dr inż. **Aleksander Zborowski**
dr inż. **Igor Ruttmar**

DIGITALIZACJA SZTUCZNA INTELIGENCJA & AUTOMATYZACJA

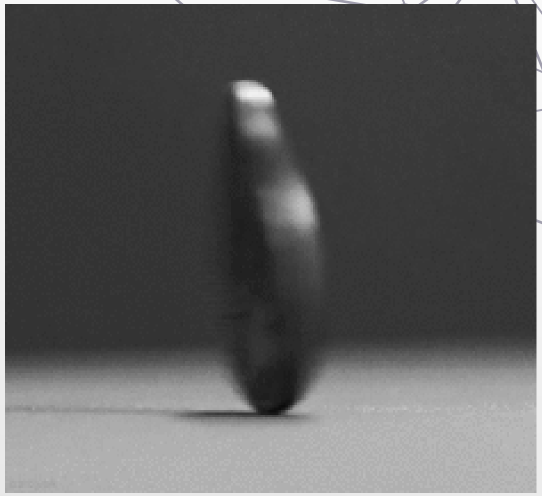
SZANSA NA ZNACZĄCE PRZYSPIESZENIE TECHNOLOGICZNE W KIERUNKU ZRÓWNOWAŻONEJ INŻYNIERII DROGOWEJ

TPA

01 ZRÓWNOWAŻONA INŻYNIERIA DROGOWA

ZRÓWNOWAŻONA INŻYNIERIA DROGOWA
WYZWANIA

- OGRANICZENIE WPŁYWU NA ŚRODOWISKO
  - ➢ **ABY SPOWOLNIĆ ZMIANY KLIMATYCZNE**
- ZWIĘKSZENIE ODPORNOŚCI INFRASTRUKTURY
  - ➢ **ABY DOSTOSOWAĆ SIĘ DO ZMIAN KLIMATYCZNYCH**



PRZEPIS NA TRWAŁE, EFEKTYWNE KOSZTOWO I ZRÓWNOWAŻONE DROGI

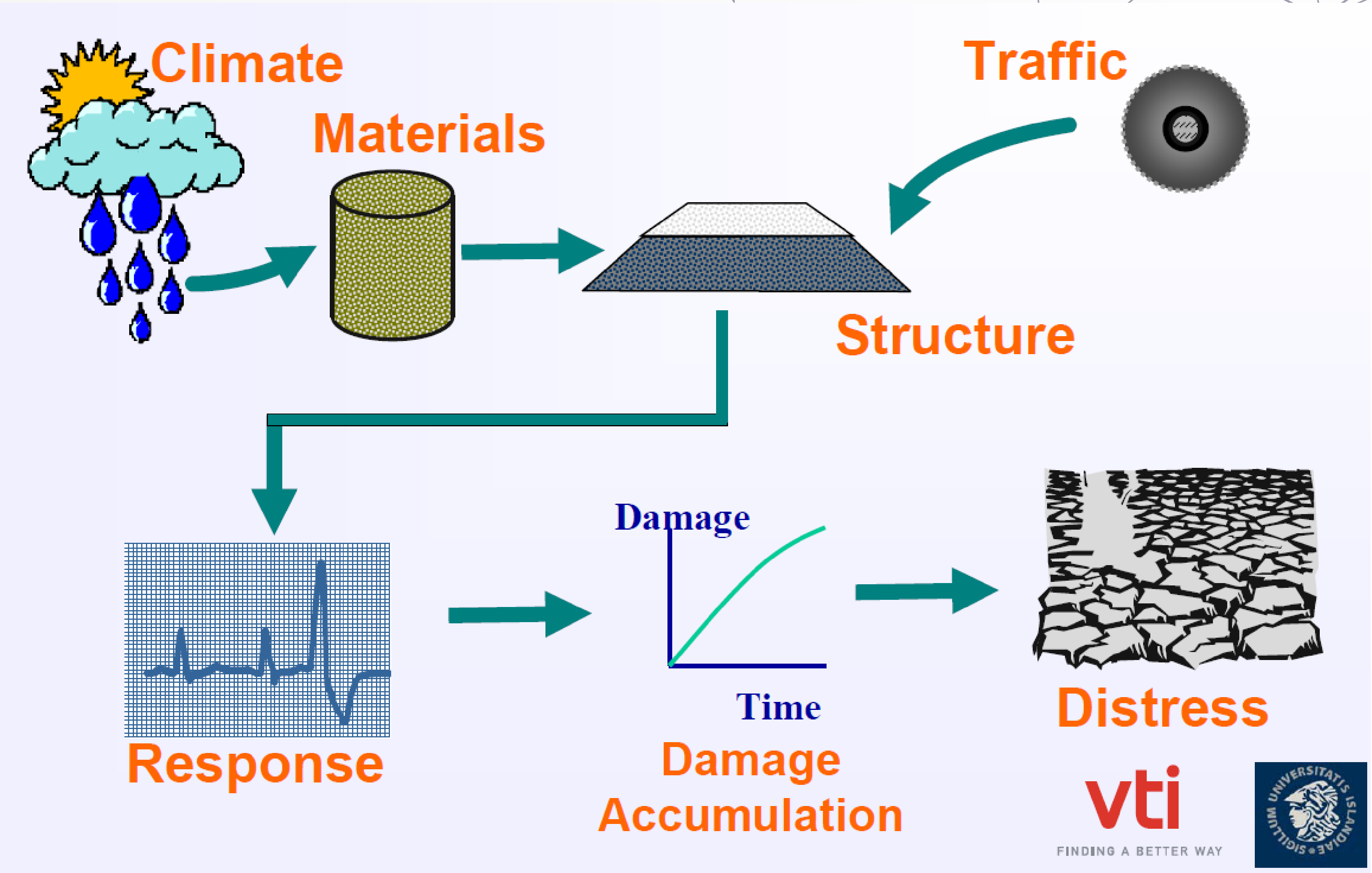
Wiele już zrobiliśmy w tej kwestii jako przemysł, środowisko akademickie i administracja, ale musimy przyspieszyć walidację i wdrażanie nowych rozwiązań.

Digitalizacja, Sztuczna Inteligencja i Automatyzacja procesów *mogą pomóc nam znacząco przyspieszyć transformację w kierunku zrównoważonego rozwoju.*

Kilka przykładów…

OPTYMALNY PROJEKT KONSTRUKCJI NAWIERZCHNI

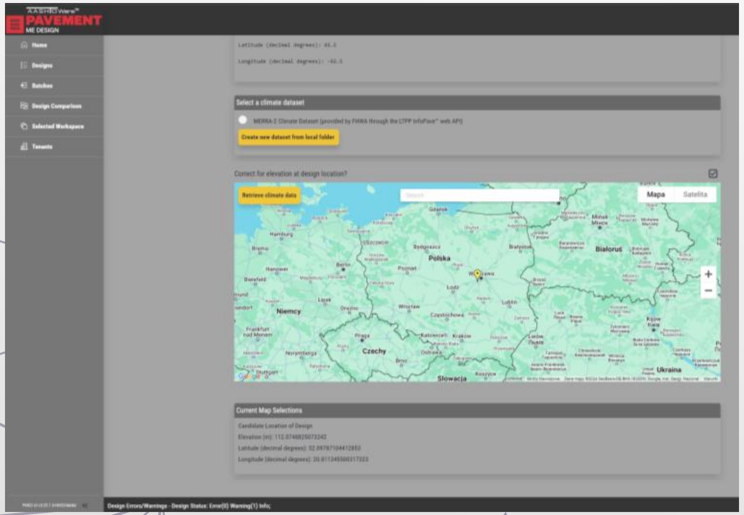
MECHANISTYCZNO-EMPIRYCZNE METODY ANALIZ

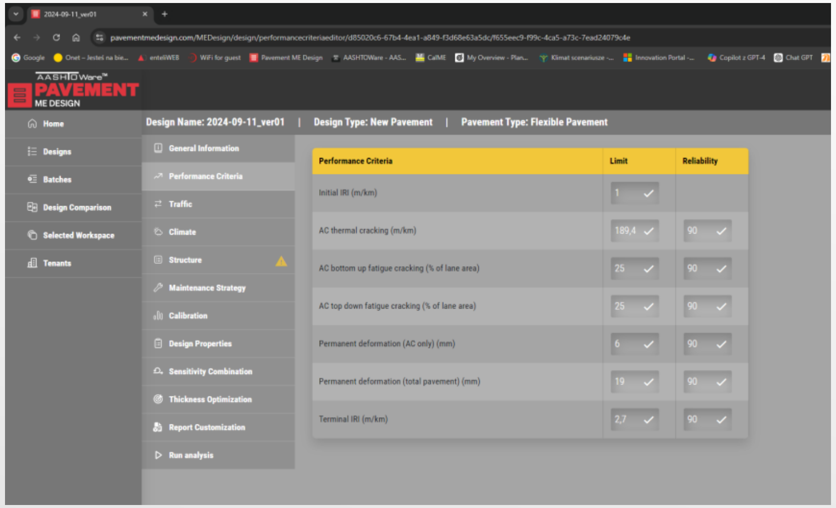


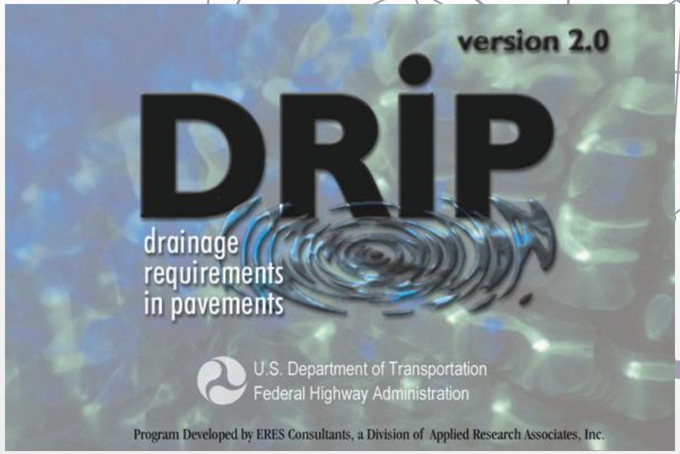
source: Mechanistic Pavement Design – Sigudur Erlingsson, Reykjavik 2007

