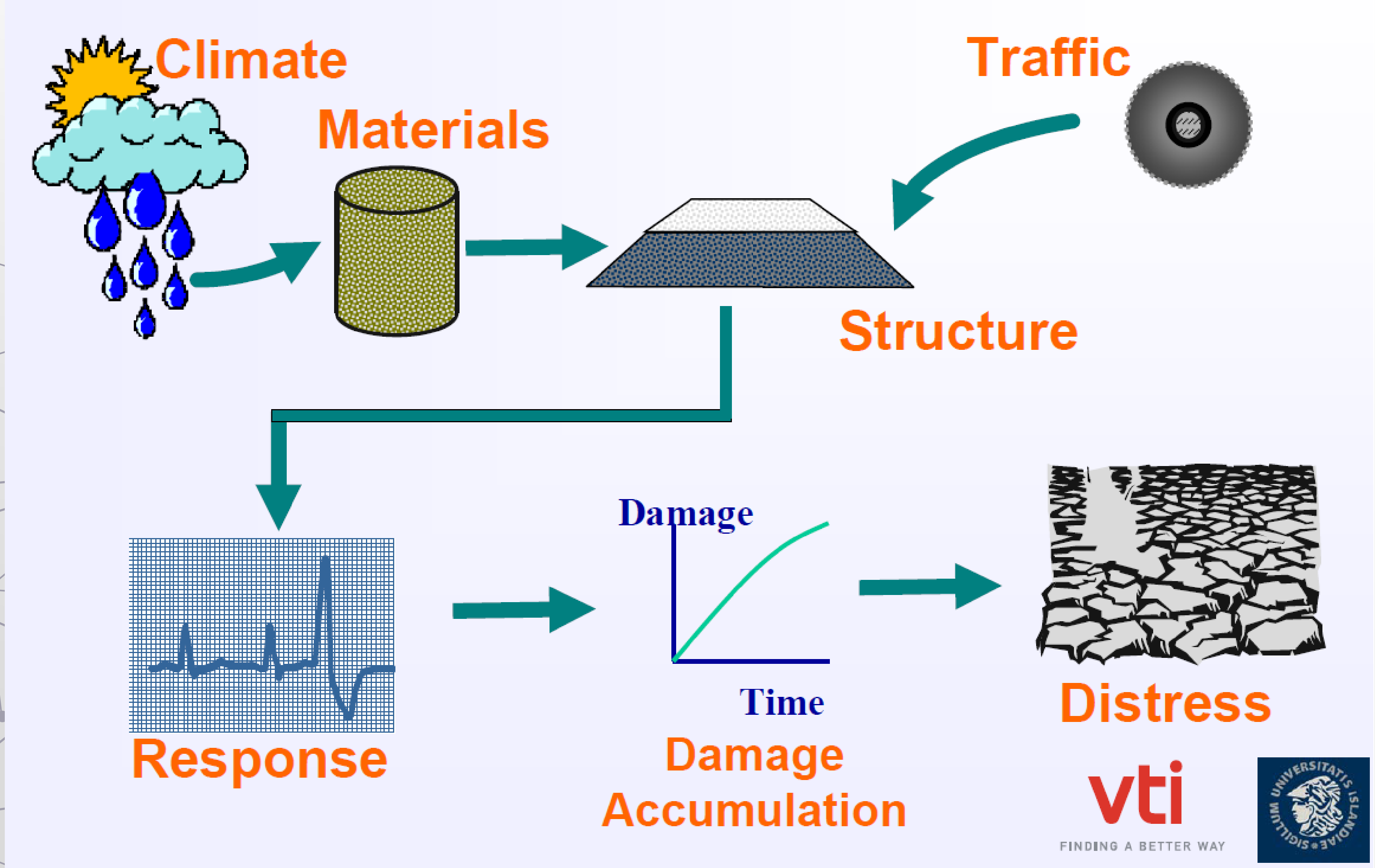
FTIR – laser spectrometry

MIT-Scan T2 – nondestructive layer thickness

E* DYNAMIC STIFFNESS MODULUS



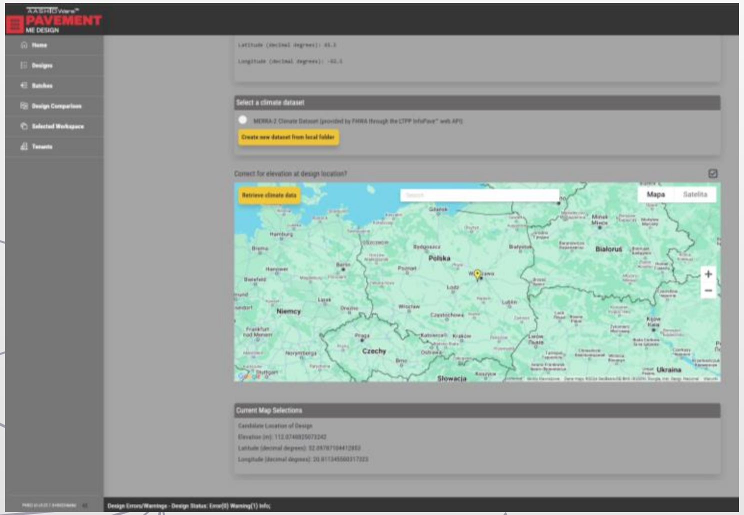
MECHANISTIC-EMPIRICAL ANALYSIS METHODS

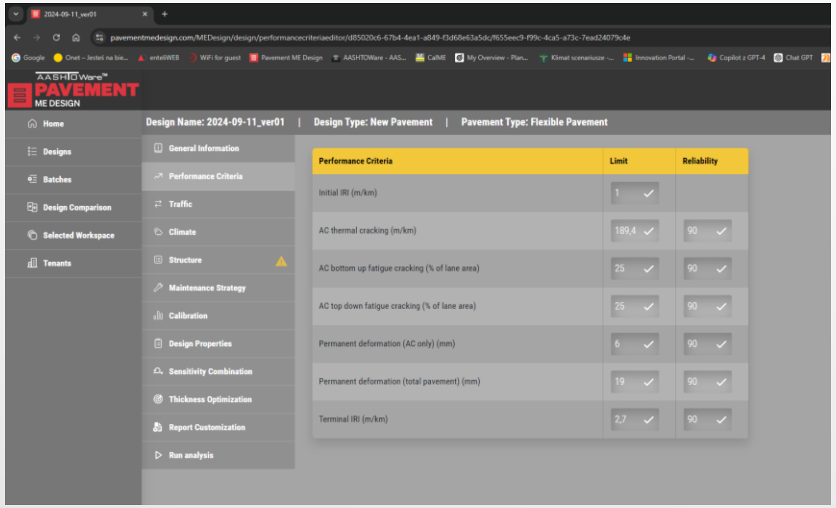


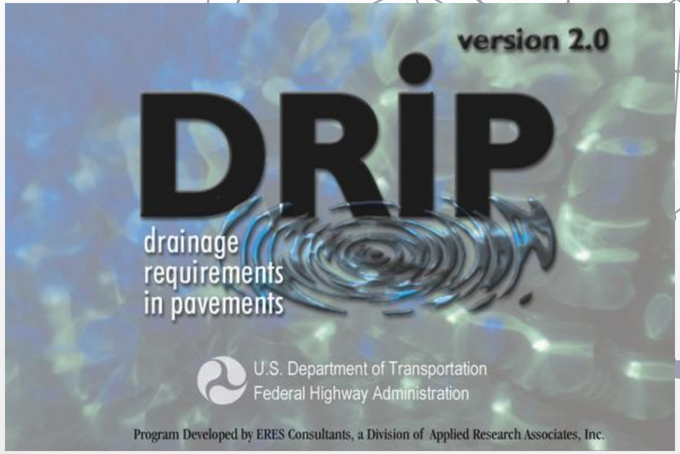
source: Mechanistic Pavement Design – Sigudur Erlingsson, Reykjavik 2007

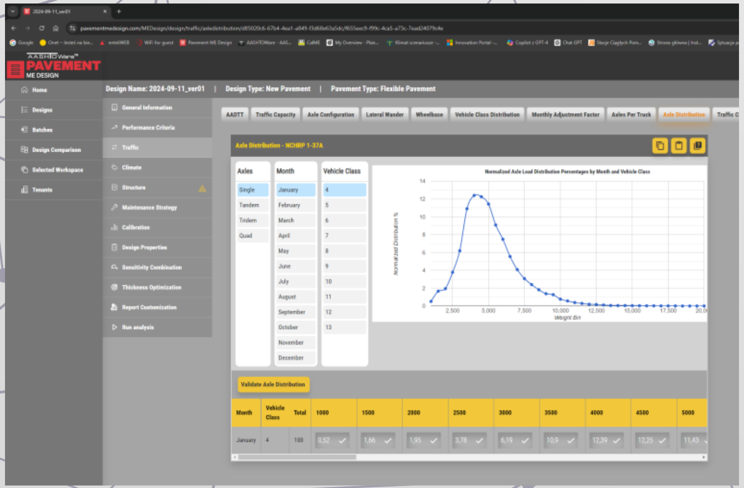
MECHANISTIC-EMPIRICAL ANALYSIS METHODS

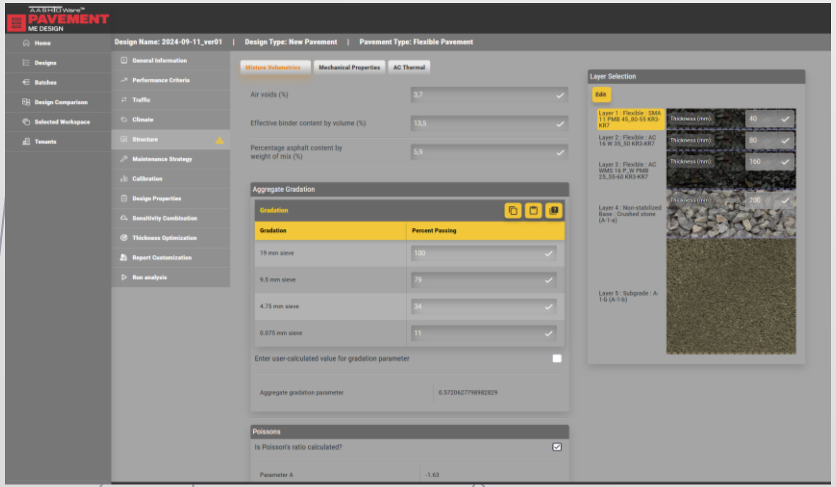
AASHTOWare Pavement ME

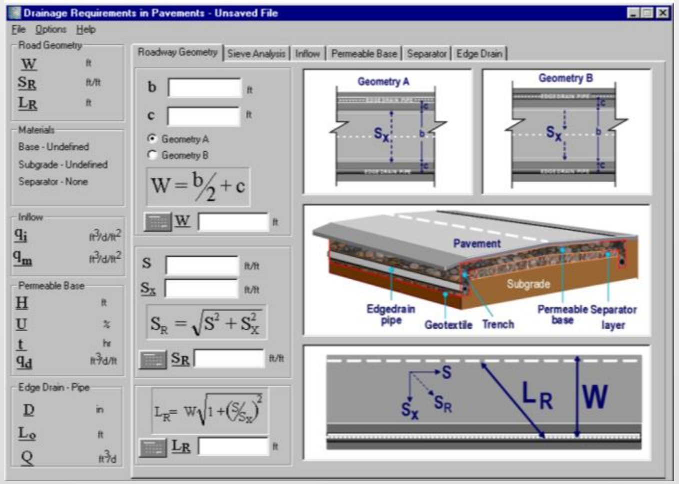






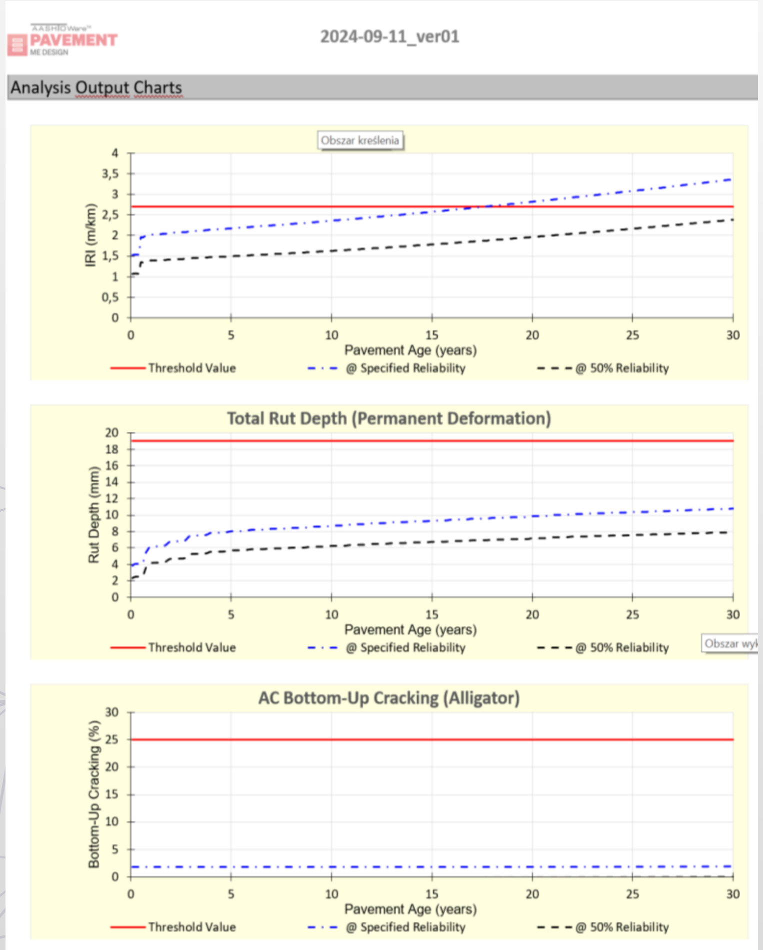


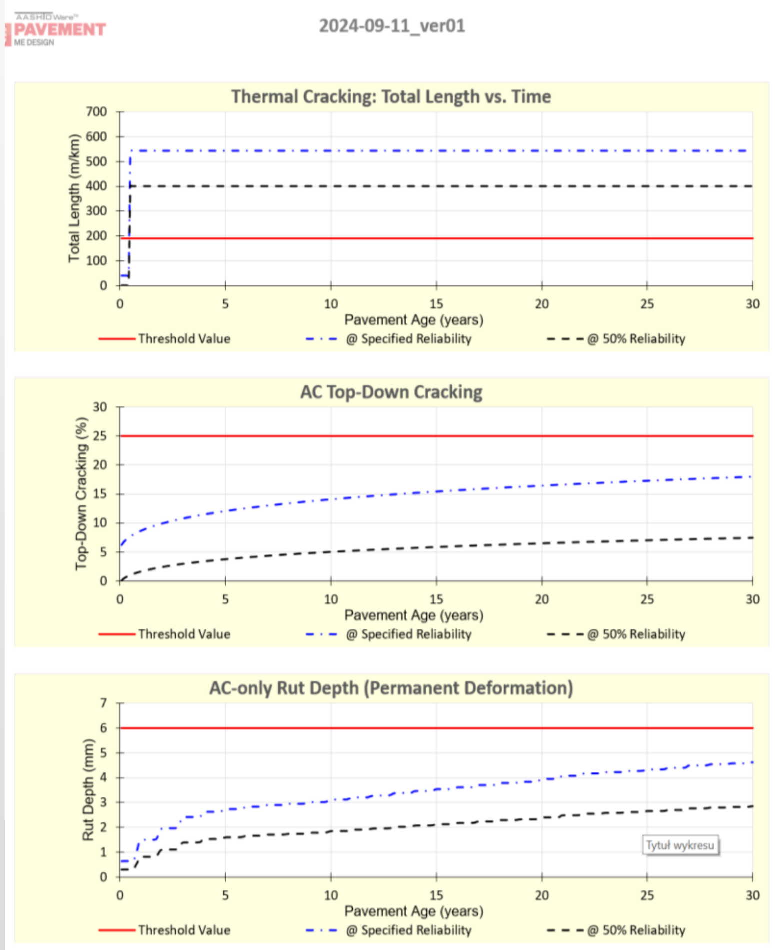


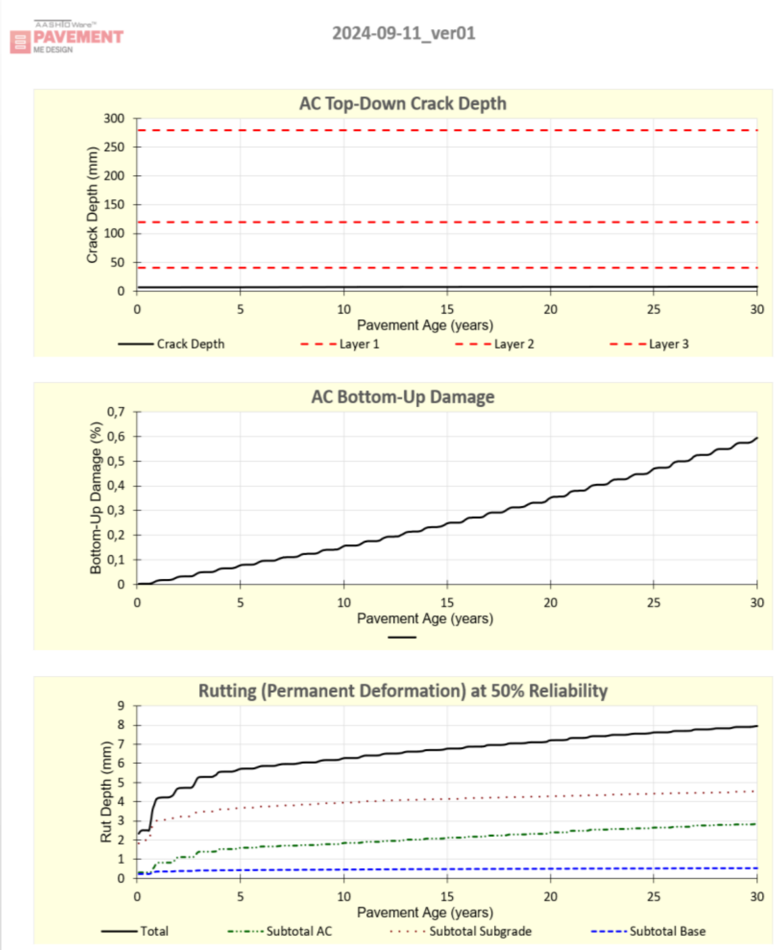


MECHANISTIC-EMPIRICAL ANALYSIS METHODS

MULTICRITERIA RESULTS OVER A FULL LIFECYCLE

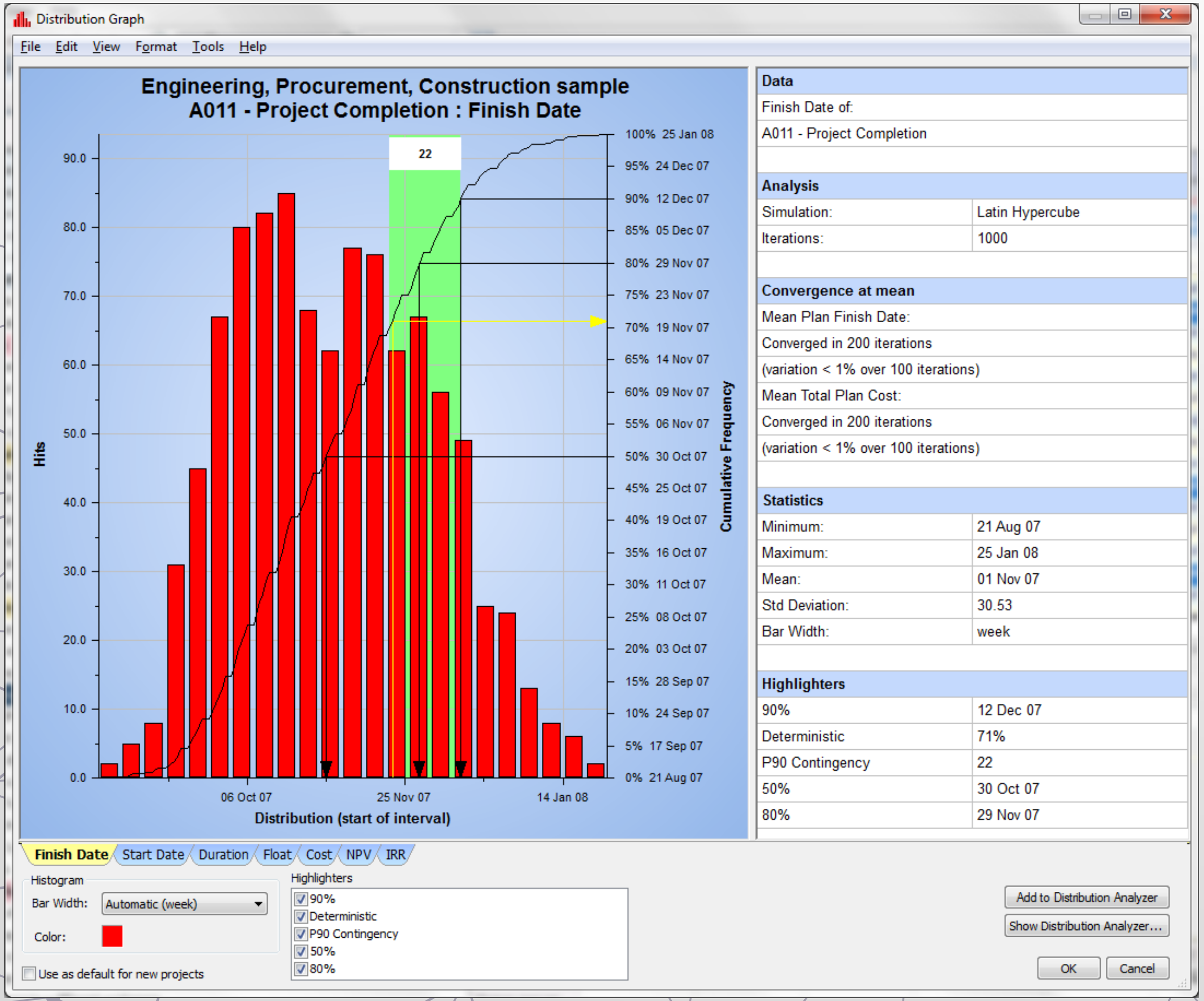






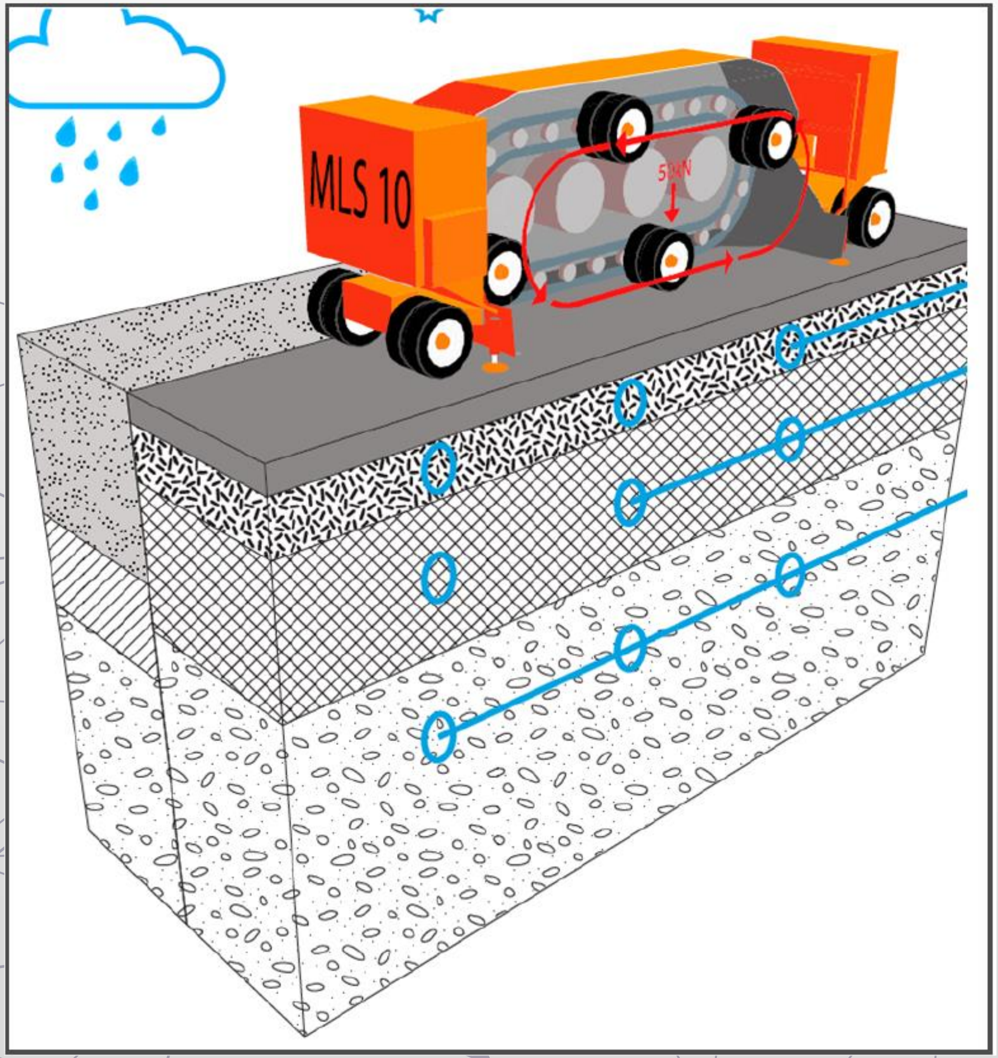
PROBABILISTIC ANALYSIS AND PREDICTION

MONTE CARLO METHOD



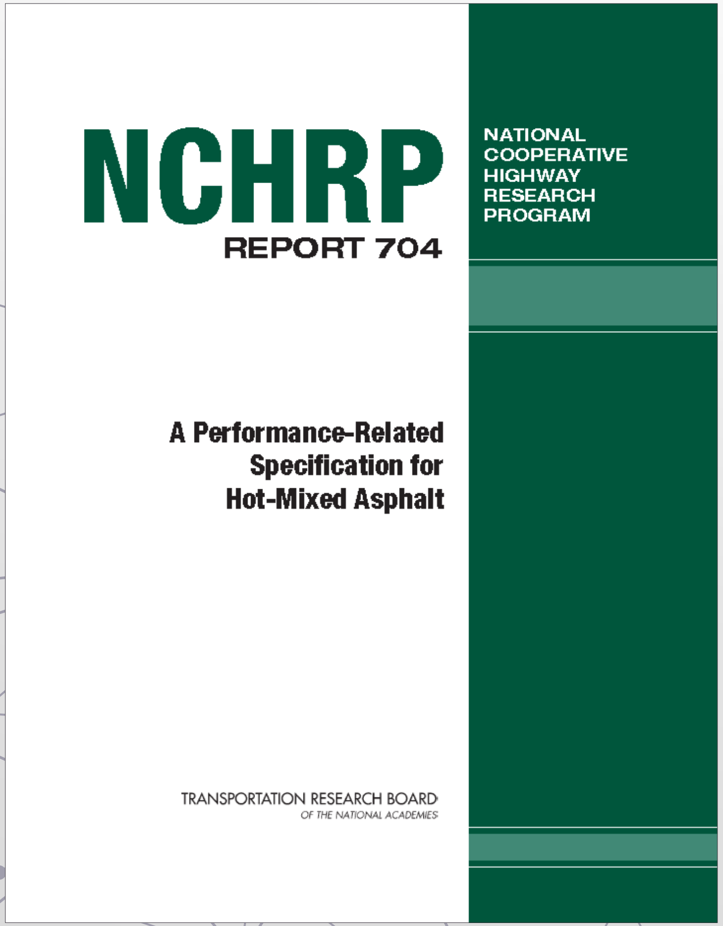
MOBILE LOAD SIMULATORS

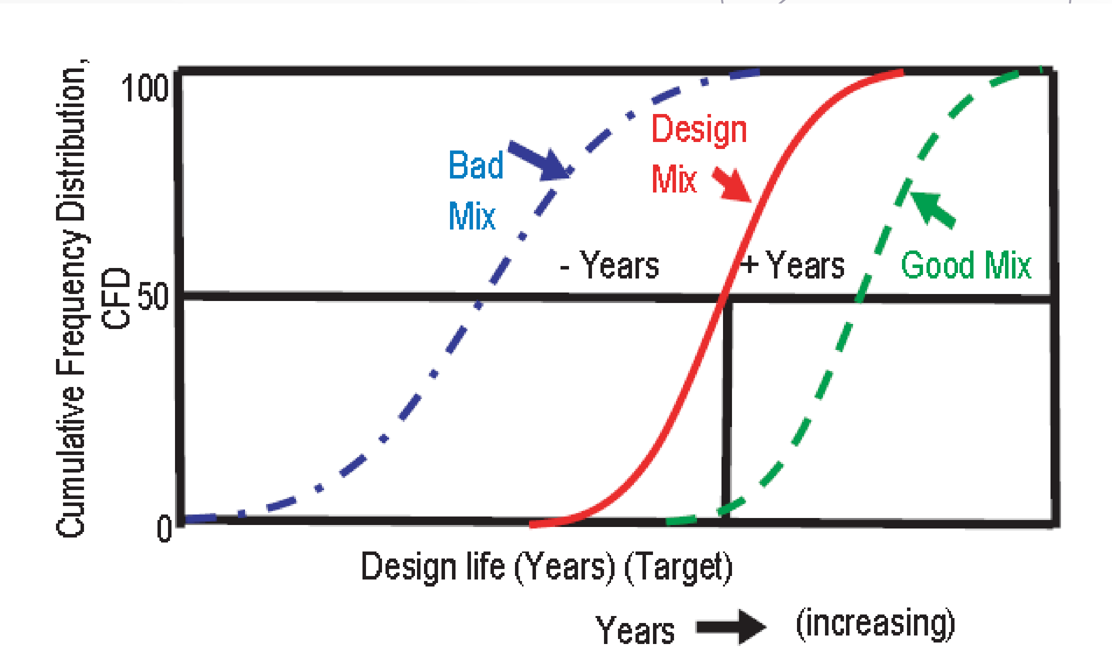
FULL SCALE ACCELERATED ROAD TEST FOR VERIFICATION AND VALIDATION



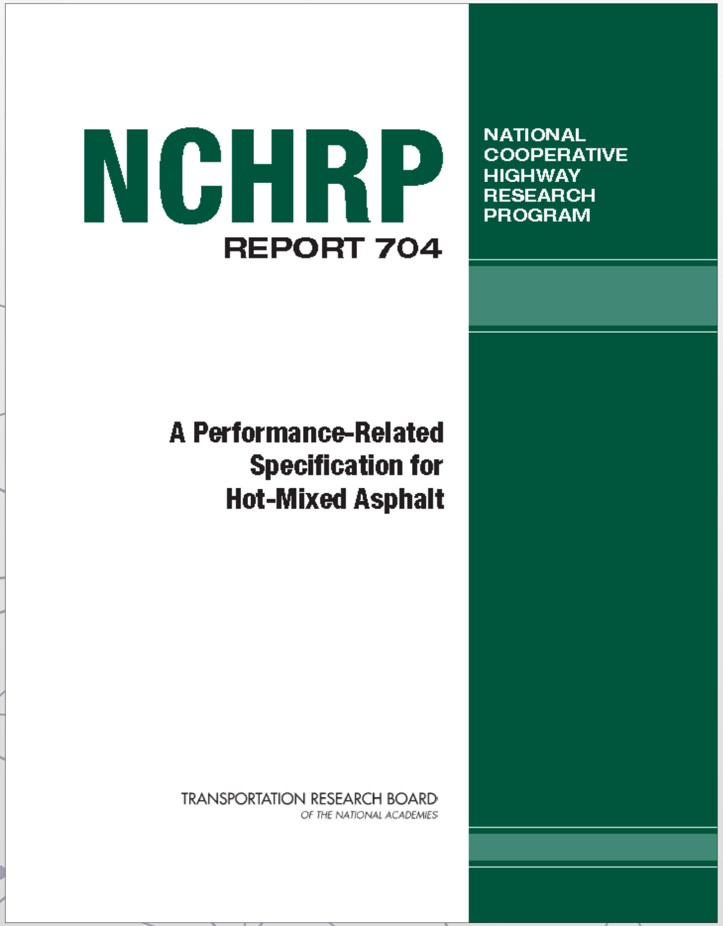
source: www.pavetesting.com and BASt homepage