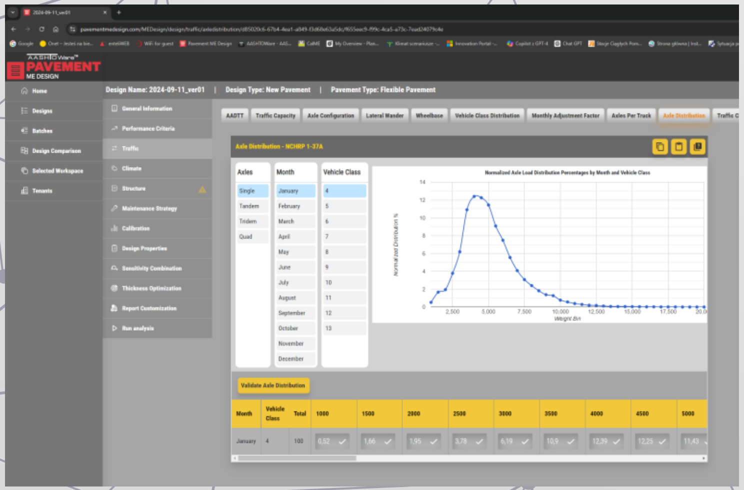
MECHANISTYCZNO-EMPIRYCZNE METODY ANALIZ

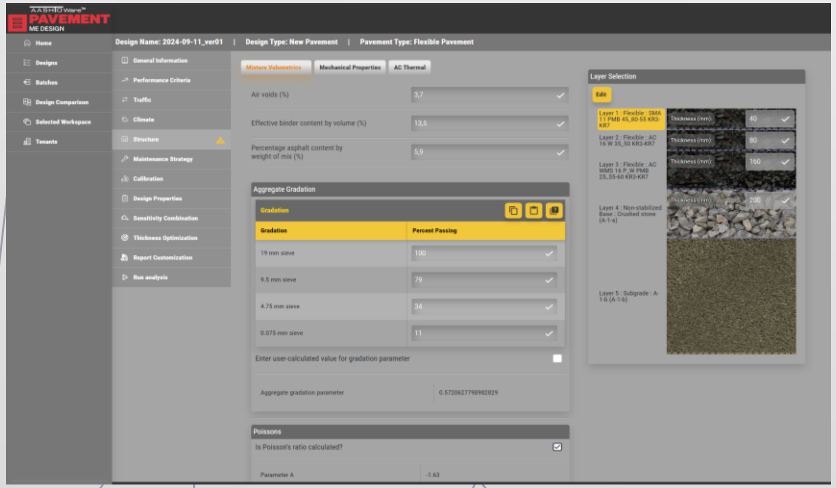
NA PRZYKŁAD AASHTOWARE PAVEMENT ME

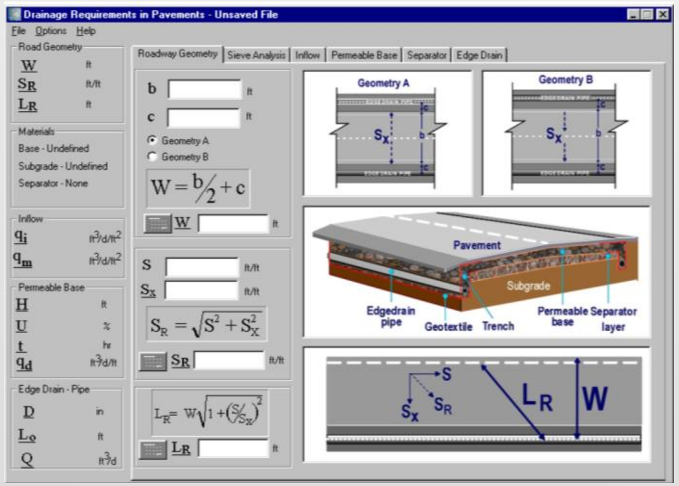










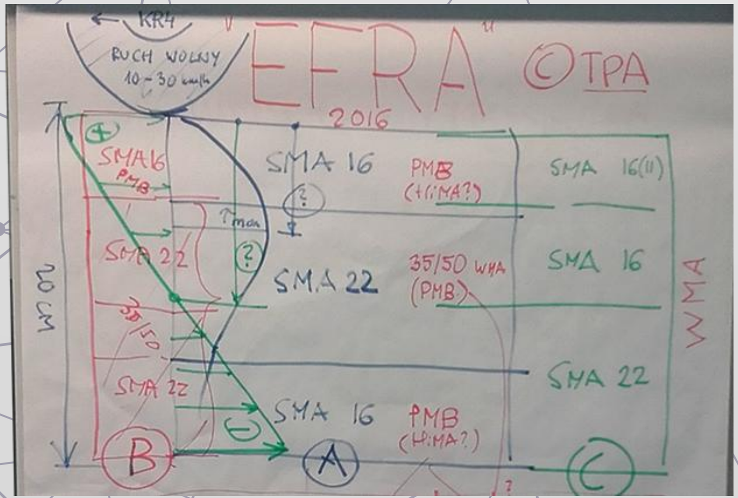


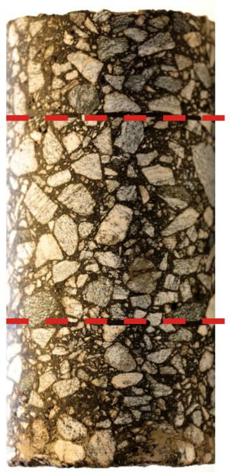
NAWIERZCHNIE WYSOKO-WYTRZYMAŁE 2015-2019

DŁUGOWIECZNA NAWIERZCHNIA PODATNA (PERPETUAL PAVEMENT)