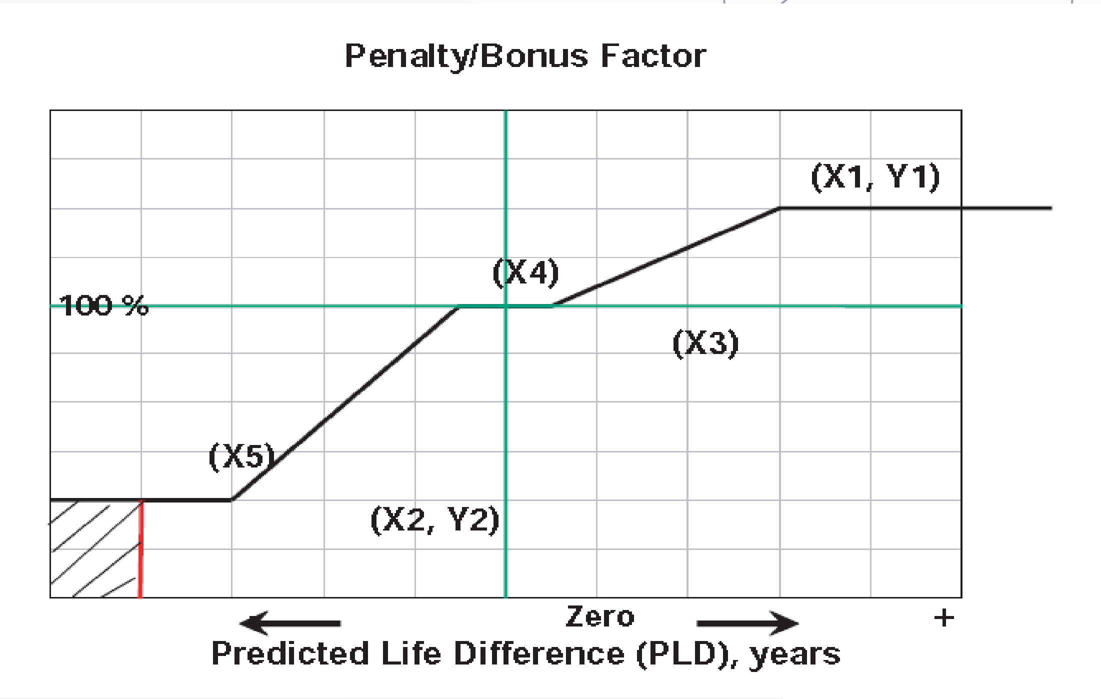
PERFORMANCE RELATED SPECIFICATIONS





PERFORMANCE RELATED SPECIFICATIONS





source: internet

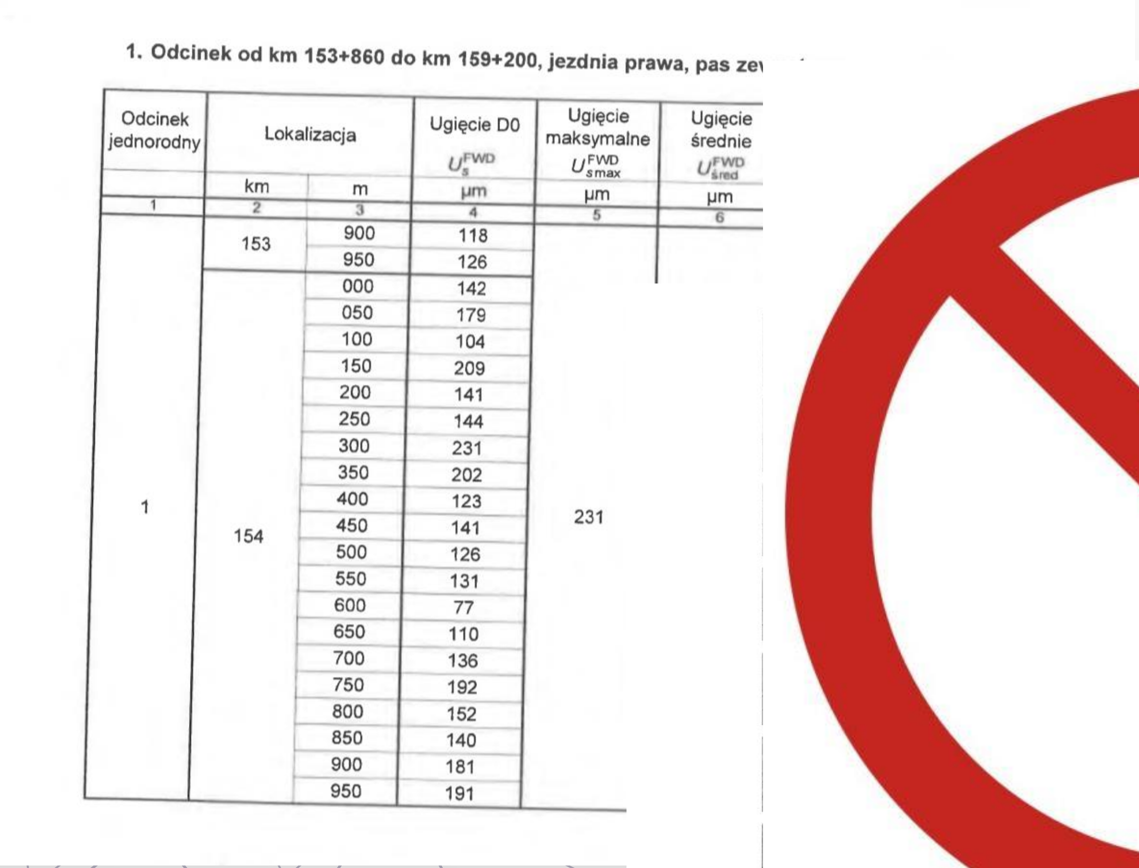
02

DIGITALIZATION FIRST

DIGITALIZATION

The first and most important task is to collect all the necessary **DATA** in the **DIGITAL FORM** and store them in a properly designed **DATABASE**.

THIS IS NOT DIGITAL FORM OF DATA

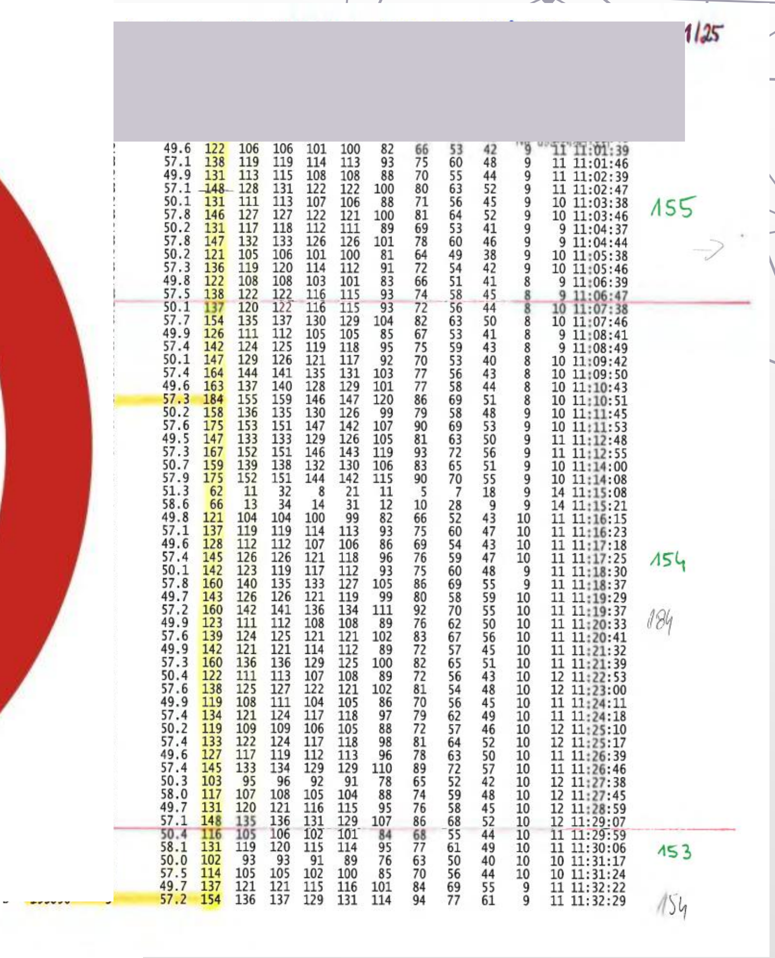


1. Odcinek od km 153+860 do km 159+200, jezdnia prawa, pas ze

Odcinek jednorodny	Lokalizacja		Ugięcie D0 U_s^{FWD}	Ugięcie maksymalne $U_{s\,max}^{FWD}$	Ugięcie średnie $U_{śred}^{FWD}$
	km	m	µm	µm	µm
1	2	3	4	5	6
1	153	900	118	231	
		950	126		
	154	000	142		
		050	179		
		100	104		
		150	209		
		200	141		
		250	144		
		300	231		
		350	202		
		400	123		
		450	141		
		500	126		
		550	131		
		600	77		
		650	110		
		700	136		
		750	192		
		800	152		
		850	140		
		900	181		
		950	191		

28,900	5,700	1,2	2,5	1,6	359	2 618 510	KR-4	Pas prawy 14,2	Pas lewy 21,4

2



1/25

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57.1	138	119	119	114	113	93	75	60	48	9	11	11:01:46
49.9	131	113	115	108	108	88	70	55	44	9	11	11:02:39
57.1	~~148~~	128	131	122	122	100	80	63	52	9	11	11:02:47
50.1	131	111	113	107	106	88	71	56	45	9	10	11:03:38
57.8	146	127	127	122	121	100	81	64	52	9	10	11:03:46
50.2	131	117	118	112	111	89	69	53	41	9	9	11:04:37
57.8	147	132	133	126	126	101	78	60	46	9	9	11:04:44
50.2	121	105	106	101	100	81	64	49	38	9	10	11:05:38
57.3	136	119	120	114	112	91	72	54	42	9	10	11:05:46
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57.7	154	135	137	130	129	104	82	63	50	8	10	11:07:46
49.9	126	111	112	105	105	85	67	53	41	8	9	11:08:41
57.4	142	124	125	119	118	95	75	59	43	8	9	11:08:49
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57.4	164	144	141	135	131	103	77	56	43	8	10	11:09:50
49.6	163	137	140	128	129	101	77	58	44	8	10	11:10:43
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57.5	114	105	105	102	100	85	70	56	44	10	10	11:31:24
49.7	137	121	121	115	116	101	84	69	55	9	11	11:32:22
57.2	154	136	137	129	131	114	94	77	61	9	11	11:32:29

155

154

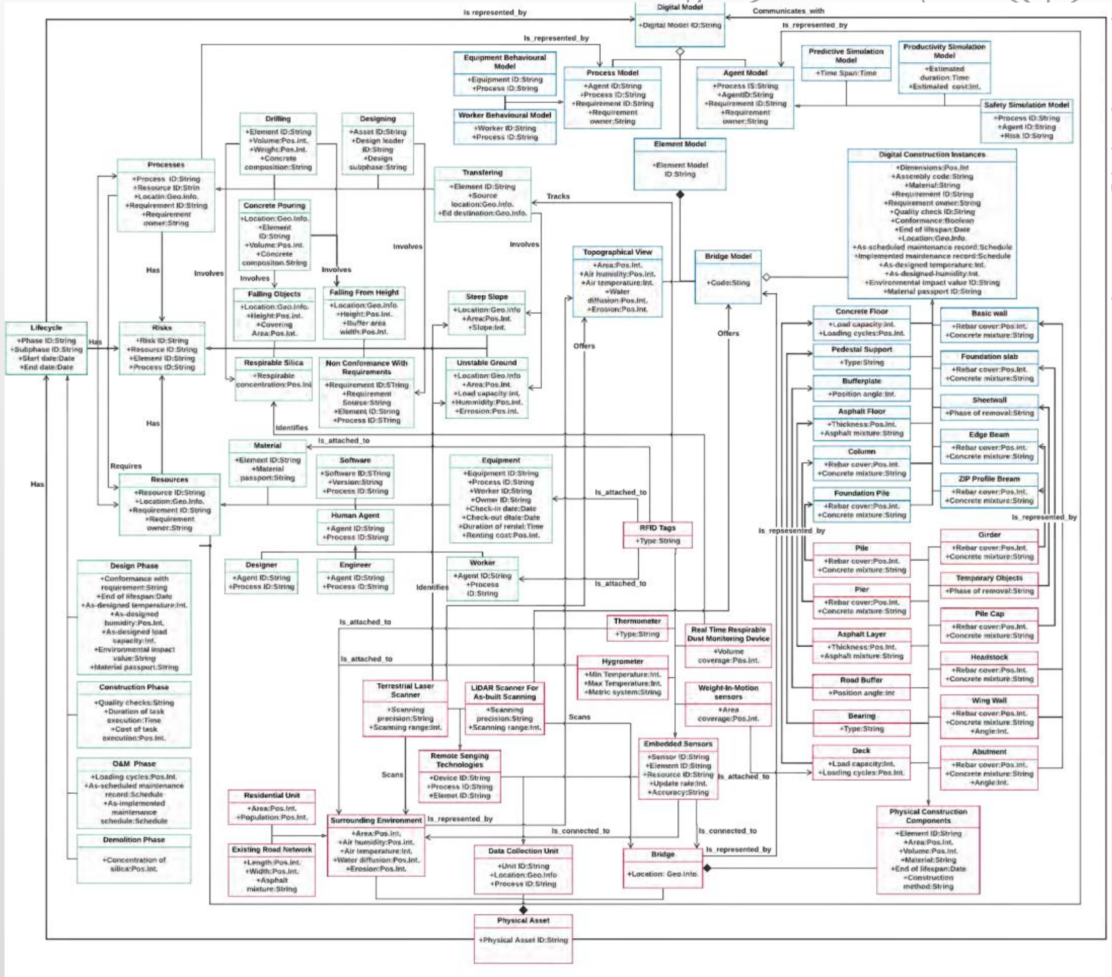
184

153

154

DIGITAL FORM OF DATA

RELATIONAL DATABASE

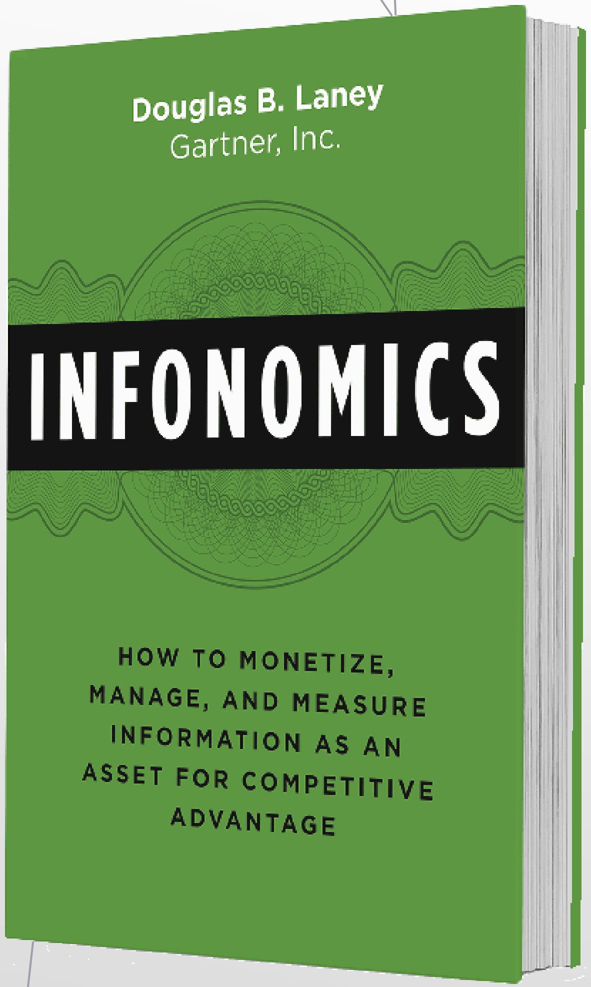


DATA is the oil of the 21st century

INFORMATION

+

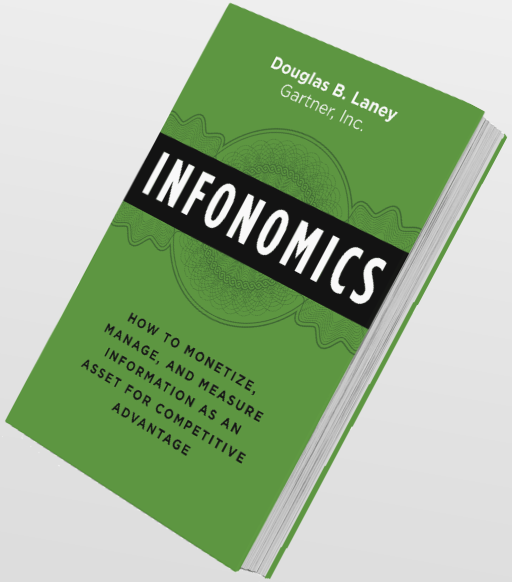
ECONOMICS



INFONOMICS

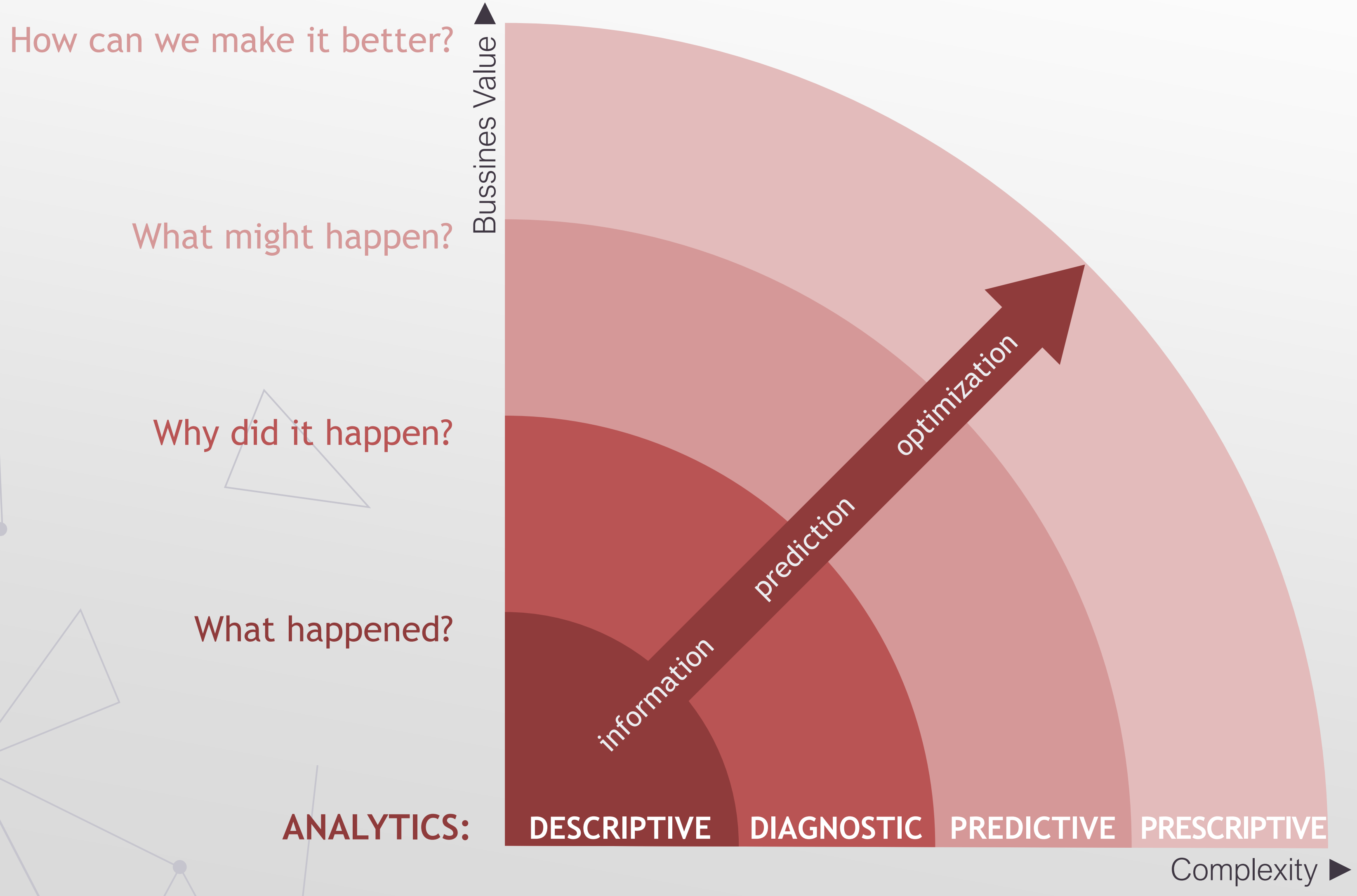
Business Information Economics
and Data Monetization