2015

TRIPLE SMA Nawierzchnia Heavy Duty EFRA – LOTOS





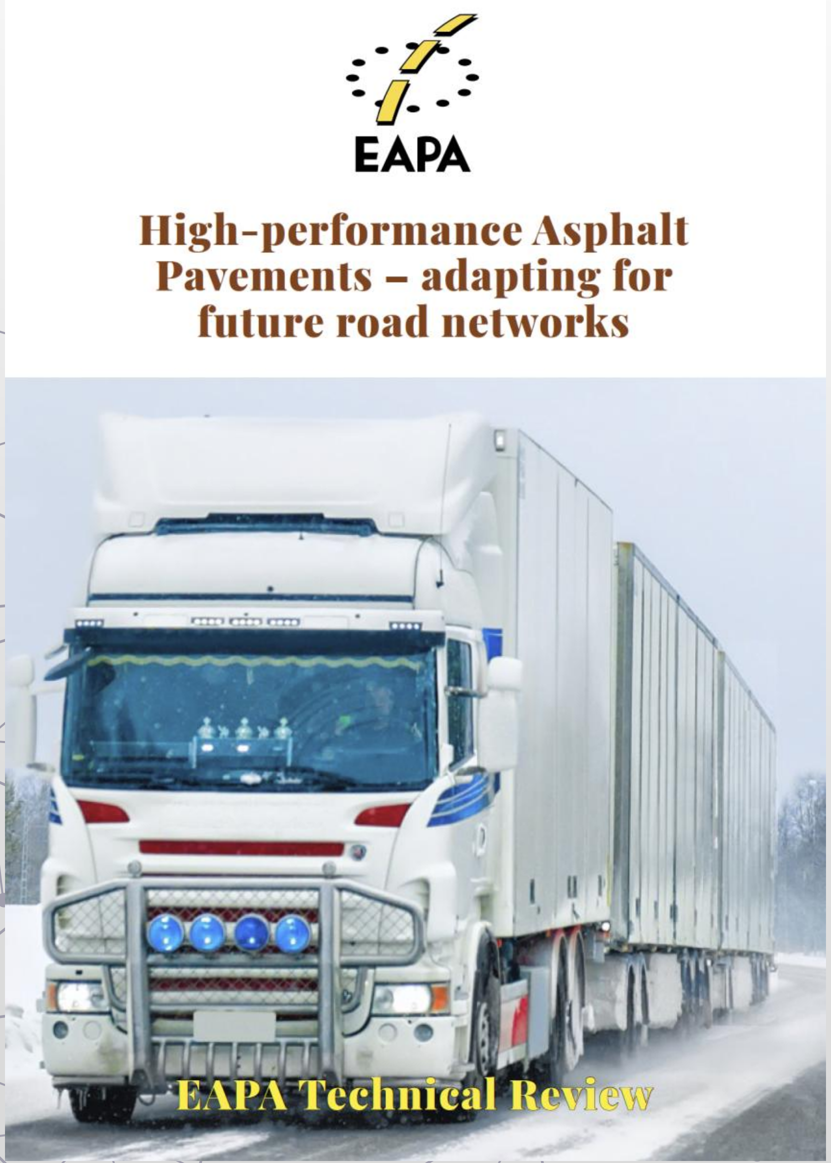
SMA 16 HiMA 45/80-80
5 CM

SMA 22 W HiMA 25/55-80
9 CM

SMA 16 P HiMA 45/80-80
6 CM

2019

NAWIERZCHNIE WYSOKO-WYTRZYMAŁE 2022



3.5 New concepts for pavement structures

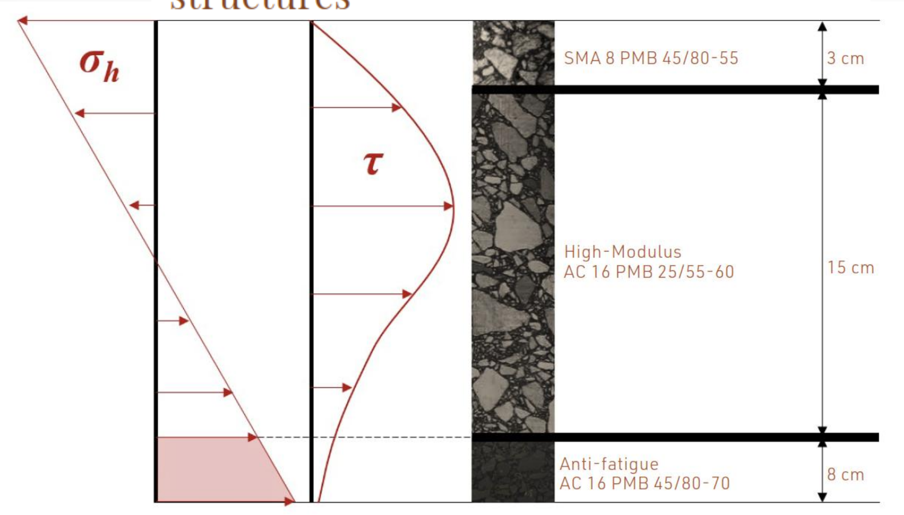


Figure 6. New pavement structure configuration incorporating anti-fatigue layer

PERPETUAL PAVEMENT

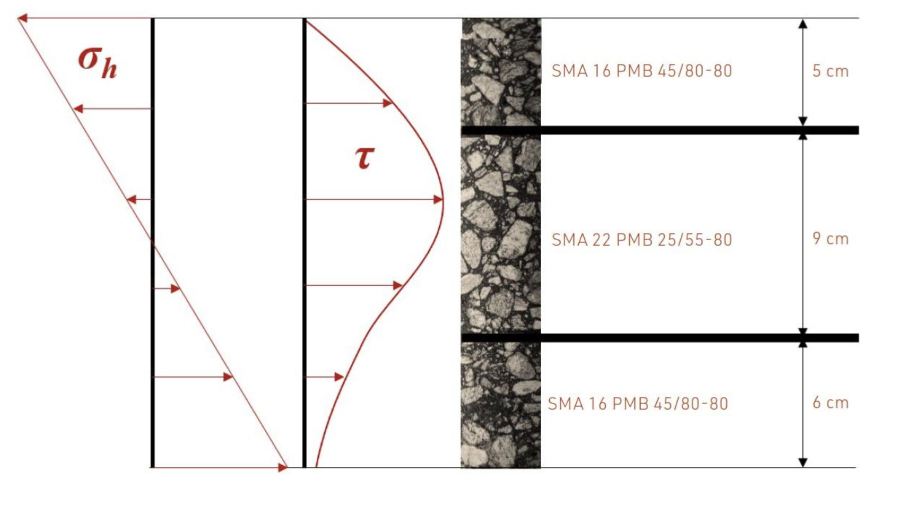


Figure 7. Triple-SMA pavement structure configuration

HEAVY DUTY TRIPLE SMA PAVEMENT

INNE ODCINKI NAWIERZCHNI DŁUGOWIECZNYCH

TRASA NOWOHUCKA

KOSZALIN – USTRONIE MORSKIE

ODCINKI PRZEJŚCIOWE
KOMORNIKI – KRZESINY

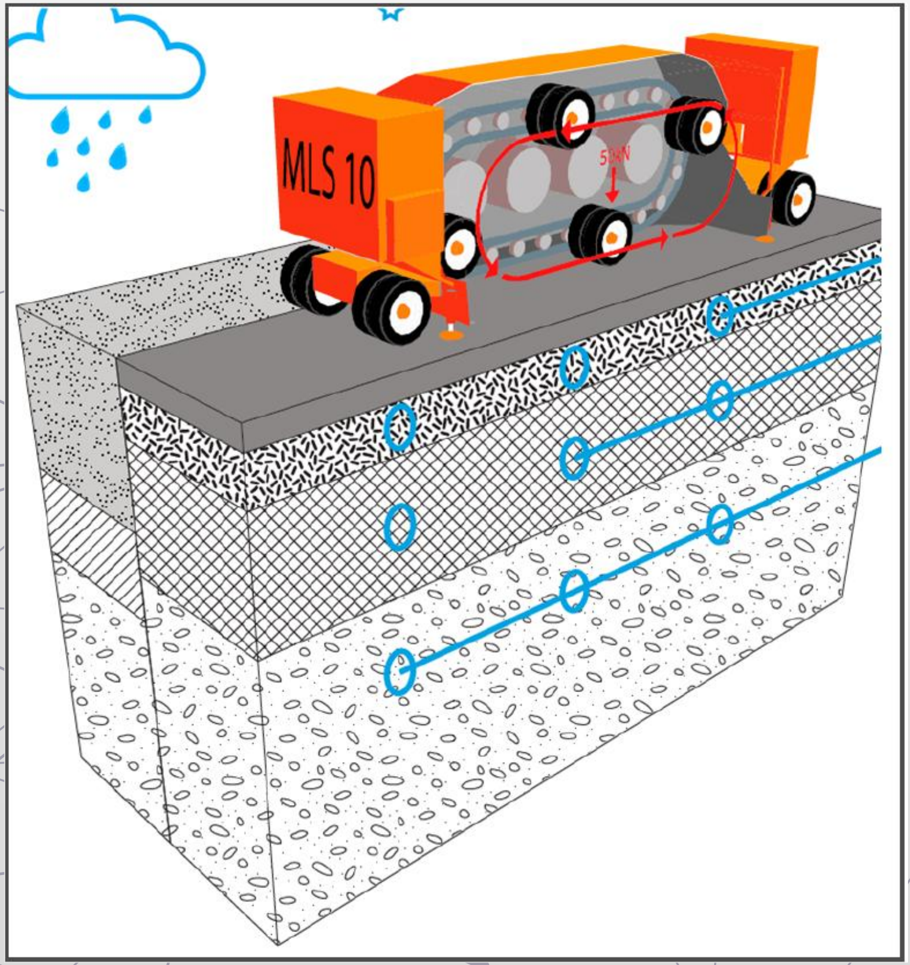
CSORNA – SOPRON

KRAŚNIK – JANÓW LUBELSKI

BÓLY - IVÁNDÁRDA

MOBILNE SYMULATORY OBCIĄŻENIA

PRZYSPIESZONE PEŁNOSKALOWE TESTY OBCIĄŻENIA W CELU WERYFIKACJI I WALIDACJI ZAŁOŻEŃ PROJEKTOWYCH



source: www.pavetesting.com and BASt homepage

ODPOWIEDNIE
MATERIAŁY & TECHNOLOGIE

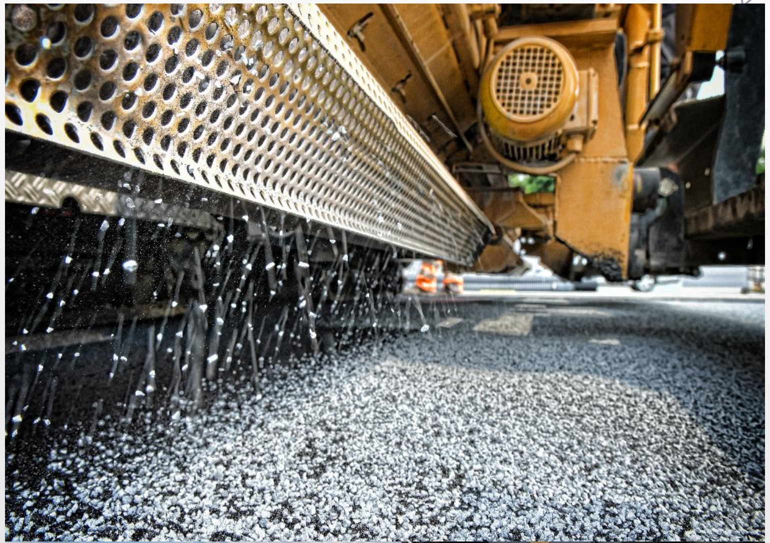
ZAAWANSOWANE MATERIAŁY I TECHNOLOGIE

INNOWACYJNE, WYSOKOWYDAJNE MATERIAŁY „SZYTE NA MIARĘ”

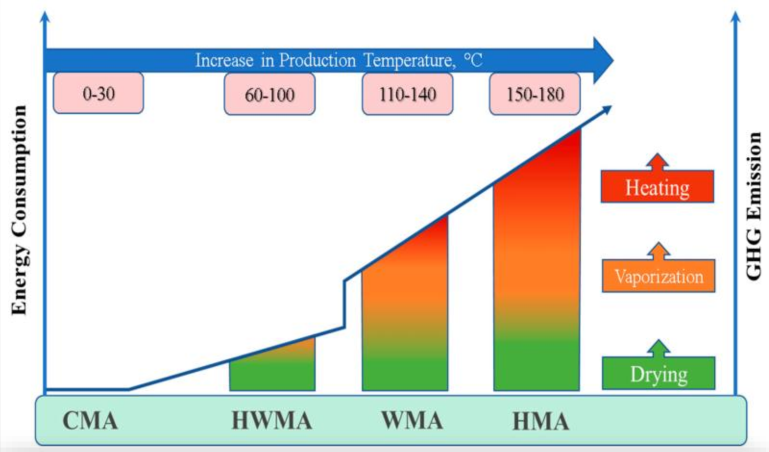
NAJLEPSZE TECHNOLOGIE WYKONAWCZE

KOMPAKTASPHALT

POSYPYWARKA ZINTEGROWANA Z ROZŚCIEŁACZEM



WMA – ASFALT SPIENIONY



WYŻSZA
KONTROLA JAKOŚCI
PRODUKCJI I WBUDOWANIA

ZAAWANSOWANE LABORATORYJNE I TERENOWE BADANIA KONTROLI JAKOŚCI

FTIR – spektrometria laserowa

DSR dla G*, MSCR, LAS

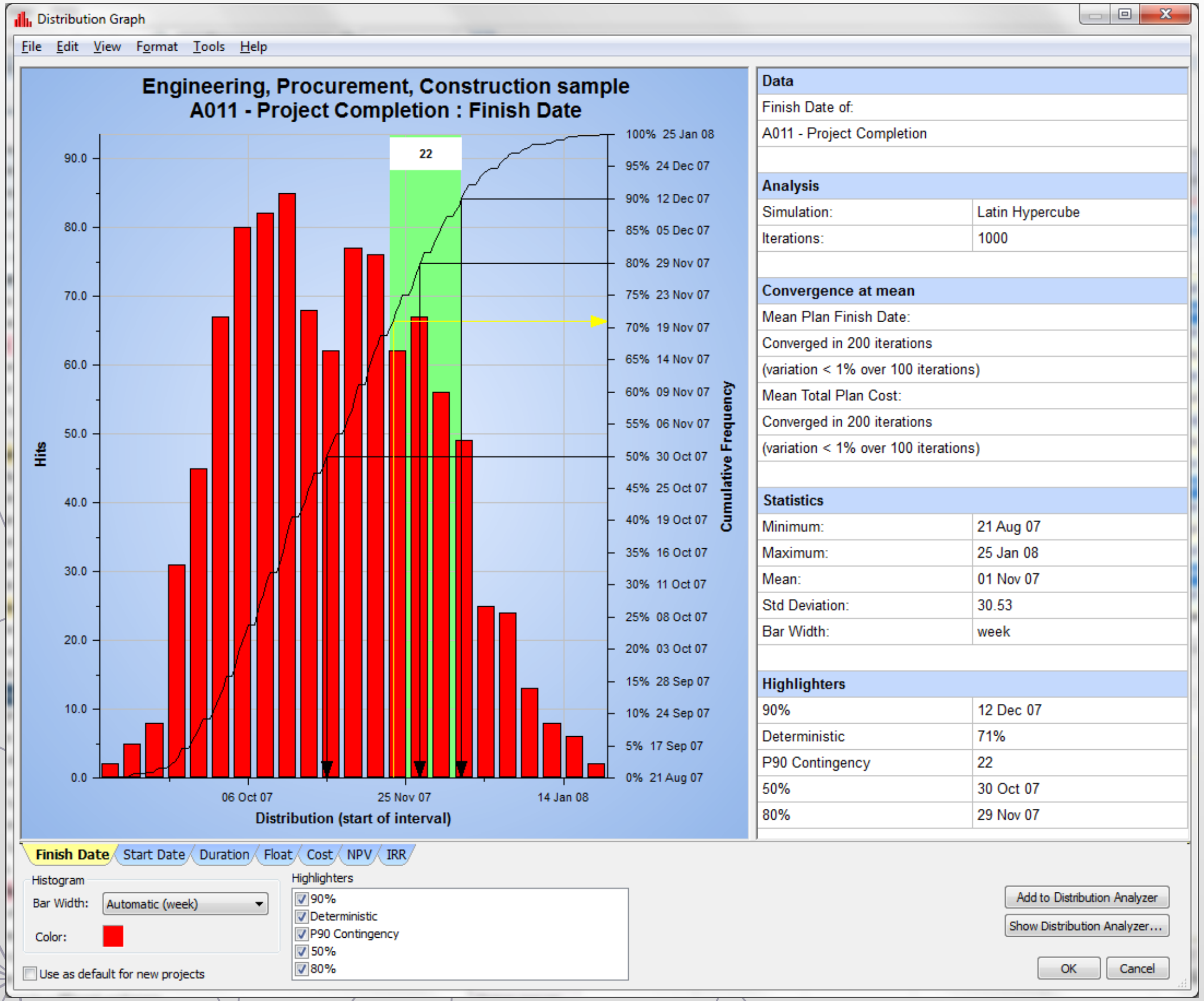
PQI – nieniszczący pomiar zagęszczenia

E* Dynamiczny Moduł Sztywności, SVECD

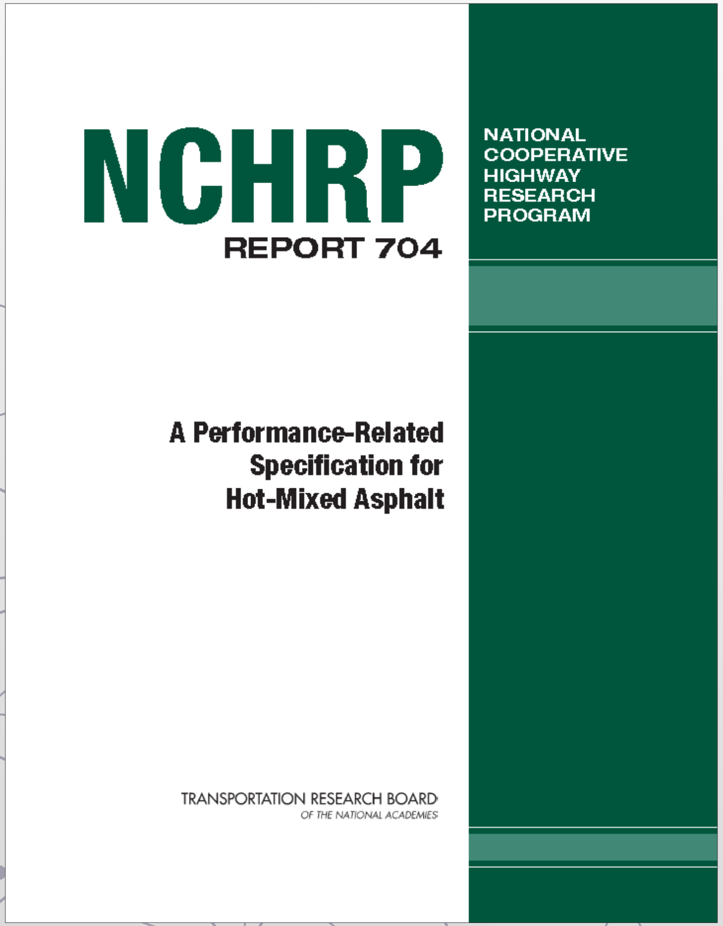
MIT-Scan T2 – nieniszczący pomiar grubości

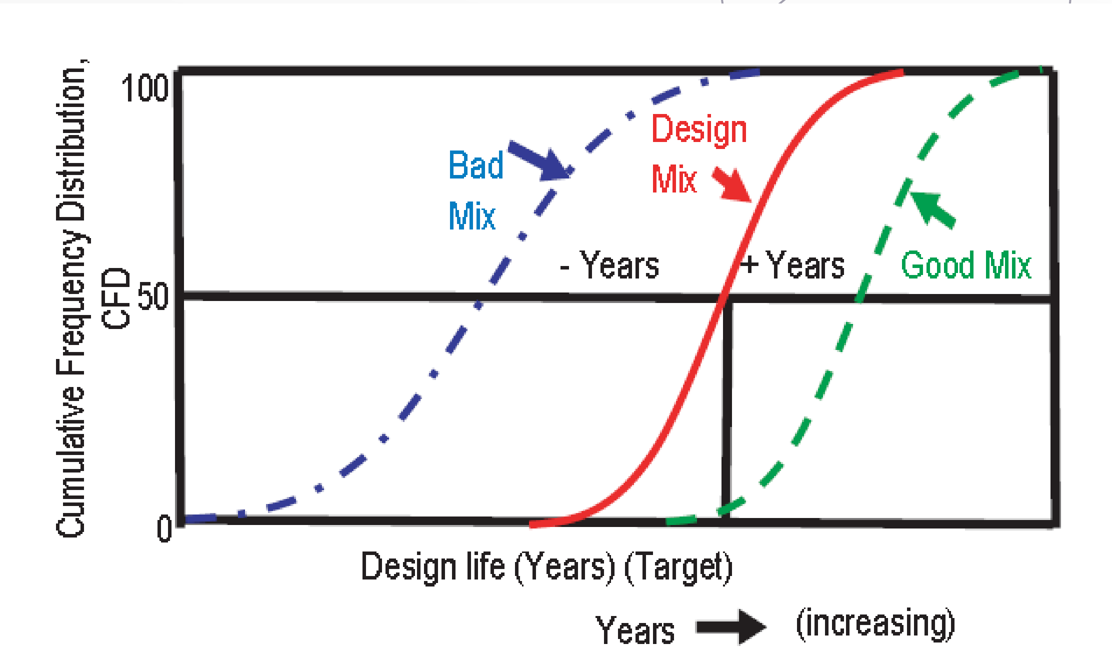
ANALIZY PROBABILISTYCZNE I PRZEWIDYWANIA

METODA MONTE CARLO

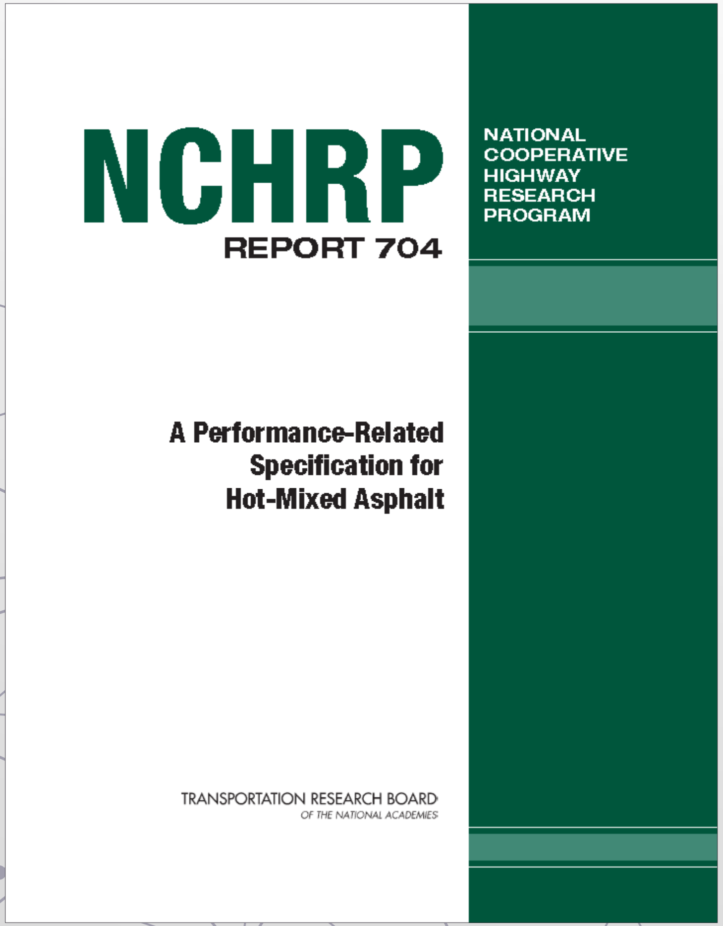


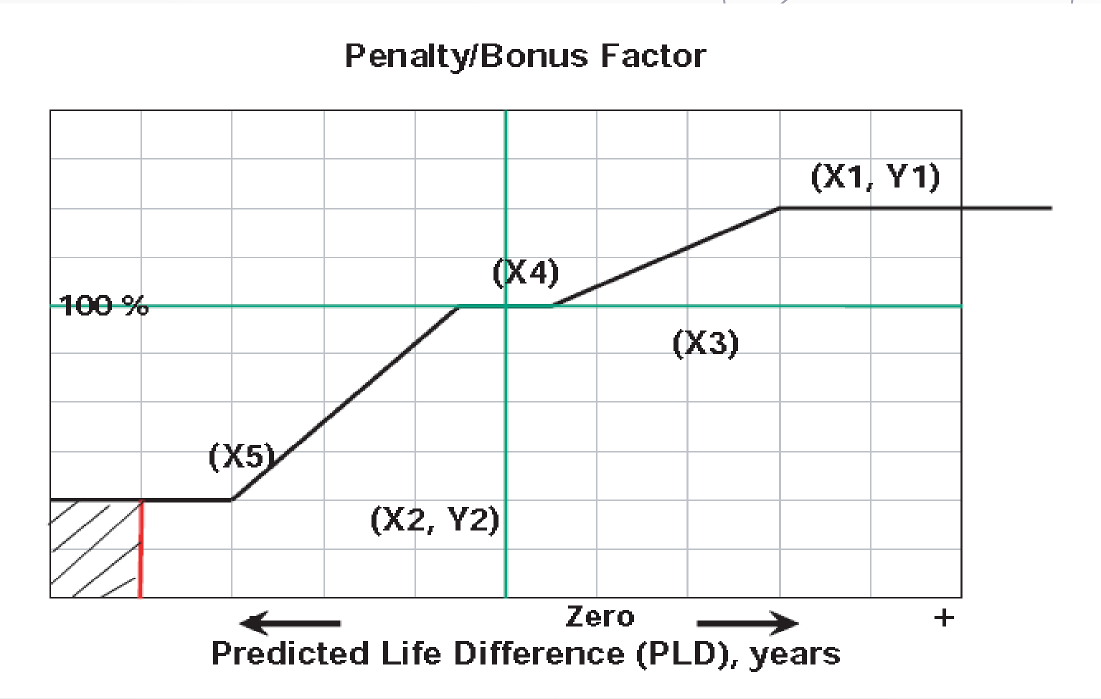
SPECYFIKACJE OPARTE NA ZACHOWANIU





SPECYFIKACJE OPARTE NA ZACHOWANIU





02

DIGITALIZACJA


DIGITALIZACJA
SZTUCZNA INTELIGENCJA
AUTOMATYZACJA & ROBOTYZACJA

NAJPIERW DIGITALIZACJA

Pierwszym i najważniejszym zadaniem jest zbieranie wszystkich niezbędnych **DANYCH** w **FORMIE CYFROWEJ** i przechowywanie ich w odpowiednio zaprojektowanej **BAZIE DANYCH.**

TO NIE JEST CYFROWA FORMA DANYCH

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

Odcinek jednorodny	Lokalizacja		Ugięcie D0 U_s^{FWD}	Ugięcie maksymalne U_{smax}^{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

49.6	122	106	106	101	100	82	66	53	42	9	11	11:01:39
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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
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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
49.8	122	108	108	103	101	83	66	51	41	8	9	11:06:39
57.5	138	122	122	116	115	93	74	58	45	8	9	11:06:47
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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
50.1	147	129	126	121	117	92	70	53	40	8	10	11:09:42
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
57.3	184	155	159	146	147	120	86	69	51	8	10	11:10:51
50.2	158	136	135	130	126	99	79	58	48	9	10	11:11:45
57.6	175	153	151	147	142	107	90	69	53	9	10	11:11:53
49.5	147	133	133	129	126	105	81	63	50	9	11	11:12:48
57.3	167	152	151	146	143	119	93	72	56	9	11	11:12:55
50.7	159	139	138	132	130	106	83	65	51	9	10	11:14:00
57.9	175	152	151	144	142	115	90	70	55	9	10	11:14:08
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57.4	145	126	126	121	118	96	76	59	47	10	11	11:17:25
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50.4	122	111	113	107	108	89	72	56	43	10	12	11:22:53
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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