Information overload has become a **curse**, but **properly analyzed** data may become a **blessing and fortune**



PRESCRIPTIVE ANALYTICS

The Holly Grail of Information Management



03 ARTIFICIAL INTELLIGENCE

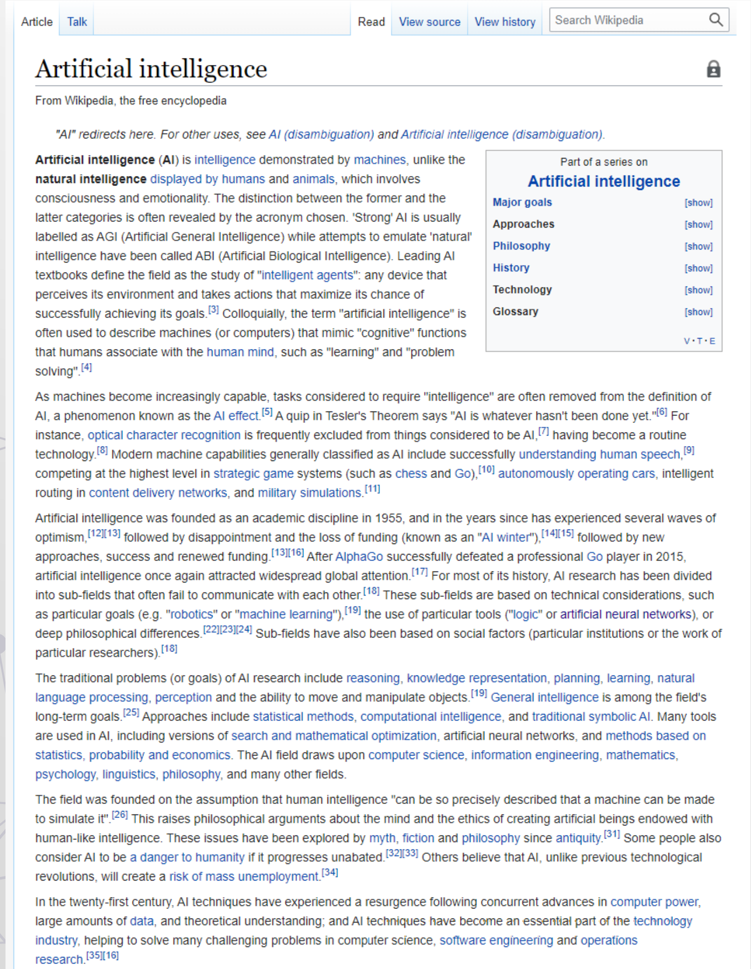
CAN IT BE USEFUL FOR US?

03 ARTIFICIAL INTELLIGENCE

HOW CAN IT BE USEFUL FOR US?

ARTIFICIAL INTELLIGENCE

DEFINITION



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Artificial intelligence

From Wikipedia, the free encyclopedia

"AI" redirects here. For other uses, see AI (disambiguation) and Artificial intelligence (disambiguation).

Part of a series on
Artificial intelligence
- Major goals [show]
- Approaches [show]
- Philosophy [show]
- History [show]
- Technology [show]
- Glossary [show]

V · T · E

Artificial intelligence (**AI**) is intelligence demonstrated by machines, unlike the **natural intelligence** displayed by humans and animals, which involves consciousness and emotionality. The distinction between the former and the latter categories is often revealed by the acronym chosen. 'Strong' AI is usually labelled as AGI (Artificial General Intelligence) while attempts to emulate 'natural' intelligence have been called ABI (Artificial Biological Intelligence). Leading AI textbooks define the field as the study of "intelligent agents": any device that perceives its environment and takes actions that maximize its chance of successfully achieving its goals.[3] Colloquially, the term "artificial intelligence" is often used to describe machines (or computers) that mimic "cognitive" functions that humans associate with the human mind, such as "learning" and "problem solving".[4]

As machines become increasingly capable, tasks considered to require "intelligence" are often removed from the definition of AI, a phenomenon known as the AI effect.[5] A quip in Tesler's Theorem says "AI is whatever hasn't been done yet."[6] For instance, optical character recognition is frequently excluded from things considered to be AI,[7] having become a routine technology.[8] Modern machine capabilities generally classified as AI include successfully understanding human speech,[9] competing at the highest level in strategic game systems (such as chess and Go),[10] autonomously operating cars, intelligent routing in content delivery networks, and military simulations.[11]

Artificial intelligence was founded as an academic discipline in 1955, and in the years since has experienced several waves of optimism,[12][13] followed by disappointment and the loss of funding (known as an "AI winter"),[14][15] followed by new approaches, success and renewed funding.[13][16] After AlphaGo successfully defeated a professional Go player in 2015, artificial intelligence once again attracted widespread global attention.[17] For most of its history, AI research has been divided into sub-fields that often fail to communicate with each other.[18] These sub-fields are based on technical considerations, such as particular goals (e.g. "robotics" or "machine learning"),[19] the use of particular tools ("logic" or artificial neural networks), or deep philosophical differences.[22][23][24] Sub-fields have also been based on social factors (particular institutions or the work of particular researchers).[18]

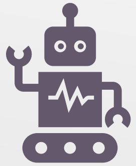
The traditional problems (or goals) of AI research include reasoning, knowledge representation, planning, learning, natural language processing, perception and the ability to move and manipulate objects.[19] General intelligence is among the field's long-term goals.[25] Approaches include statistical methods, computational intelligence, and traditional symbolic AI. Many tools are used in AI, including versions of search and mathematical optimization, artificial neural networks, and methods based on statistics, probability and economics. The AI field draws upon computer science, information engineering, mathematics, psychology, linguistics, philosophy, and many other fields.

The field was founded on the assumption that human intelligence "can be so precisely described that a machine can be made to simulate it".[26] This raises philosophical arguments about the mind and the ethics of creating artificial beings endowed with human-like intelligence. These issues have been explored by myth, fiction and philosophy since antiquity.[31] Some people also consider AI to be a danger to humanity if it progresses unabated.[32][33] Others believe that AI, unlike previous technological revolutions, will create a risk of mass unemployment.[34]

In the twenty-first century, AI techniques have experienced a resurgence following concurrent advances in computer power, large amounts of data, and theoretical understanding; and AI techniques have become an essential part of the technology industry, helping to solve many challenging problems in computer science, software engineering and operations research.[35][16]

mimics „cognitive” functions, such as **„learning”** and **„problem solving”**

works much better than standard algorithms in case of **insufficient amount of data**



doesn't involve consciousness and personality

TPA

WHAT IS AN AI TODAY?

THE FUTURE IS NOW

SOCIAL MEDIA

user feeds showing individually selected set of data and commercials

E-COMERCE

logistics optimization based on predictions of user behaviors (big data predictive analysis)

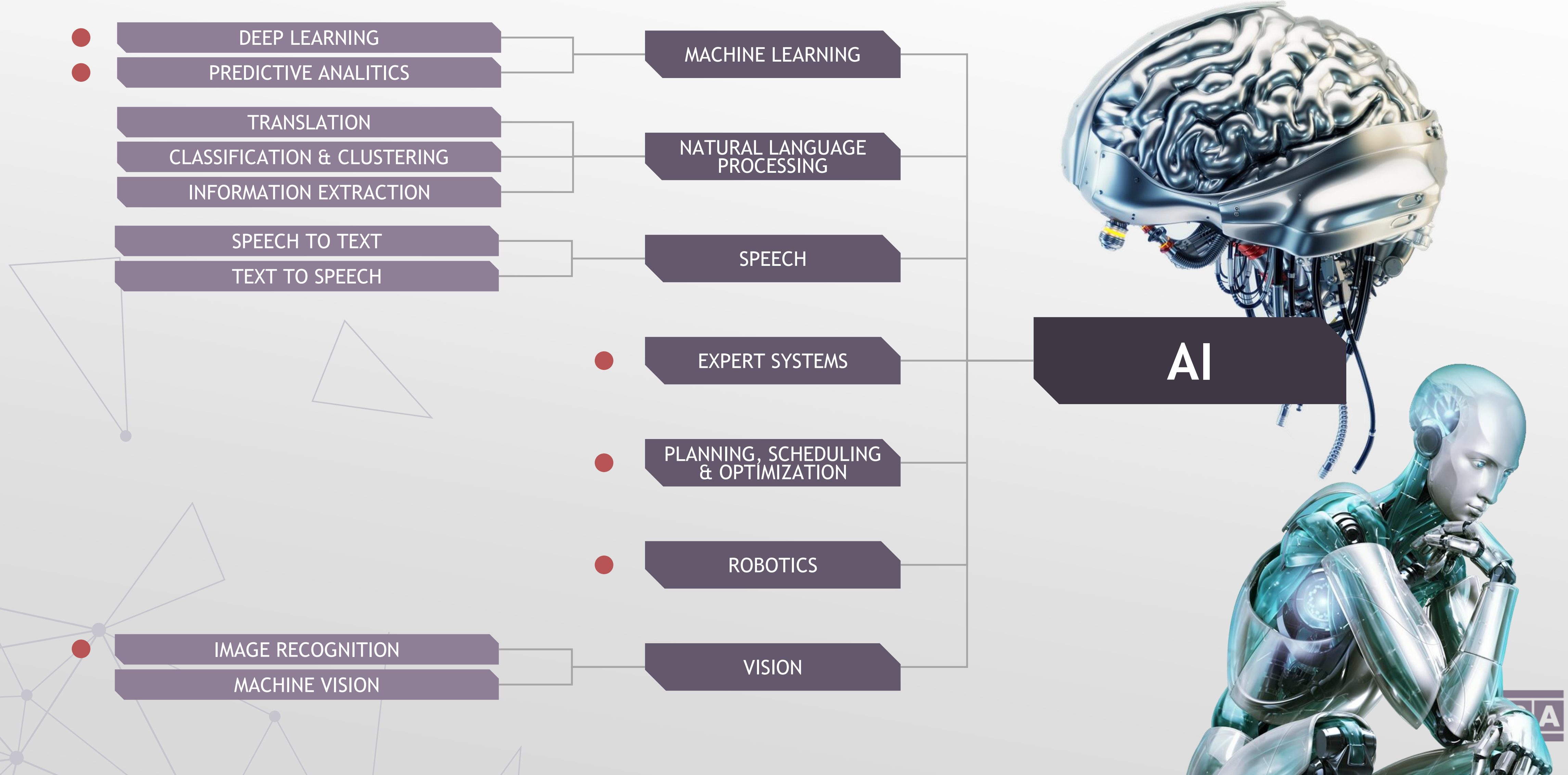
AUTONOMOUS CARS

AI Autopilot: machine vision, neural networks, autonomy algorithms

SELF-LANDING ROCKETS

AI Autopilot: controlling the rocket launches, flights and landings

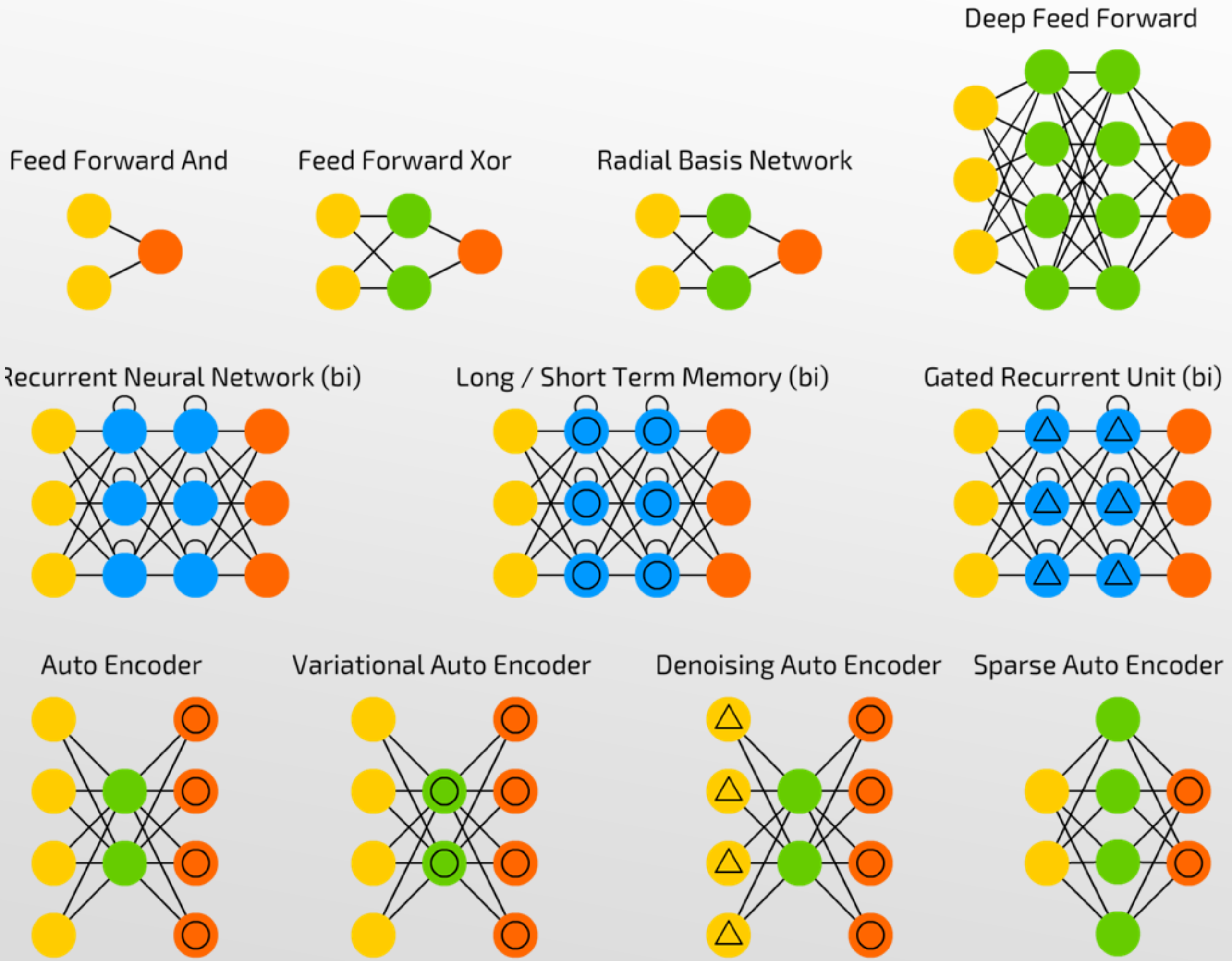
ARTIFICIAL INTELLIGENCE SCHEME



ARTIFICIAL NEURAL NETWORKS

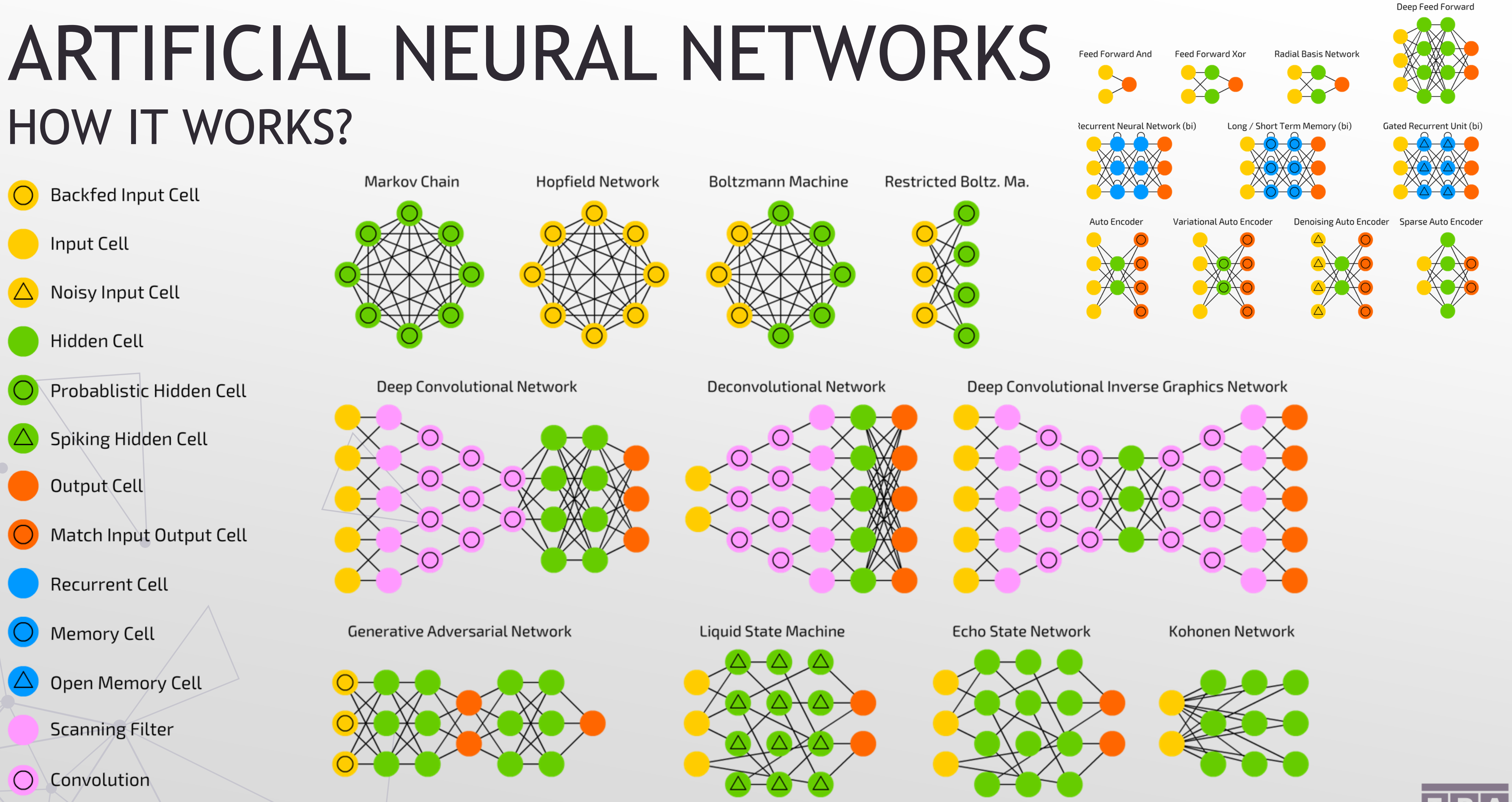
HOW IT WORKS?

- Backfed Input Cell
- Input Cell
- Noisy Input Cell
- Hidden Cell
- Probablistic Hidden Cell
- Spiking Hidden Cell
- Output Cell
- Match Input Output Cell
- Recurrent Cell
- Memory Cell
- Open Memory Cell
- Scanning Filter
- Convolution



ARTIFICIAL NEURAL NETWORKS

HOW IT WORKS?



04

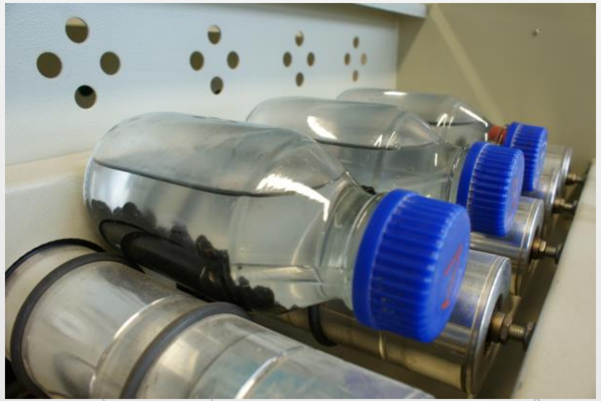
POSSIBLE APPLICATIONS IN HIGHWAY ENGINEERING

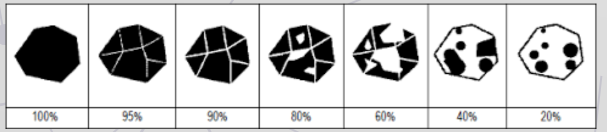
Just a few ideas…

AUTOMATION
&
ROBOTICS

IMAGE RECOGNITION SYSTEMS

AGGREGATE COATING ANALYSES (EN 12697-11:2020-07)





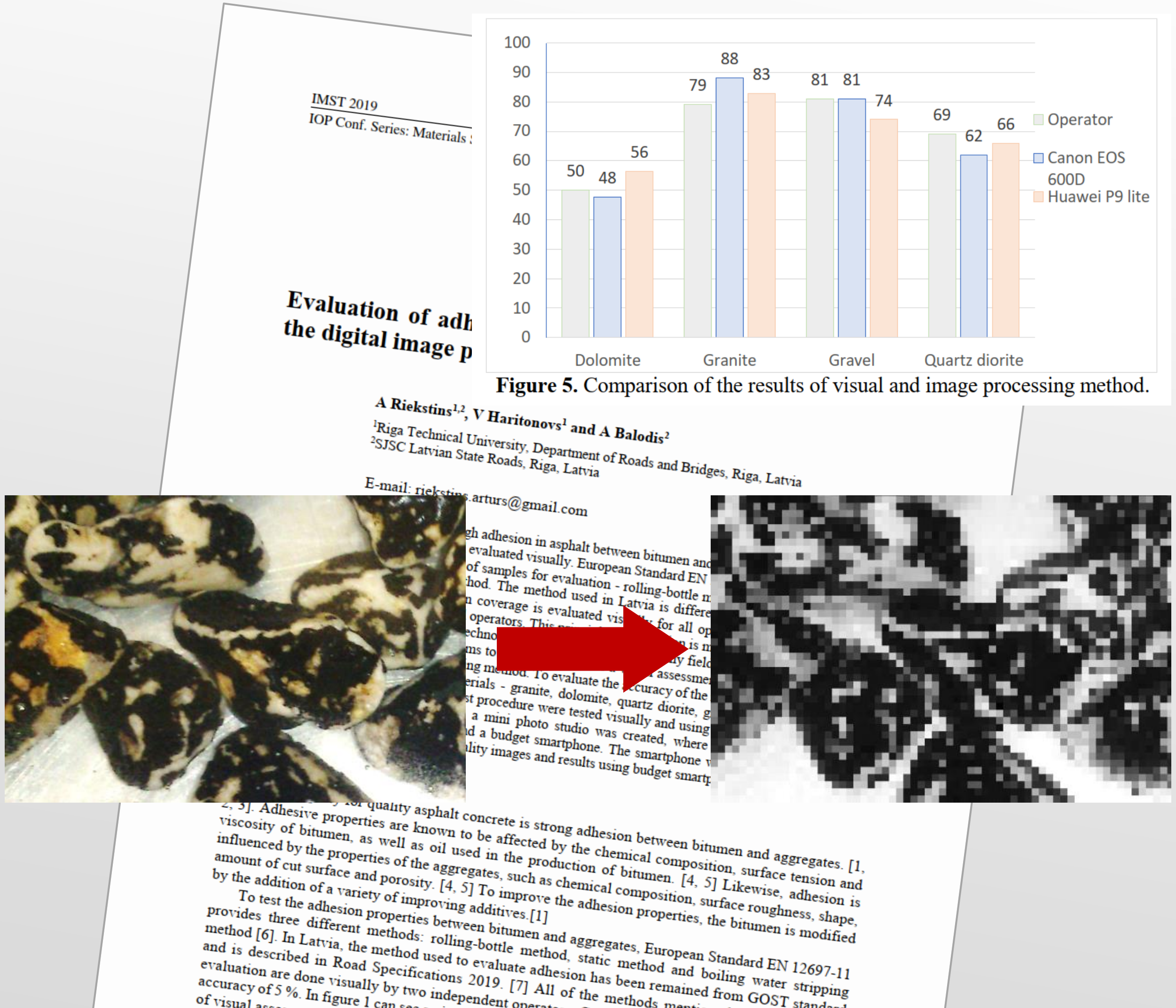


Figure 5. Comparison of the results of visual and image processing method.

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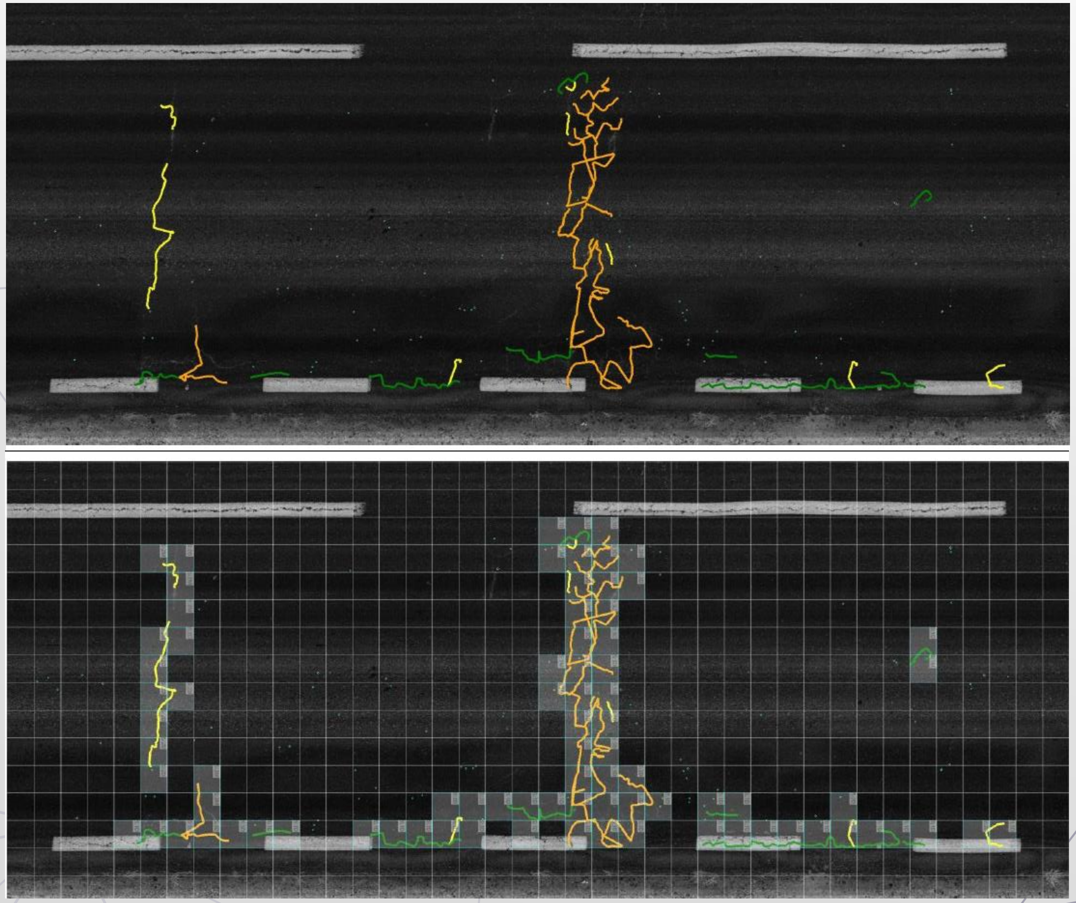
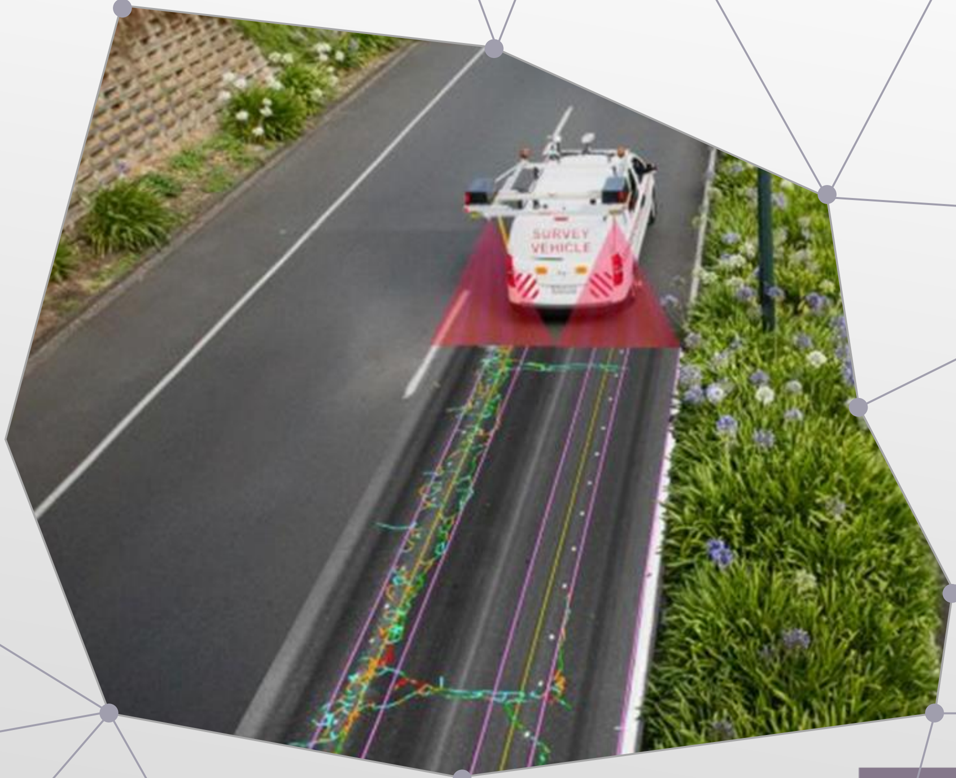
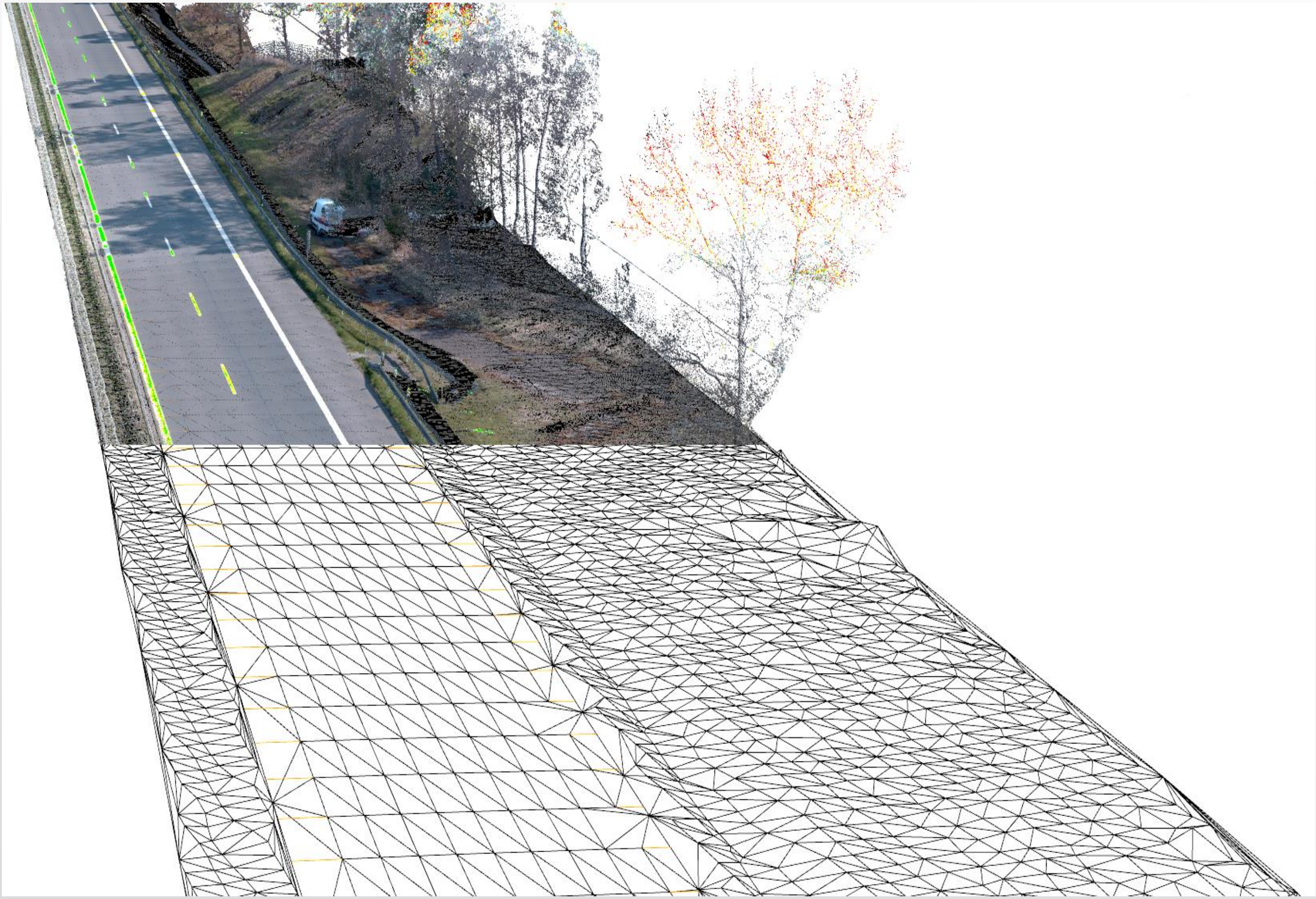
IMAGE RECOGNITION SYSTEMS

DISTRESSES IDENTIFICATION FROM VIDEOREGISTRATION





AUTOMATIC DISTRESSES IDENTIFICATION FROM VIDEOREGISTRATION AND LIDAR



AUTOMATIC DISTRESSES IDENTIFICATION FROM VIDEOREGISTRATION AND LIDAR

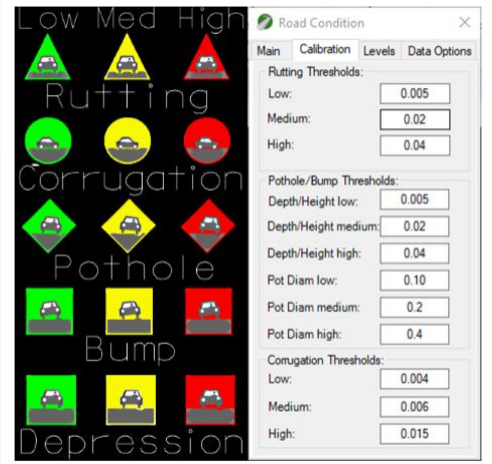
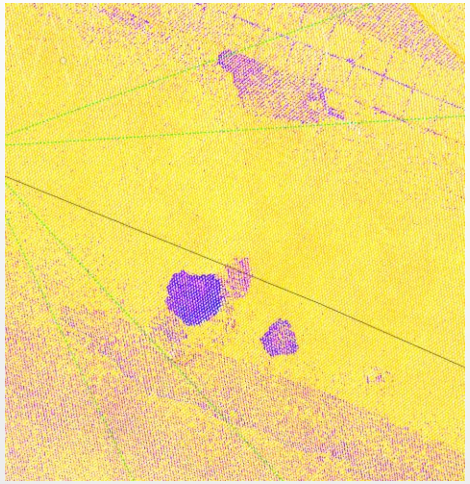
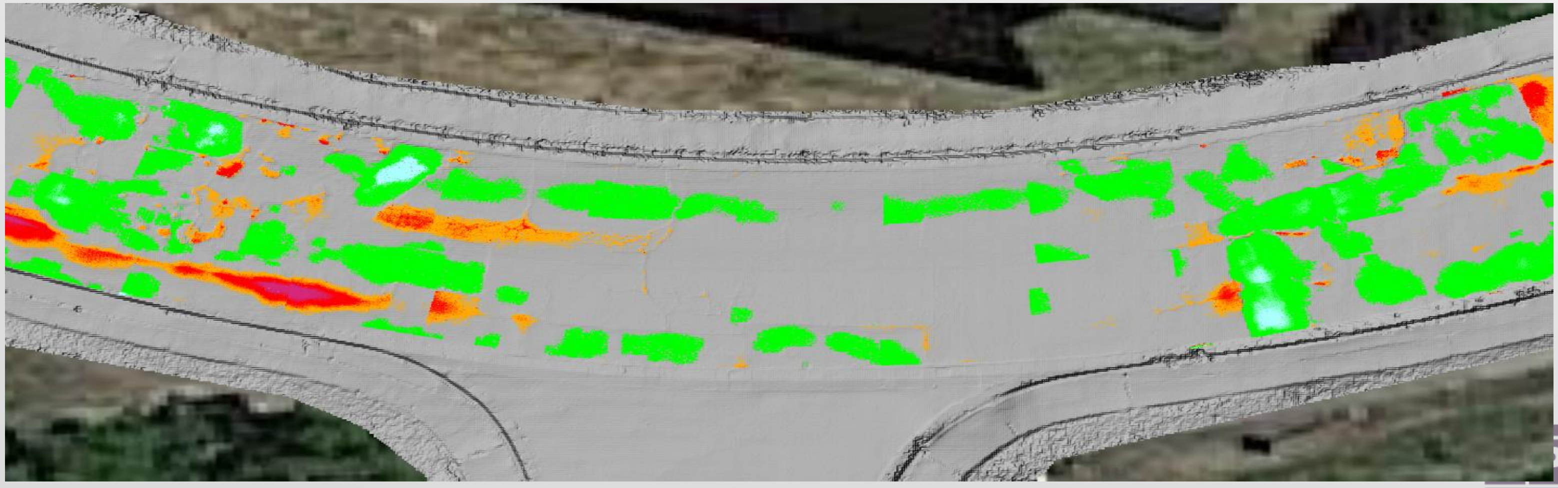


Figure 16 Flagging of different types of unevenness in the Road Condition tool in TopoDC





FULLY INTEGRATED ROAD SURFACE AND SUB-SURFACE CONDITION ASSESSMENT AT TRAFFIC SPEED

COVER STORY

across the world in diverse regions that include Australia, the UK, USA, China, and several European countries. ARRB Systems has two iPAVe vehicles deployed in South Africa and has surveyed more than 76 000 km of the country's paved road network since 2016. The iPAVe regularly undertakes surveys for provincial, metropolitan and national road authorities and consulting engineers under taking project level design work.