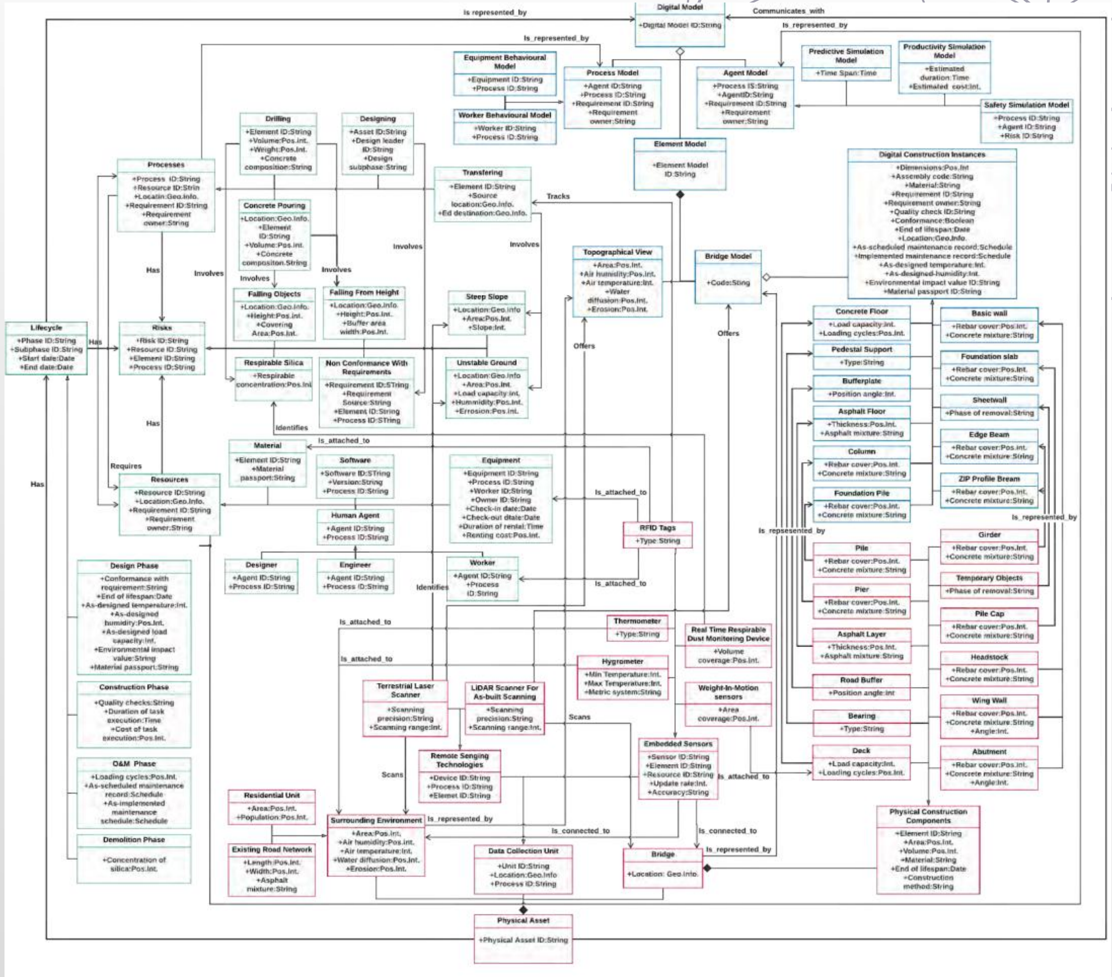
184

153

154

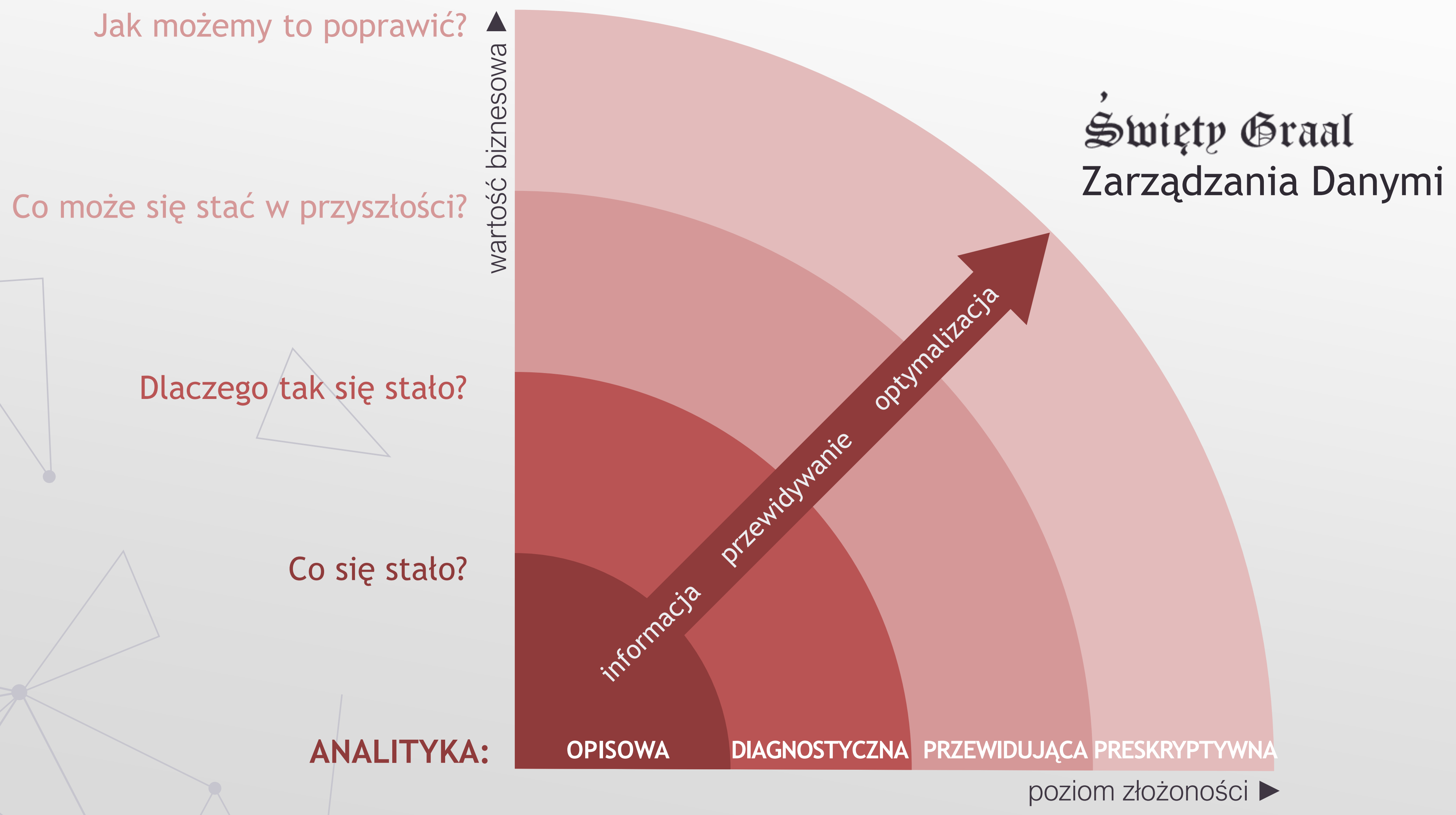
CYFROWA FORMA DANYCH

RELACYJNE BAZY DANYCH



DANE są ropą 21 wieku

ROZWÓJ METOD ANALITYCZNYCH



TPA

03

SZTUCZNA INTELIGENCJA

CZY MOŻE SIĘ NAM PRZYDAĆ?

TPA

03 SZTUCZNA INTELIGENCJA

JAK MOŻE SIĘ NAM PRZYDAĆ?

CZYM SI JEST OBECNIE?

LARGE LANGUAGE MODELS

zaawansowane systemy sztucznej inteligencji zaprojektowane w celu rozumienia, interpretowania i generowania odpowiedzi podobnych do ludzkich nawet na bardzo złożone pytania

E-COMERCE

optymalizacja logistyki w oparciu o przewidywania zachowań użytkowników (analiza predykcyjna Big Data)

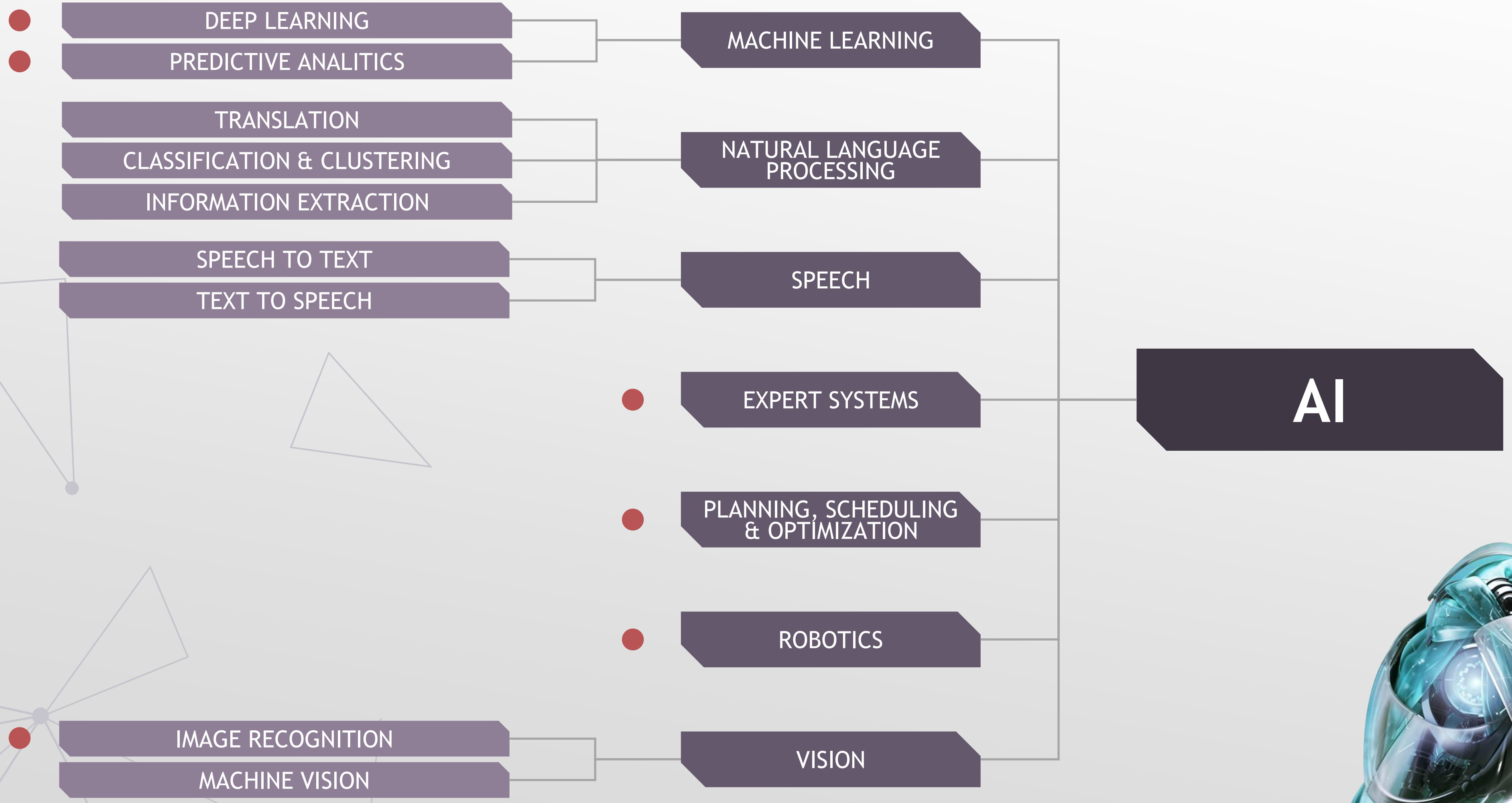
AUTONOMICZNE AUTA

AI Autopilot: wizja maszynowa, sieci neuronowe, algorytmy autonomii

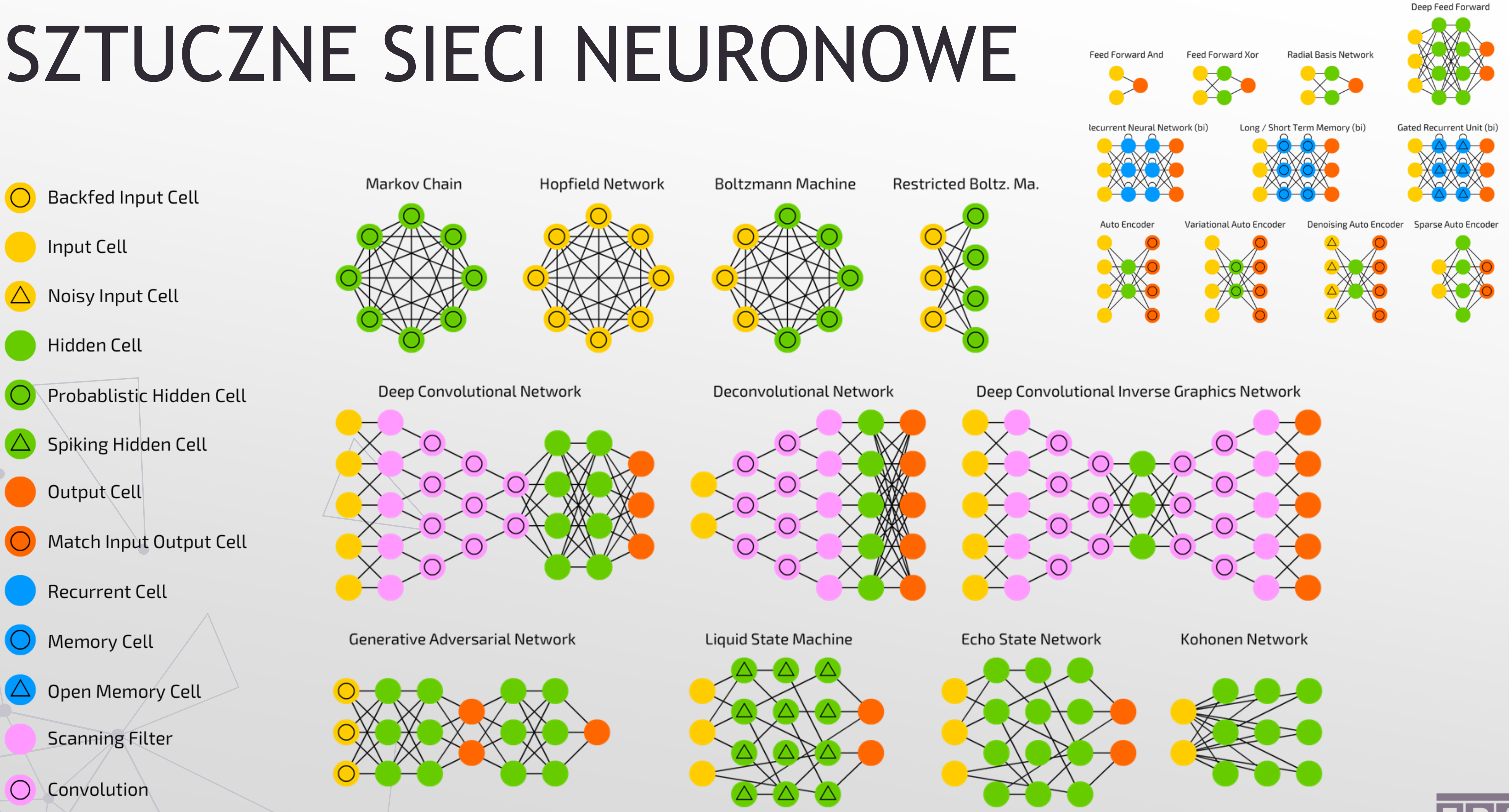
SAMOLĄDUJĄCE RAKIETY

Autopilot AI: kontrolowanie startów rakiet, lotów i lądowań

SYSTEMY SZTUCZNEJ INTELIGENCJI



SZTUCZNE SIECI NEURONOWE



04

MOŻLIWE ZASTOSOWANIA W INŻYNIERII DROGOWEJ

Kilka pomysłów…

ANALITYKA PREDYKCYJNA

UCZENIE MASZYNOWE – ANALITYKA PREDYKCYJNA

SZTUCZNA SIEĆ NEURONOWA DO PRZEWIDYWANIA PARAMETRÓW MATERIAŁÓW NA PODSTAWIE DANYCH HISTORYCZNYCH

PRZYKŁAD: Sztuczna Sieć Neuronowa dla E* - Dynamiczny Moduł Sztywności Zespolonej MMA