Meanwhile, ARRB Systems' global teams have collectively surveyed over 750 000 km to date. In the USA, the TSDD technology has surveyed roads in 30 states, with New Mexico being the latest state to award a multiyear routine TSDD testing contract for pavement management and rehabilitation purposes.

"ARRB Systems is also a member of the DaRTS (Deflection at Road Traffic Speed) focus group, which is a global forum of TSDD operators and users that meets on a bi-annual basis to share knowledge, discuss projects and give feedback on technological developments. Members include numerous state and federal road authorities in the USA, Europe and Australasia, as well as operators including the Australian Road Research Board, BASt (Germany), TRRL (UK), IBDiM (Poland) and the FHWA (USA)," says Balaram.

iPAVE COST BENEFITS

The iPAVe is a powerful tool that uses advanced technologies to collect and analysefull-spectrum structural, surface and functional road condition data that is critical for the efficient life-cycle management of road networks, saving billions towards the fiscus by enabling optimal proactive, rather than reactive, maintenance strategies to be identified.

Benefits and uses include:

- Significant cost saving per test/metre over traditional structural testing methods
- The measured data is vigorously analysed and used towards the provision of safer road infrastructure
- Collects all pavement surface and structural parameters with high accuracy inone pass
- Ability to operate at traffic speeds, improving production, safety and efficiency
- Continuous measurements at significantly higher resolution than traditional techniques such as FWD
- Provides comprehensive data with which to make better informed decisions forfinancially and technically appropriate rehabilitation and surfacing treatments
- Better QA/QC for road agencies, consultants and contractorspromotes accountability

In South Africa and across the world, there's been a strong uptake in demand for iPAVe from design engineers and transportation specialists

Removing the guesswork

The high accuracy and resolution of the iPAVe data enables engineers to pinpoint precise locations (down to 1 m) and areas where the capacity of the pavement structure is of concern. iPAVe provides additional and essential input to network level assessment and evaluation, which is crucial for deterioration modelling and future maintenance budgeting based on accurate determination of the expected serviceable lifespan. This information also influences the selection of optimal maintenance and rehabilitation strategies.

"Engineers design roads based on their structure. In many parts of the world, though, road asset managers still maintain roads based on their sur face characteristics. However, to reliably determine the remaining life of the pavement, both the structural and functional condition must be factored into the equation. This can only be truly

ARRB Systems' iPAVe intelligent pavement assessment vehicle is the first and only comprehensive pavement measurement system in the world, providing seamlessly integrated structural and surface condition data at highway speeds

TPA

AUTOMATIC AND INTELIGENT PAVEMENT CONDITION ASSESSMENT USING ANN

sustainability

MDPI

Article

Intelligent Assessment of Pavement Condition Indices Using Artificial Neural Networks

Sami Abdullah Osman [1], Meshal Almoshaogeh [2,*], Arshad Jamal [1,*], Fawaz Alharbi [2], Abdulhamid Al Mojil [1] and Muhammad Abubakar Dalhat [1]

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[2] Department of Civil Engineering, College of Engineering, Qassim University, Buraidah 51452, Saudi Arabia
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Abstract: The traditional manual approach of pavement condition evaluation is being replaced by more sophisticated automated vehicle systems. Although these automated systems have eased and hastened pavement management processes, research is ongoing to further improve their performances. An average state road agency handles thousands of kilometers of the road network, most of which have multiple lanes. Yet, for practical reasons, these automated systems are designed to evaluate road networks one lane at a time. This requires time, energy, and possibly more equipment and manpower. Multiple Linear Regression (MLR) analysis and Artificial Neural Network (ANN) were employed to examine the feasibility of modeling and predicting pavement distresses of multiple lanes as functions of pavement distresses of a single adjacent lane. The successful implementation of this technique has the potential to cut the energy and time requirement at the condition evaluation stage by at least half, for a uniform multi-lane highway. Results showed promising model performances that indicate the possibility of evaluating a multi-lane highway pavement condition (PC) by single lane inspection. Traffic direction parameters, location, and lane matching parameters contributed significantly to the performance of the ANN PC prediction models.

Keywords: pavement condition; degradation; prediction; artificial intelligence; artificial neural network; regression analysis; pavement evaluation; Saudi Arabia

1. Introduction

Artificial intelligence (AI) is an emerging area of computer science that uses different types of machines and sensors to mimic intelligent human behavior. John McCarthy first introduced AI in 1956 [1]; however, lack of technological innovations by the time limited its applications. In the following decade (between 1960 to 1970) researchers explored AI through artificial neural networks (ANNs) and Knowledge-based systems (KBS) [1]. ANNs are systems of neurons connected in various layers and inspired by the human brain to solve various complex real-life tasks. On the other hand, KBS systems are computers that offer guidance based on pre-established rules based on the information fed to them by humans. Application of the latest Machine Learning (ML) and Deep Learning (DL) based technologies have revolutionized AI. ML and DL have found various applications in diverse fields such as face recognition and tracking [2], visual tracking [3,4], vision and language navigation [5–7], and image and video editing [8–10]. In recent years, application of such soft computing methodologies has received widespread applications for various civil and transportation engineering-related problems, including road safety [11–14], mode choice modeling [15], energy demand modeling for electric vehicles [16–18], and traffic sign detection and recognition [19,20]. Similarly, applications of these predictive modeling approaches are reshaping the field of pavement evaluation and management.

check for updates

Citation: Osman, S.A.; Almoshaogeh, M.; Jamal, A.; Alharbi, F.; Al Mojil, A.; Dalhat, M.A. Intelligent Assessment of Pavement Condition Indices Using Artificial Neural Networks. *Sustainability* **2023**, *15*, 561. https://doi.org/10.3390/su15010561

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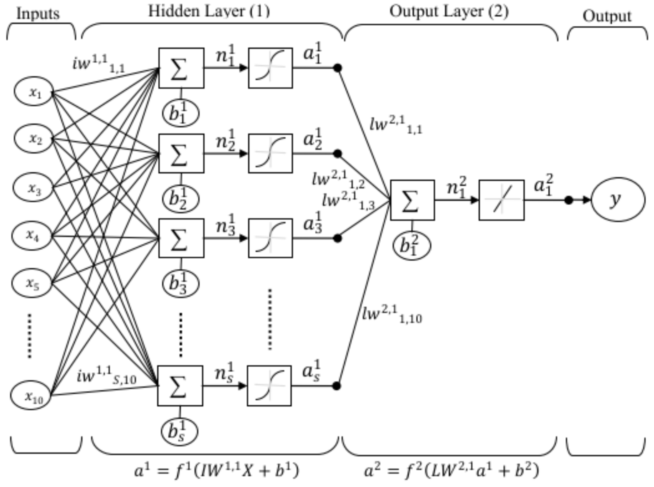

Figure 3. ANN Models Architecture.

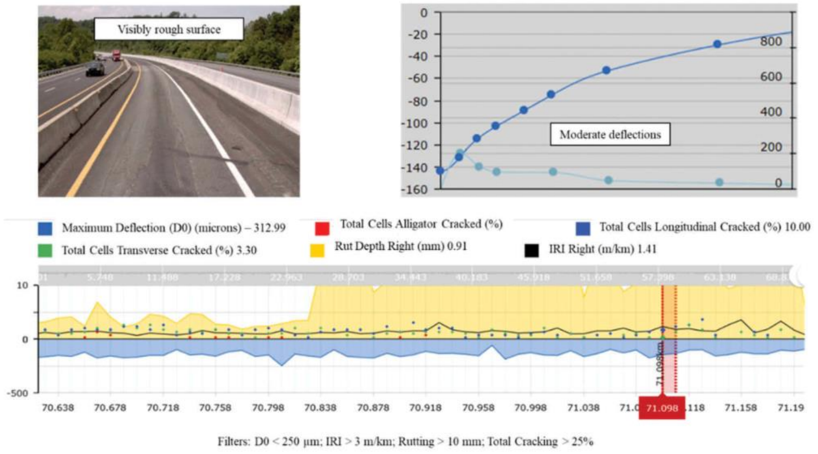

Figure 6. Low deflection and a rough, uneven road surface.

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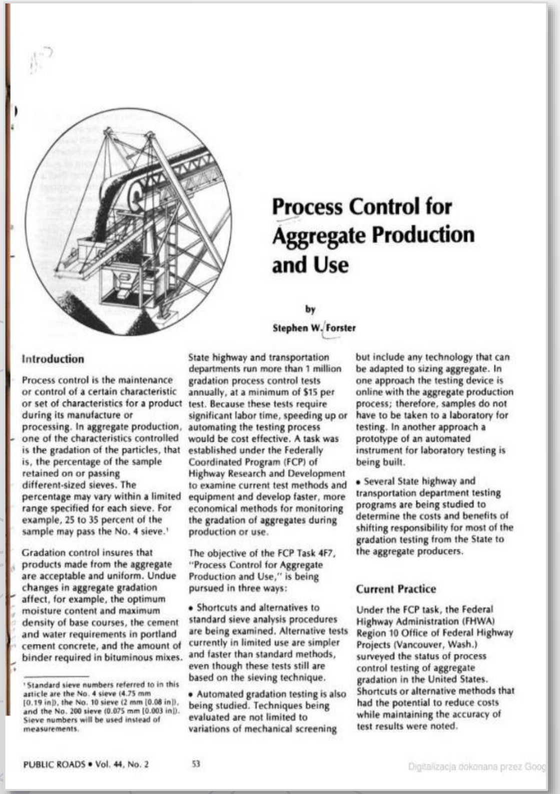
INTEGRATED AUTOMATIC SYSTEM FOR QC OF MATERIAL PRODUCTION AND ASPHALT PAVING PROCESS



Process Control for Aggregate Production and Use

by

Stephen W. Forster

Introduction

Process control is the maintenance or control of a certain characteristic or set of characteristics for a product during its manufacture or processing. In aggregate production, one of the characteristics controlled is the gradation of the particles, that is, the percentage of the sample retained on or passing different-sized sieves. The percentage may vary within a limited range specified for each sieve. For example, 25 to 35 percent of the sample may pass the No. 4 sieve.[1]

Gradation control insures that products made from the aggregate are acceptable and uniform. Undue changes in aggregate gradation affect, for example, the optimum moisture content and maximum density of base courses, the cement and water requirements in portland cement concrete, and the amount of binder required in bituminous mixes.

State highway and transportation departments run more than 1 million gradation process control tests annually, at a minimum of $15 per test. Because these tests require significant labor time, speeding up or automating the testing process would be cost effective. A task was established under the Federally Coordinated Program (FCP) of Highway Research and Development to examine current test methods and equipment and develop faster, more economical methods for monitoring the gradation of aggregates during production or use.

The objective of the FCP Task 4F7, "Process Control for Aggregate Production and Use," is being pursued in three ways:

- Shortcuts and alternatives to standard sieve analysis procedures are being examined. Alternative tests currently in limited use are simpler and faster than standard methods, even though these tests still are based on the sieving technique.
- Automated gradation testing is also being studied. Techniques being evaluated are not limited to variations of mechanical screening but include any technology that can be adapted to sizing aggregate. In one approach the testing device is online with the aggregate production process; therefore, samples do not have to be taken to a laboratory for testing. In another approach a prototype of an automated instrument for laboratory testing is being built.
- Several State highway and transportation department testing programs are being studied to determine the costs and benefits of shifting responsibility for most of the gradation testing from the State to the aggregate producers.

Current Practice

Under the FCP task, the Federal Highway Administration (FHWA) Region 10 Office of Federal Highway Projects (Vancouver, Wash.) surveyed the status of process control testing of aggregate gradation in the United States. Shortcuts or alternative methods that had the potential to reduce costs while maintaining the accuracy of test results were noted.

[1] Standard sieve numbers referred to in this article are the No. 4 sieve (4.75 mm [0.19 in]), the No. 10 sieve (2 mm [0.08 in]), and the No. 200 sieve (0.075 mm [0.003 in]). Sieve numbers will be used instead of measurements.

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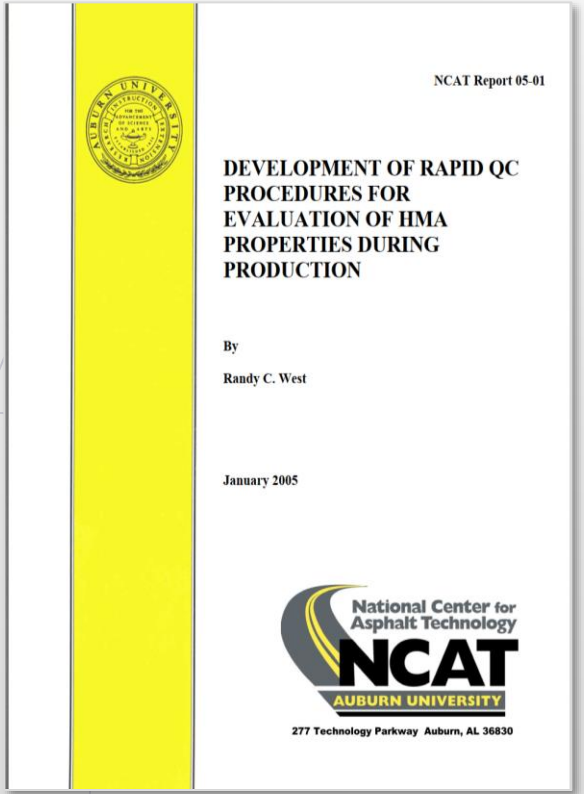


NCAT Report 05-01

DEVELOPMENT OF RAPID QC PROCEDURES FOR EVALUATION OF HMA PROPERTIES DURING PRODUCTION

By

Randy C. West

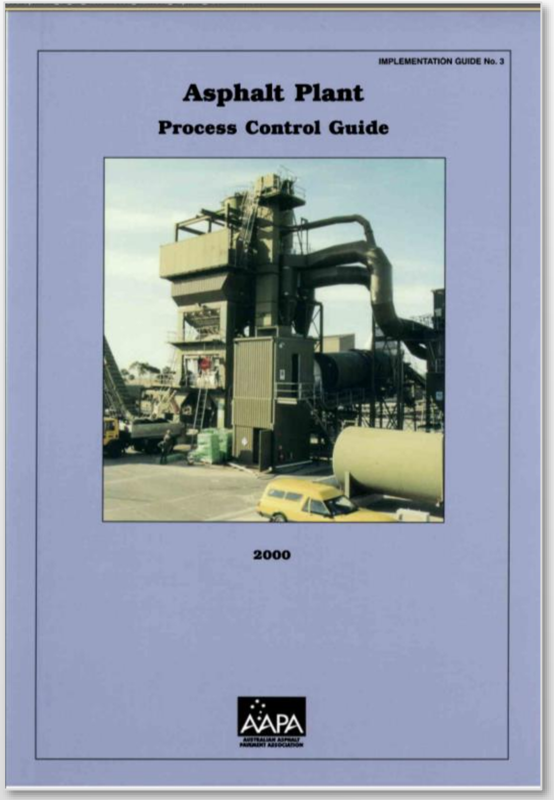
January 2005

National Center for Asphalt Technology

NCAT

AUBURN UNIVERSITY

277 Technology Parkway Auburn, AL 36830



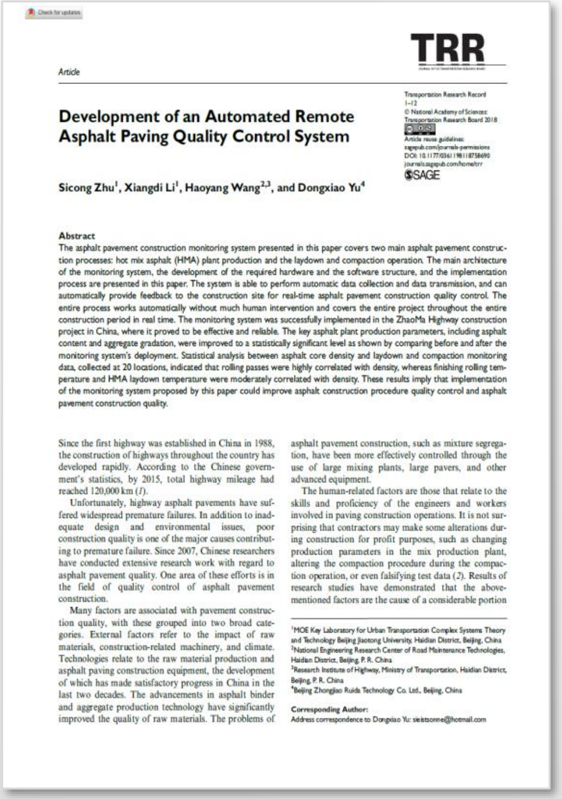
IMPLEMENTATION GUIDE No. 3

Asphalt Plant

Process Control Guide

2000

AAPA



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Development of an Automated Remote Asphalt Paving Quality Control System

Sicong Zhu[1], Xiangdi Li[1], Haoyang Wang[2,3], and Dongxiao Yu[4]

Abstract

The asphalt pavement construction monitoring system presented in this paper covers two main asphalt pavement construction processes: hot mix asphalt (HMA) plant production and the laydown and compaction operation. The main architecture of the monitoring system, the development of the required hardware and the software structure, and the implementation process are presented in this paper. The system is able to perform automatic data collection and data transmission, and can automatically provide feedback to the construction site for real-time asphalt pavement construction quality control. The entire process works automatically without much human intervention and covers the entire project throughout the entire construction period in real time. The monitoring system was successfully implemented in the ZhaoMa Highway construction project in China, where it proved to be effective and reliable. The key asphalt plant production parameters, including asphalt content and aggregate gradation, were improved to a statistically significant level as shown by comparing before and after the monitoring system's deployment. Statistical analysis between asphalt core density and laydown and compaction monitoring data, collected at 20 locations, indicated that rolling passes were highly correlated with density, whereas finishing rolling temperature and HMA laydown temperature were moderately correlated with density. These results imply that implementation of the monitoring system proposed by this paper could improve asphalt construction procedure quality control and asphalt pavement construction quality.

Since the first highway was established in China in 1988, the construction of highways throughout the country has developed rapidly. According to the Chinese government's statistics, by 2015, total highway mileage had reached 120,000 km (*1*).

Unfortunately, highway asphalt pavements have suffered widespread premature failures. In addition to inadequate design and environmental issues, poor construction quality is one of the major causes contributing to premature failure. Since 2007, Chinese researchers have conducted extensive research work with regard to asphalt pavement quality. One area of these efforts is in the field of quality control of asphalt pavement construction.

Many factors are associated with pavement construction quality, with these grouped into two broad categories. External factors refer to the impact of raw materials, construction-related machinery, and climate. Technologies relate to the raw material production and asphalt paving construction equipment, the development of which has made satisfactory progress in China in the last two decades. The advancements in asphalt binder and aggregate production technology have significantly improved the quality of raw materials. The problems of asphalt pavement construction, such as mixture segregation, have been more effectively controlled through the use of large mixing plants, large pavers, and other advanced equipment.

The human-related factors are those that relate to the skills and proficiency of the engineers and workers involved in paving construction operations. It is not surprising that contractors may make some alterations during construction for profit purposes, such as changing production parameters in the mix production plant, altering the compaction procedure during the compaction operation, or even falsifying test data (*2*). Results of research studies have demonstrated that the above-mentioned factors are the cause of a considerable portion

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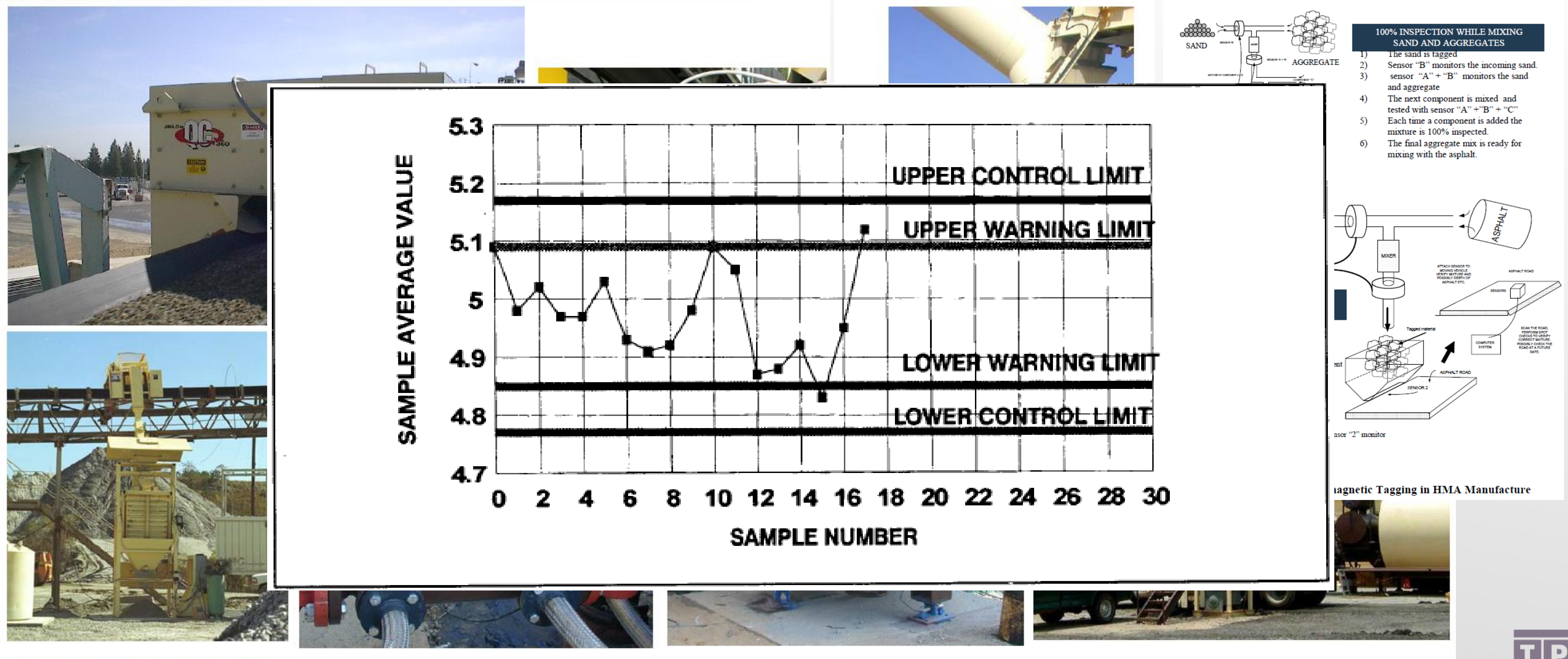
TPA

ROBOTIC MATERIAL SAMPLING AND AUTOMATIC TESTING SYSTEMS



agnetic Tagging in HMA Manufacture

Figure 4. Automated Gradation Device

Figure 5. In-line Asphalt Viscometer

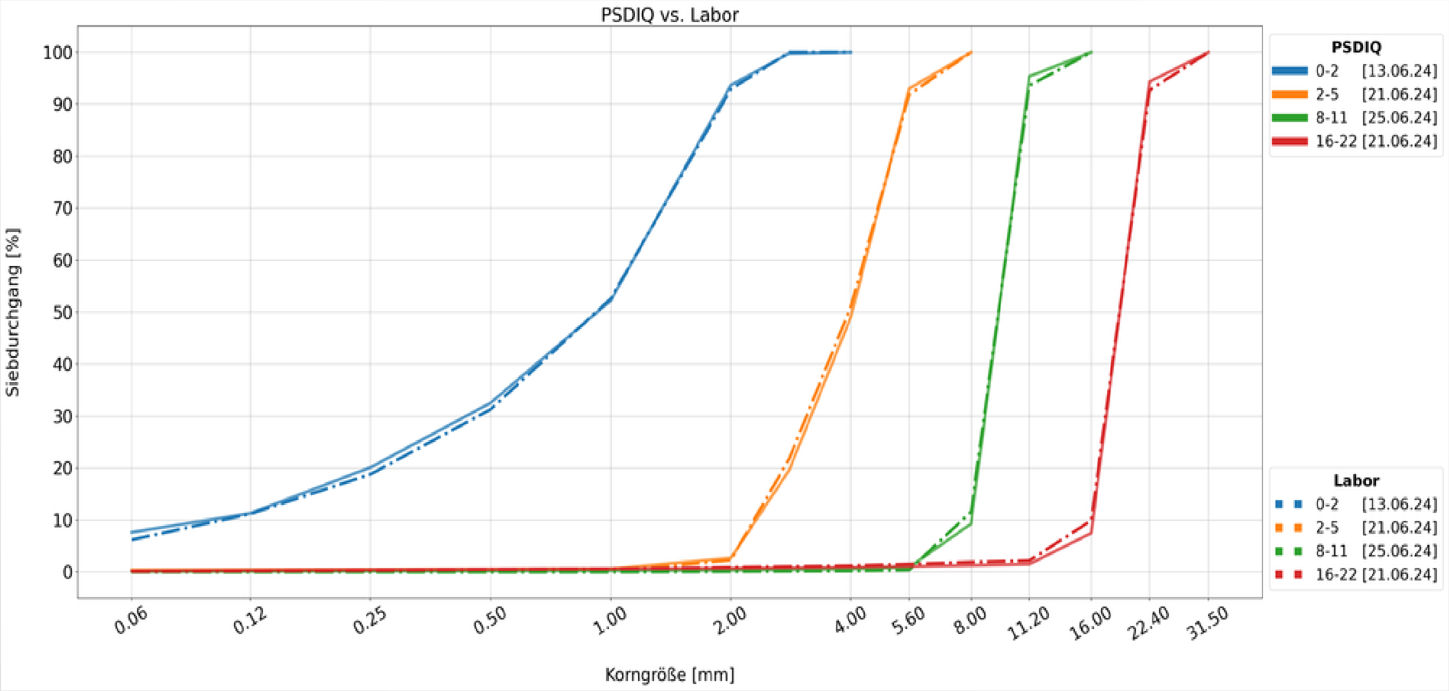
Figure 6. Asphalt Meter Calibration Tank

Figure 7. Robotic Truck Sampler

REAL-TIME QUALITY CONTROL IN THE QUARRY

TPA GmbH & TIPCO GmbH RESEARCH PROGRAM

THE GRAIN SIZE DISTRIBUTION IN A DYNAMIC MATERIAL STREAM LIVE AND DIGITALLY



AUTOMATED OPTIMIZATION OF ASPHALT PAVING AND COMPACTION PROCESS

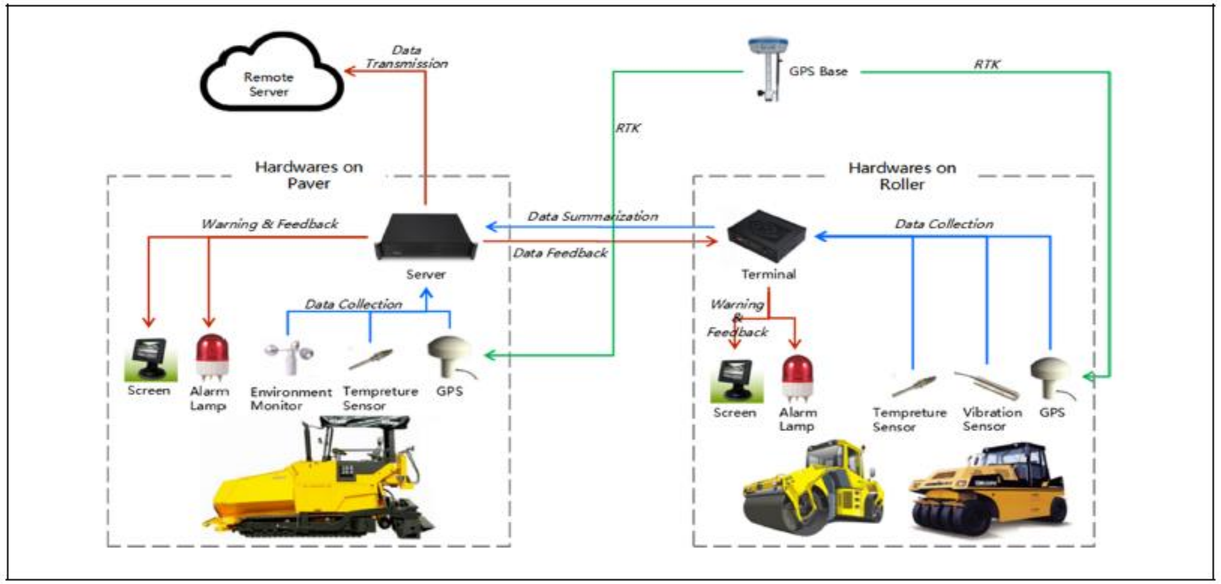


Figure 4. Composition of HMA paving and compaction quality check system.
Note: RTK = real-time kinematic.

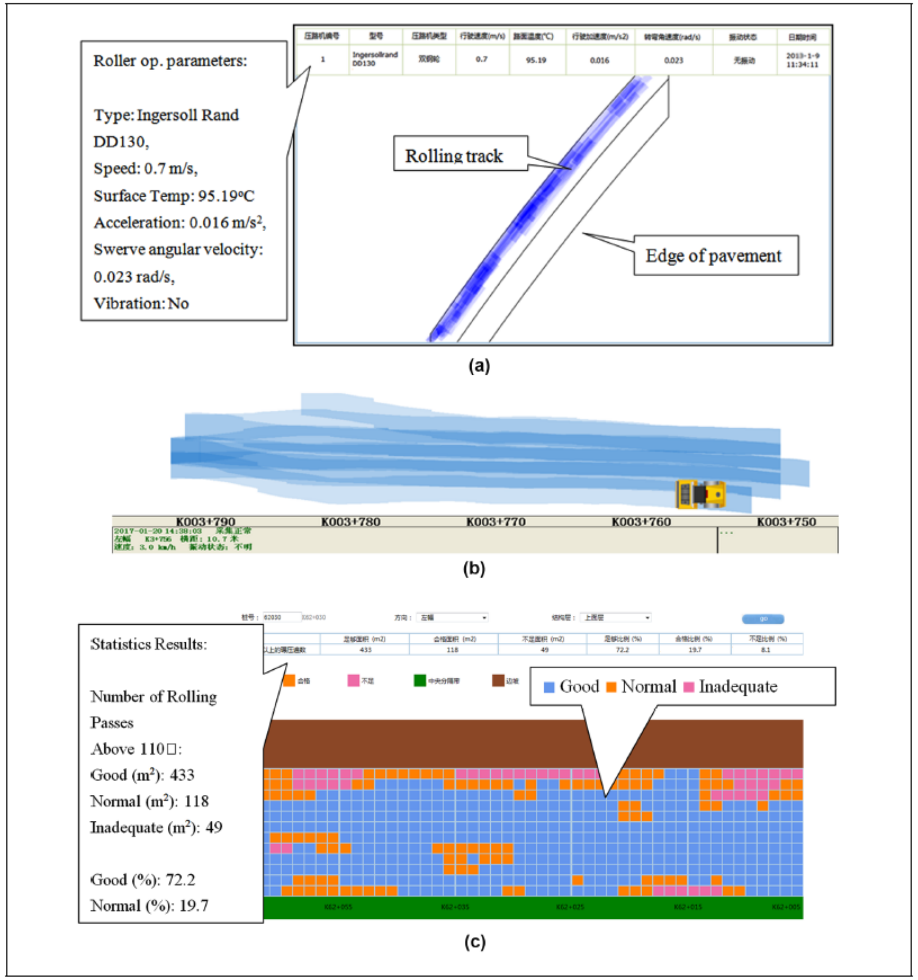
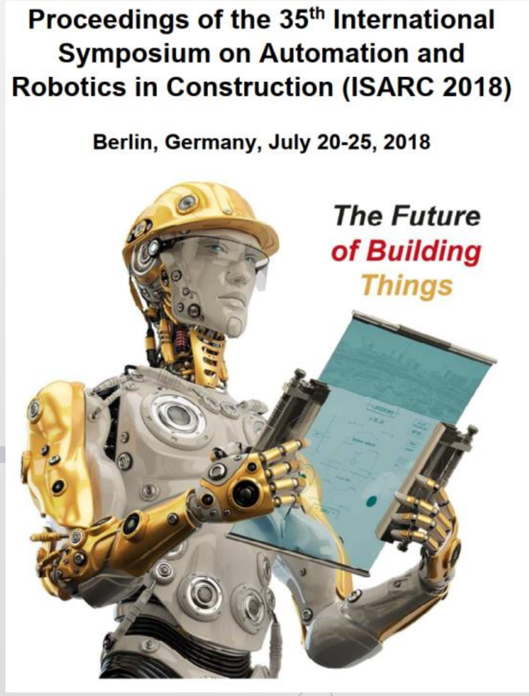


Figure 6. (*a*) Web-based roller real-time working status; (*b*) roller driver working status user graphic interface; and (*c*) graphic display of rolling quality statistics.