PRZEWIDYWANIE MODUŁU SZTYWNOŚCI DYNAMICZNEJ MMA

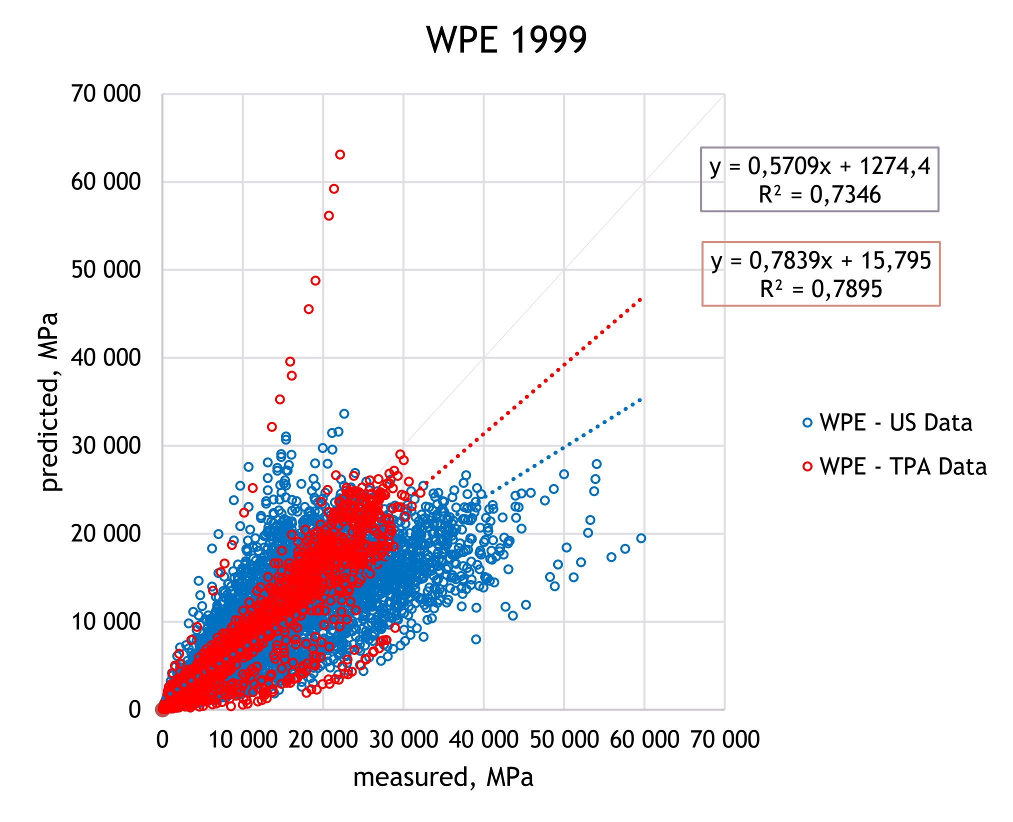
STANDARDOWE PODEJŚCIE – RÓWNANIE PRZEWIDUJĄCE

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

Where the variables represent:

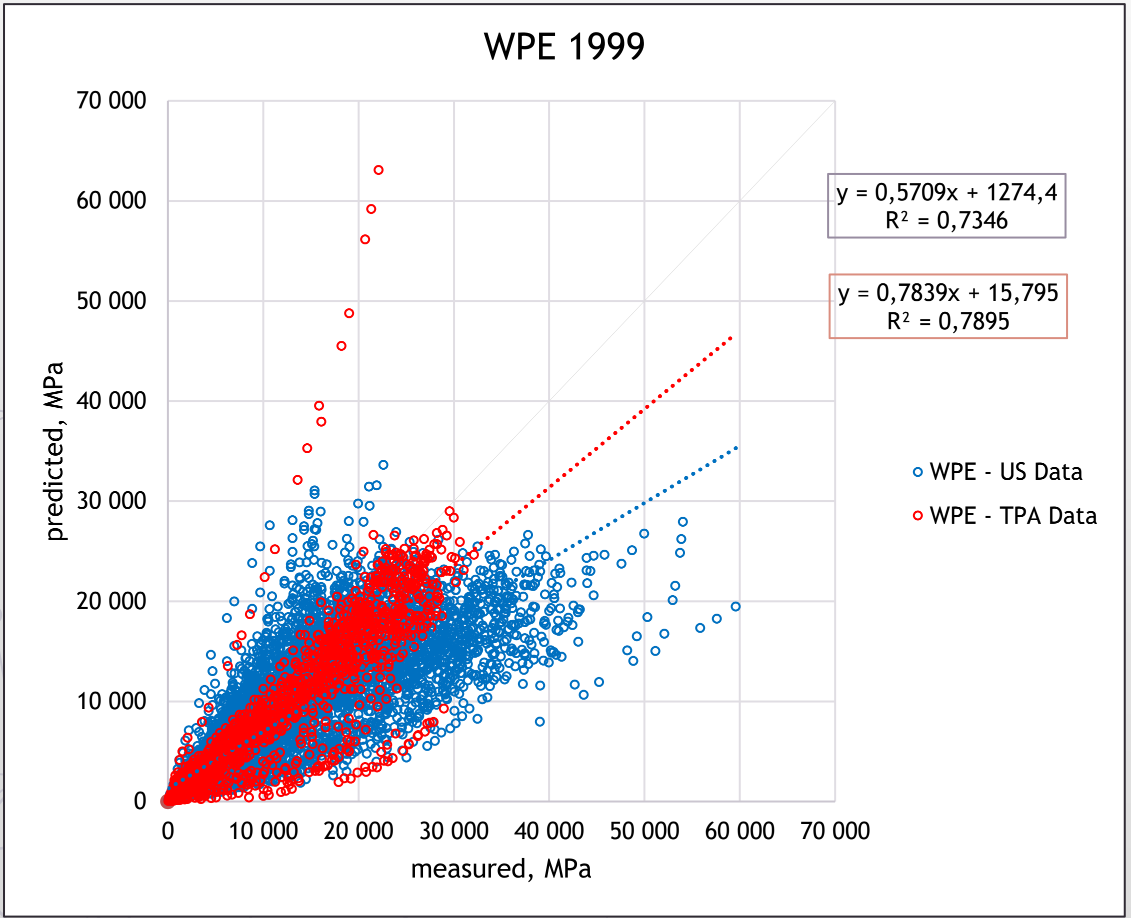
E	Asphalt Mix Dynamic Modulus, in 10^5 psi
η	Bitumen viscosity in 10^6 poise (at any temperature, degree of aging)
f	Load frequency in Hz
Va	% air voids in the mix, by volume
Vb_{eff}	% effective bitumen content, by volume
p_{34}	% retained on the ¾ inch sieve, by total aggregate weight (cumulative)
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

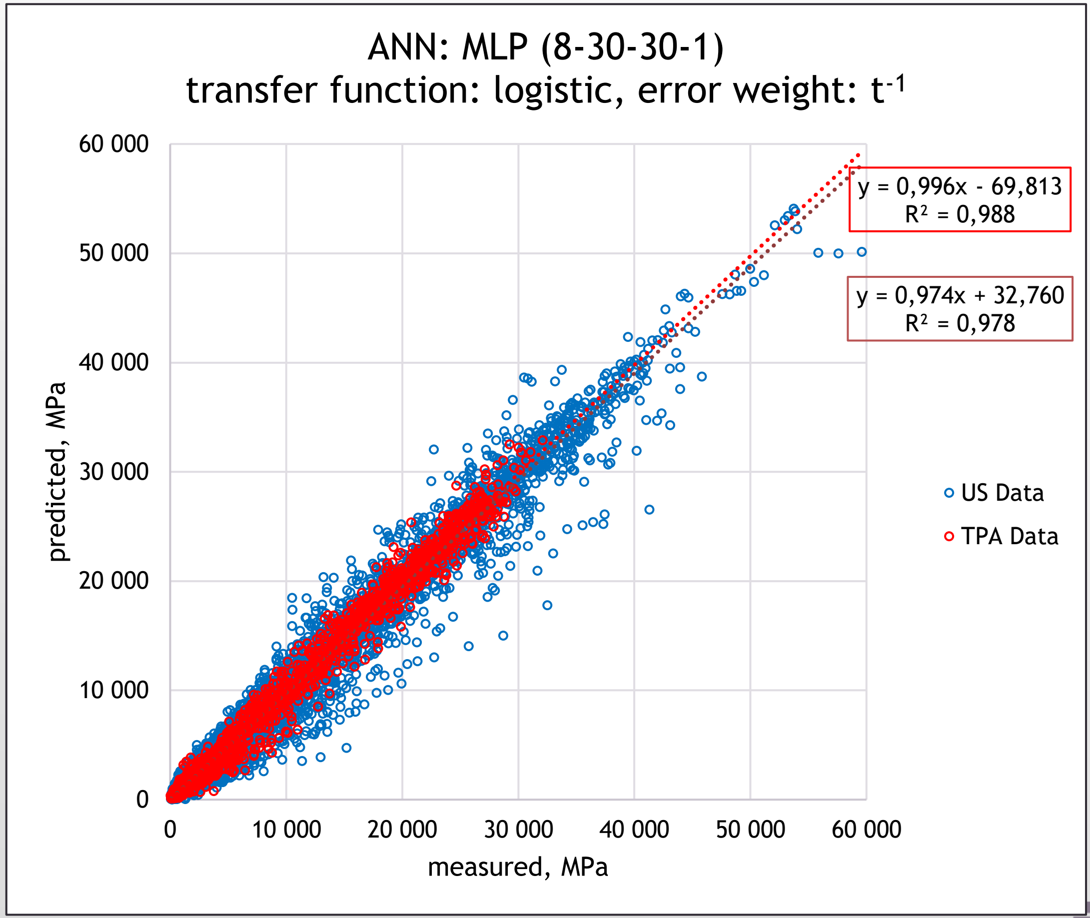
FIGURE 26. Revised Dynamic Modulus Predictive Equation



PRZEWIDYWANIE MODUŁU SZTYWNOŚCI DYNAMICZNEJ MMA

STANDARDOWE PODEJŚCIE VS SZTUCZNA SIEĆ NEURONOWA (MATLAB)

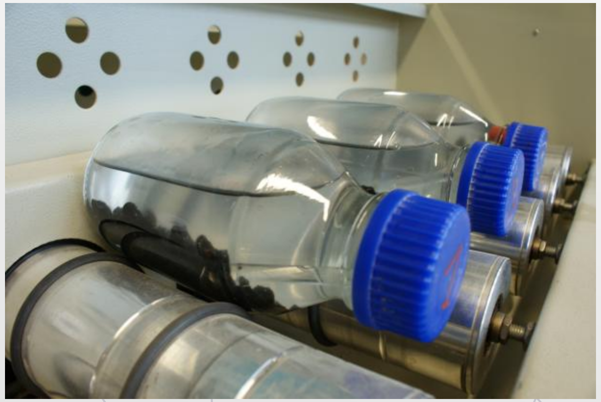


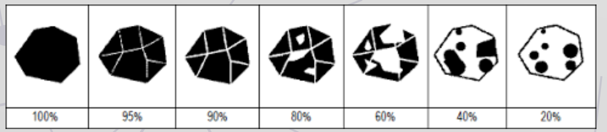


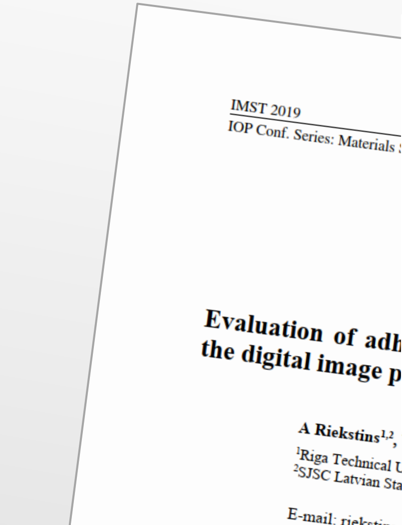
AUTOMATYZACJA PROCESÓW
&
ROBOTYZACJA PRODUKCJI

SYSTEMY ROZPOZNAWANIA OBRAZU

ANALIZA POKRYCIA KRUSZYWA LEPISZCZEM (EN 12697-11:2020-07)






IMST 2019
IOP Conf. Series: Materials

Evaluation of adh... the digital image p...