AUTOMATED PAVEMENT CONSTRUCTION INSPECTION USING DRONES



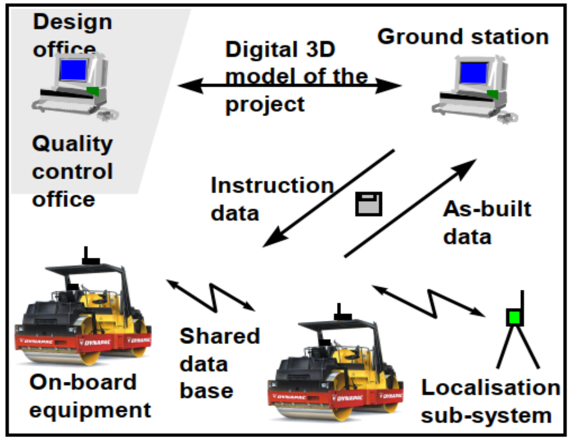


Figure 1: general architecture of a CIRC system

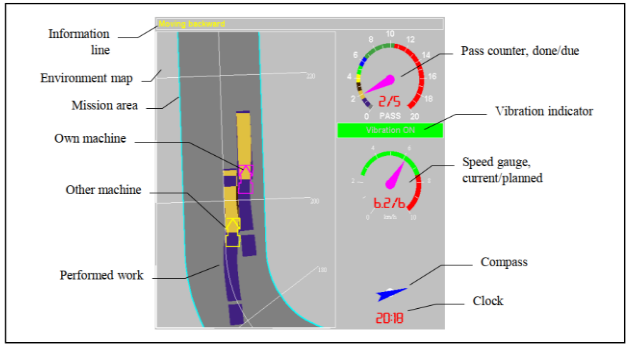


Figure 3: CIRCOM on-board sub-system MMI

Figure 3. UAS thermal imaging set up on I-69 (**A**: Placing GCPs, **B**,**C**: Pilot flying the UAS, **D**: UAS flying at about 24m (80 ft)).

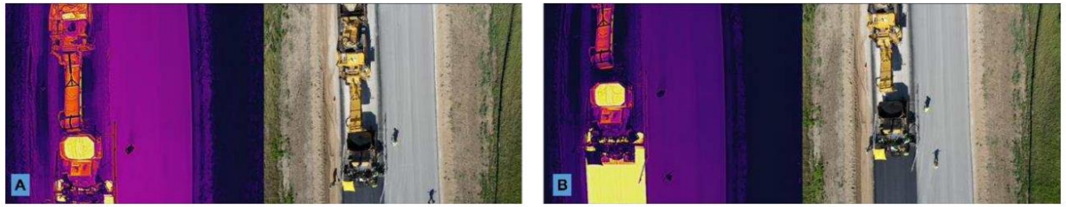


Figure 9. Thermal profile of HMA in the hopper (**A**) and behind the paver (**B**).

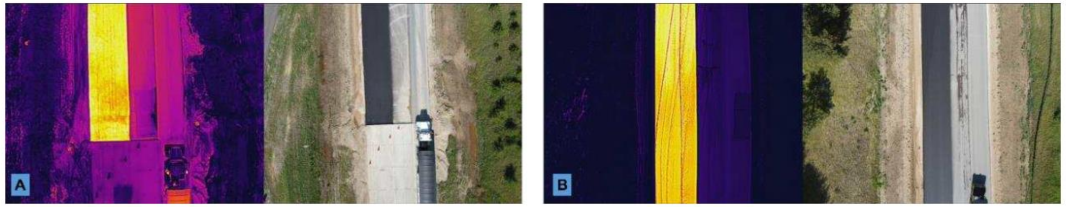


Figure 10. Differential cooling on the freshly placed HMA at the very beginning of the paving (**A**) and along the roller tracks (**B**).

SMARTER, DIGITAL AND SUSTAINABLE CONSTRUCTION

WalzGen – RESEARCH PROGRAM IN COOPERATION OF TPA GmbH, BOMAG, RPTU Kaiserslautern AND InfraTest

TPA

PREDICTIVE ANALYTICS

MACHINE LEARNING – PREDICTIVE ANALYTICS

ARTIFICIAL NEURAL NETWORK FOR PREDICTING MATERIALS PARAMETERS FROM HISTORIC DATA

EXAMPLE: ANN for E* - Dynamic Complex Stiffness Modulus of HMA

PREDICTING DYNAMIC COMPLEX STIFFNESS MODULUS OF HMA

PREDICTIVE EQUATION USED IN AASHTO MEPDG (NCHRP 1-37A)

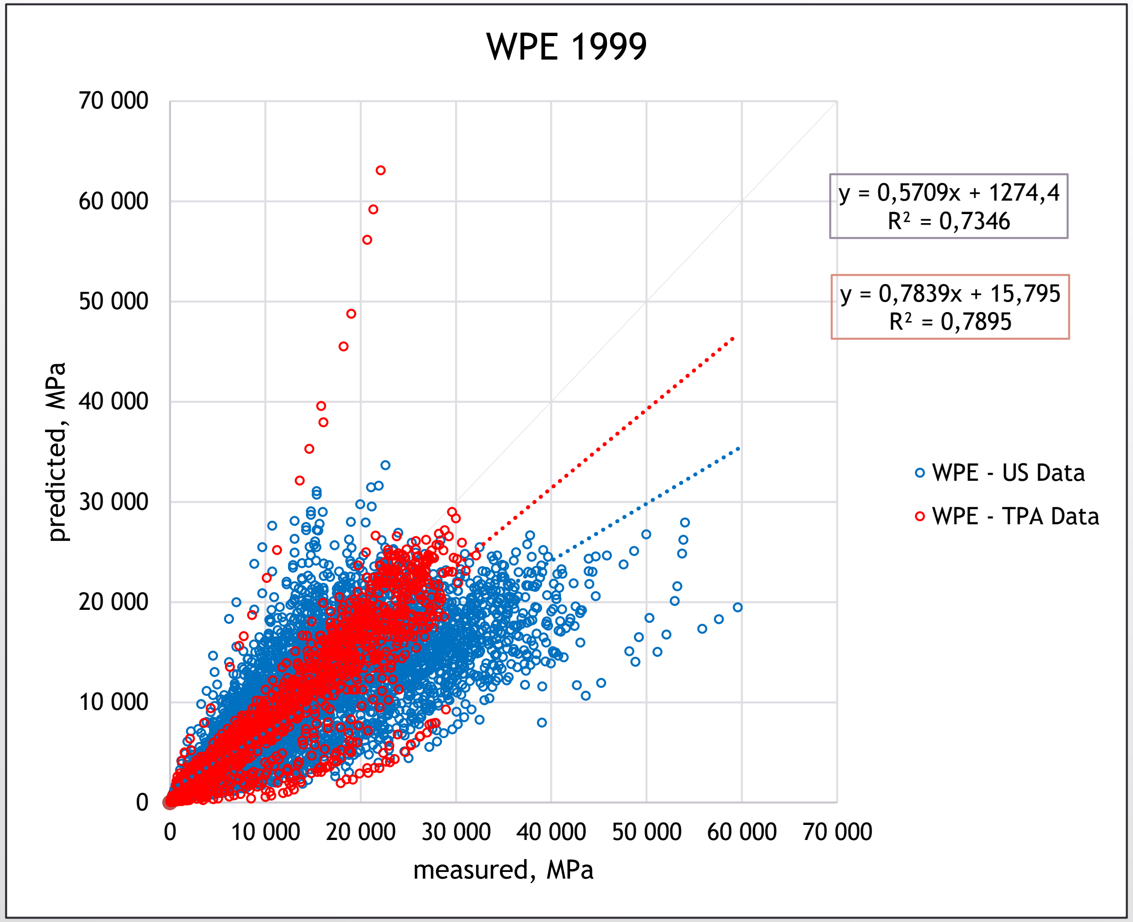
current most sophisticated approach – Witczak Predictive Equation

$$\log E = -1.249937 + 0.029232 \cdot p_{200} - 0.001767 \cdot (p_{200})^2 - 0.002841 \cdot p_4 - 0.058097 \cdot Va - 0.802208 \cdot \frac{Vb_{eff}}{(Vb_{eff} + Va)} + \frac{3.871977 - 0.0021 \cdot p_4 + 0.003958 \cdot p_{38} - 0.000017 \cdot (p_{38})^2 + 0.005470 \cdot p_{34}}{1 + e^{(-0.603313 - 0.313351 \cdot \log(f) - 0.393532 \cdot \log(\eta))}}$$

Where the variables represent:

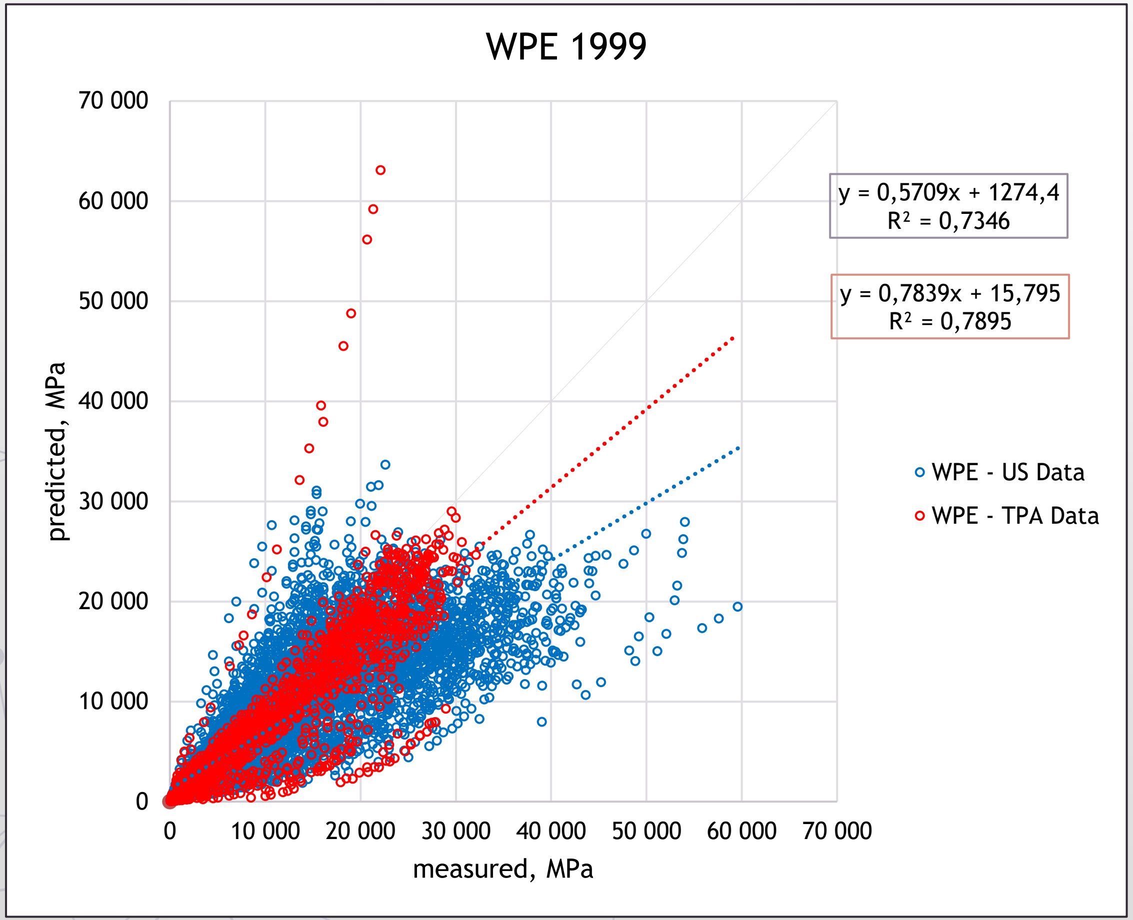
E	Asphalt Mix Dynamic Modulus, in 10^5 psi
η	Bitumen viscosity in 10^6 poise (at any temperature, degree of aging)
f	Load frequency in Hz
Va	% air voids in the mix, by volume
Vb_{eff}	% effective bitumen content, by volume
p_{34}	% retained on the ¾ inch sieve, by total aggregate weight (cumulative)
p_{38}	% retained on the 3/8 inch sieve, by total aggregate weight (cumulative)
p_4	% retained on the No. 4 sieve, by total aggregate weight (cumulative)
p_{200}	% passing the No. 200 sieve, by total aggregate weight

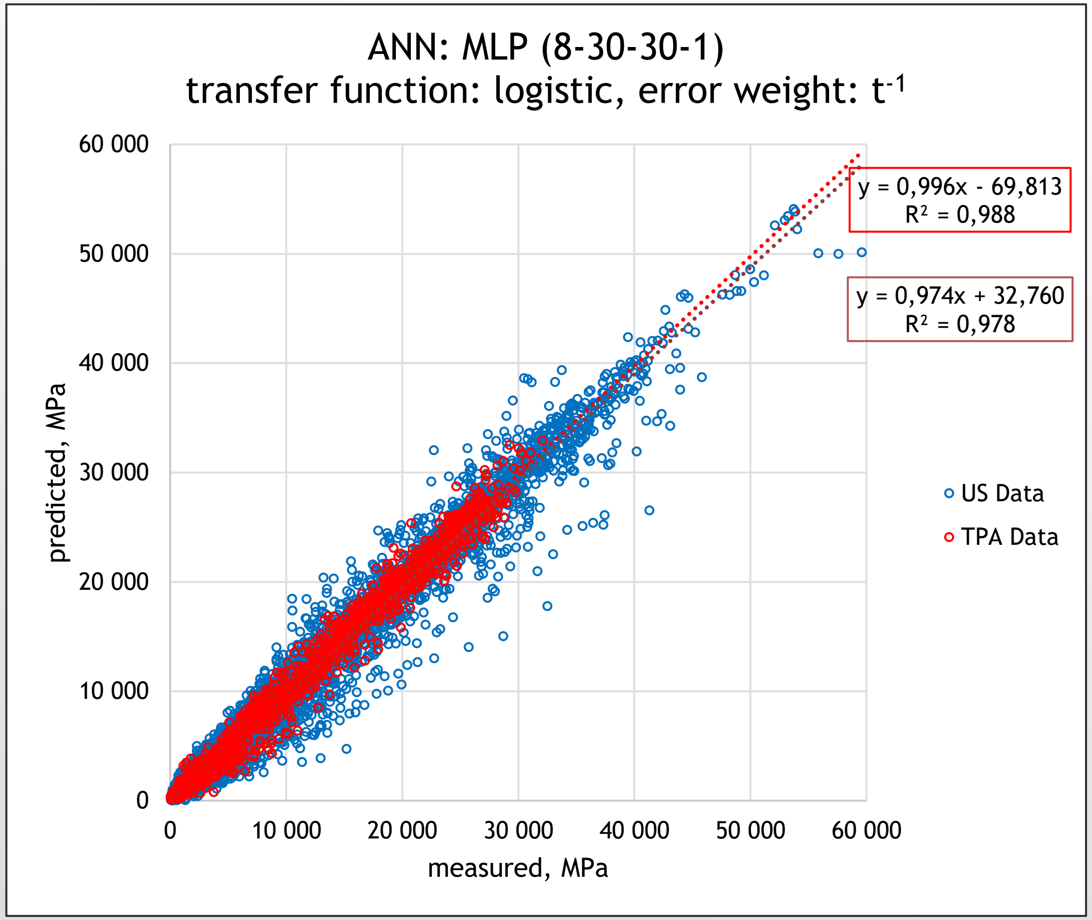
FIGURE 26. Revised Dynamic Modulus Predictive Equation



PREDICTING DYNAMIC COMPLEX STIFFNESS MODULUS OF HMA

STANDARD APPROACH vs. ARTIFICIAL NEURAL NETWORK (MATLAB)



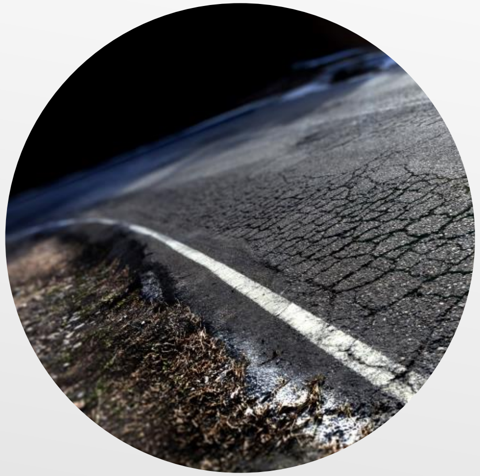


EXPERT SYSTEMS

VIRTUAL TECHNOLOGIST or EXPERT

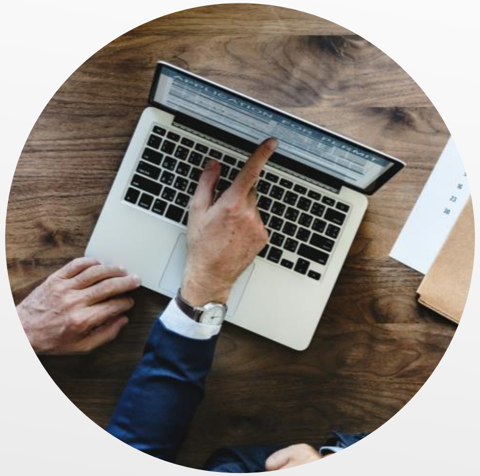
HMA / PCC TYPE TESTING

acceleration of the recipe design process and achieving optimal composition solutions



DAMAGE CAUSES EVALUATION

identification & assessment of the causes of premature damage to pavements or building structures based on combined information on material parameters, quality of workmanship and operating conditions



PREDICTION & PRESCRIPTION

ability to predict (Predictive Analysis) and prevent errors (Prescriptive Analysis) at the stage of design, production and execution in real time (online) based on constantly flowing data and information

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THANK YOU FOR YOUR ATTENTION!

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