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... for quality asphalt concrete is strong adhesion between bitumen and aggregates. [1, 2, 3]. Adhesive properties are known to be affected by the chemical composition, surface tension and viscosity of bitumen, as well as oil used in the production of bitumen. [4, 5] Likewise, adhesion is influenced by the properties of the aggregates, such as chemical composition, surface roughness, shape, amount of cut surface and porosity. [4, 5] To improve the adhesion properties, the bitumen is modified by the addition of a variety of improving additives.[1]

To test the adhesion properties between bitumen and aggregates, European Standard EN 12697-11 provides three different methods: rolling-bottle method, static method and boiling water stripping method [6]. In Latvia, the method used to evaluate adhesion has been remained from GOST standard and is described in Road Specifications 2019. [7] All of the methods ... evaluation are done visually by two independent operat... accuracy of 5 %. In figure 1 can se... of visual ass...

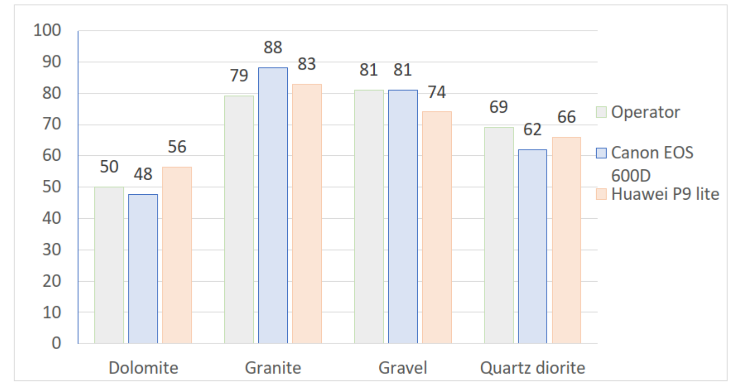
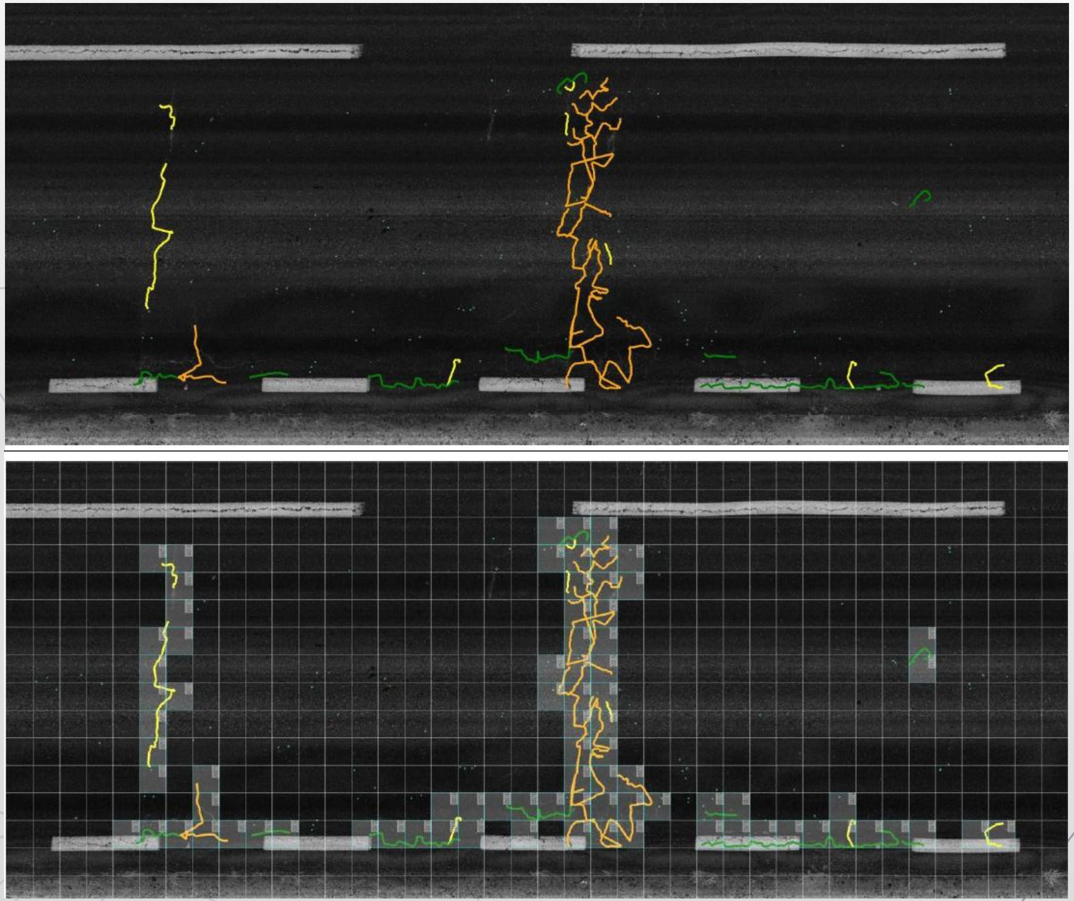


Figure 5. Comparison of the results of visual and image processing method.

SYSTEMY ROZPOZNAWANIA OBRAZU

ROZPOZNAWANIE USZKODZEŃ NAWIERZCHNI NA PODSTAWIE WIDEOREJESTRACJI



AUTOMATYCZNA IDENTYFIKACJA USZKODZEŃ Z VIDEOREJESTRACJI ORAZ LIDAR

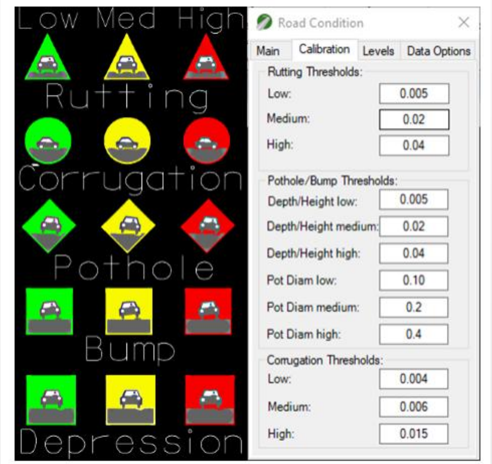
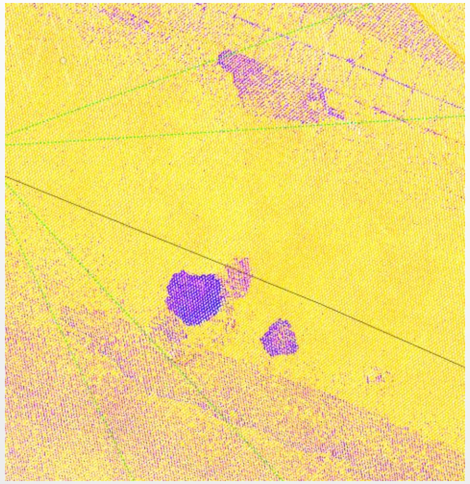
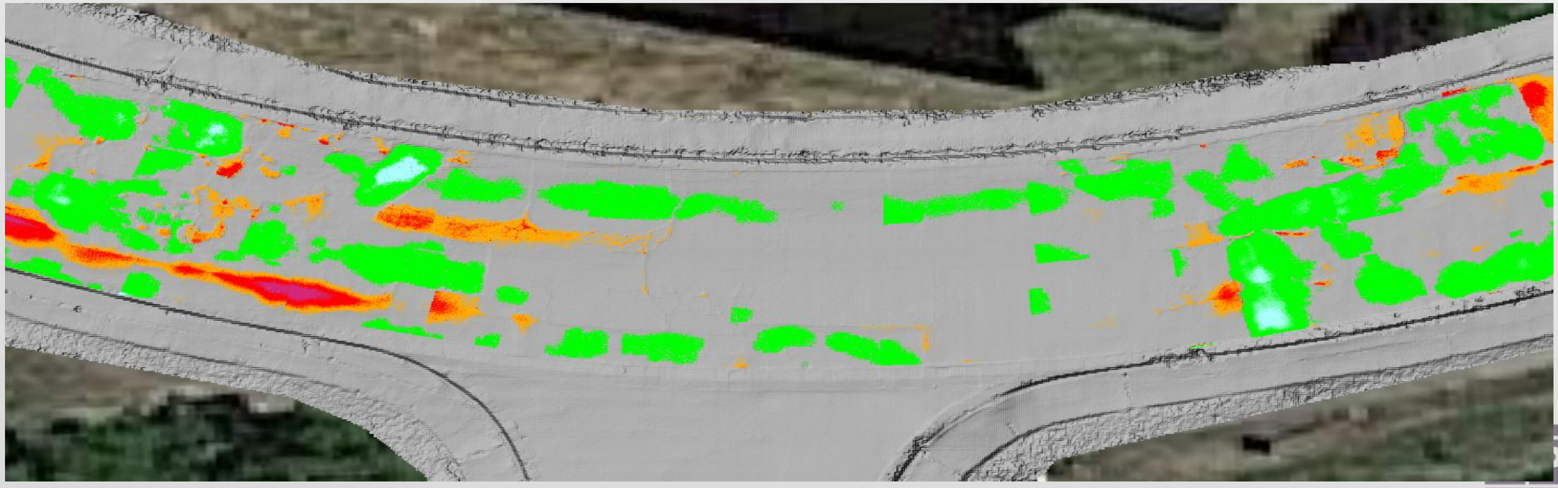


Figure 16 Flagging of different types of unevenness in the Road Condition tool in TopoDC





AUTOMATYCZNA OCENA STANU NAWIERZCHNI Z WYKORZYSTANIEM SIECI NEURONOWYCH

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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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

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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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.

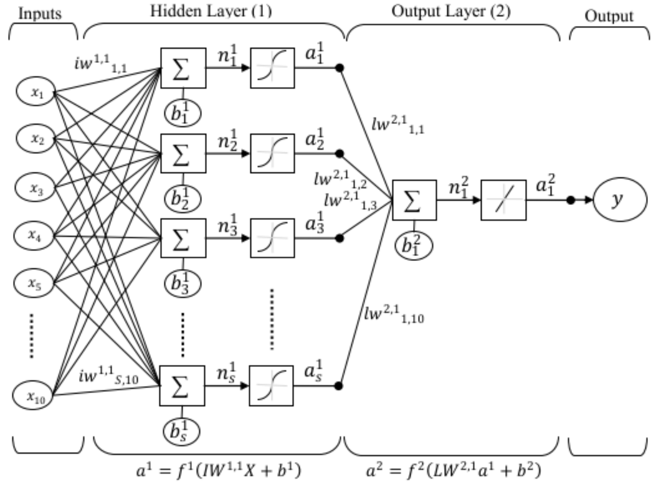


Figure 3. ANN Models Architecture.

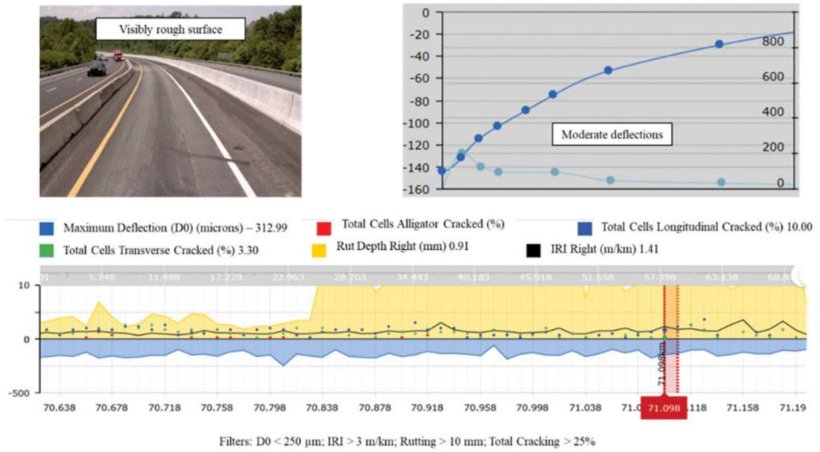


Figure 6. Low deflection and a rough, uneven road surface.

TPA

W PEŁNI ZINTEGROWANA I AUTOMATYCZNA OCENA STANU NAWIERZCHNI PRZY PRĘDKOŚCI RUCHU DROGOWEGO

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

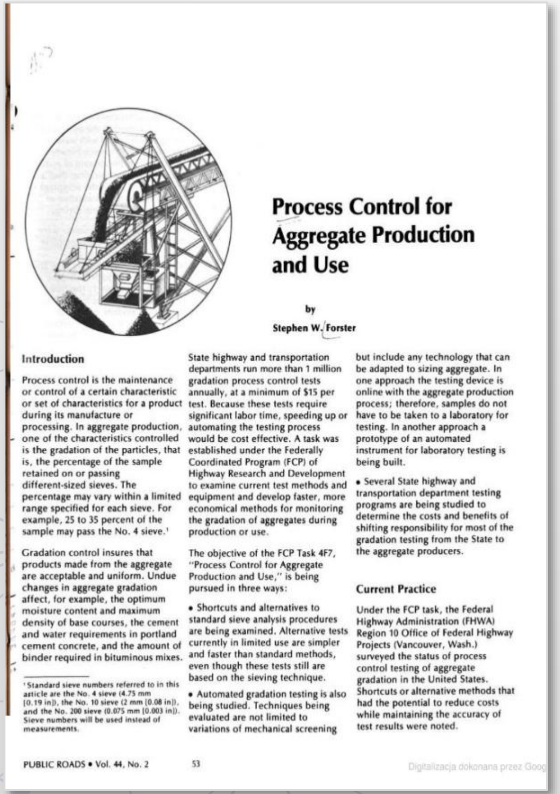
The high accuracy and resolution of the iPAVe data enables engineers to pinpoint precise locations (down to 1 m) and areas where the capacity of the pavement structure is of concern. iPAVe provides additional and essential input to network level assessment and evaluation, which is crucial for deterioration 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

ZINTEGROWANY AUTOMATYCZNY SYSTEM KONTROLI JAKOŚCI PRODUKCJI MATERIAŁÓW I UKŁADANIA NAWIERZCHNI ASFALTOWEJ



Process Control for Aggregate Production and Use

by

Stephen W. Forster

PUBLIC ROADS • Vol. 44, No. 2

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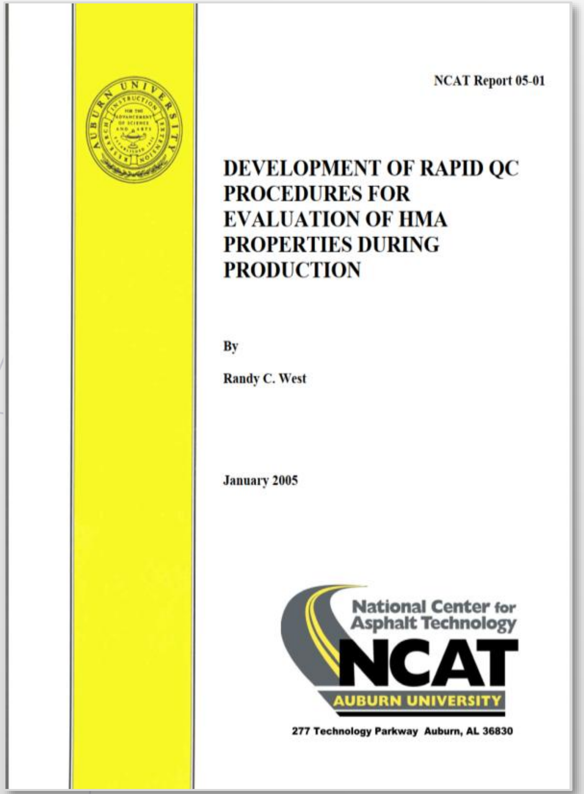


NCAT Report 05-01

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

By

Randy C. West

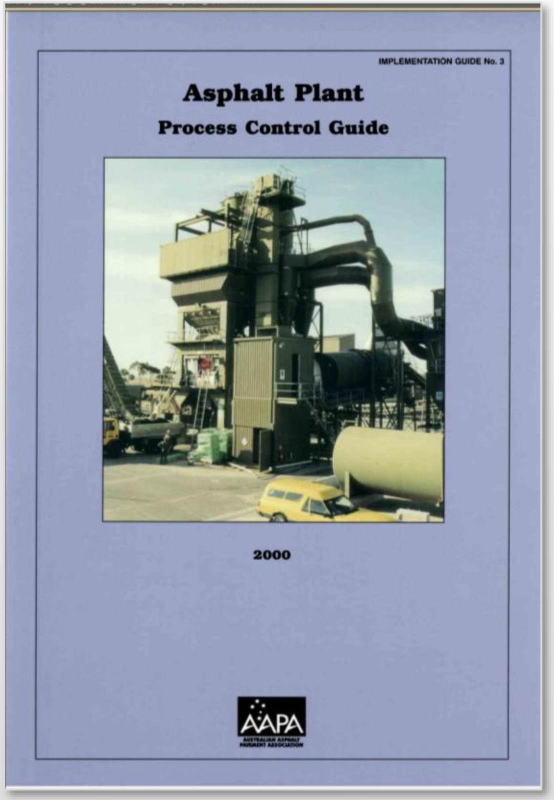
January 2005

National Center for Asphalt Technology

NCAT

AUBURN UNIVERSITY

277 Technology Parkway Auburn, AL 36830



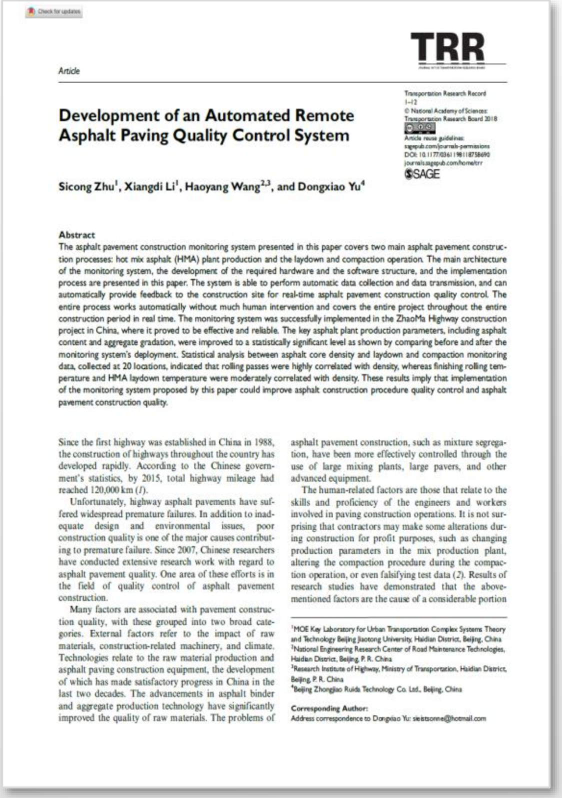
IMPLEMENTATION GUIDE No. 3

Asphalt Plant

Process Control Guide

2000

AAPA



TRR

Article

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

ROBOTYCZNE SYSTEMY POBIERANIA PRÓBEK MATERIAŁÓW I AUTOMATYCZNE SYSTEMY TESTOWE

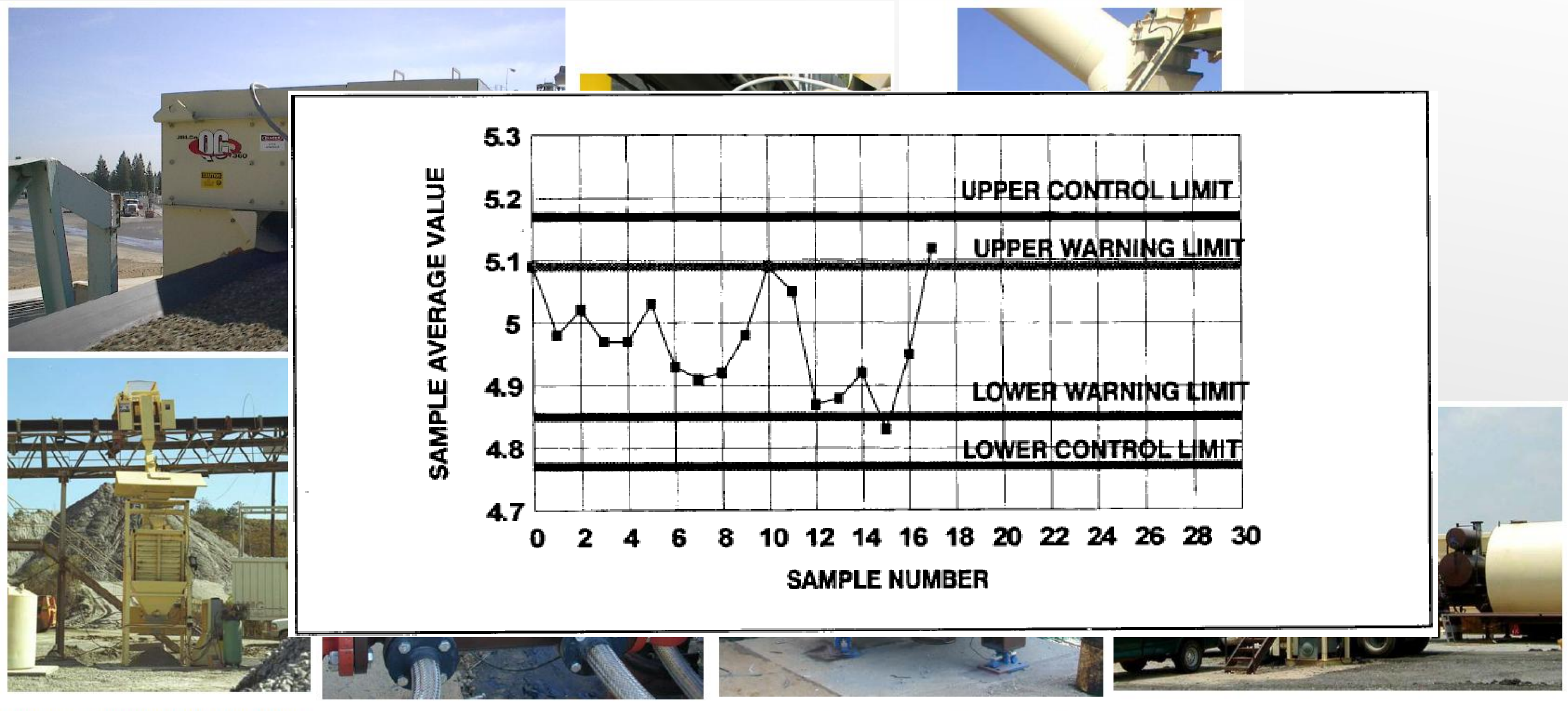


Figure 4. Automated Gradation Device

Figure 5. In-line Asphalt Viscometer

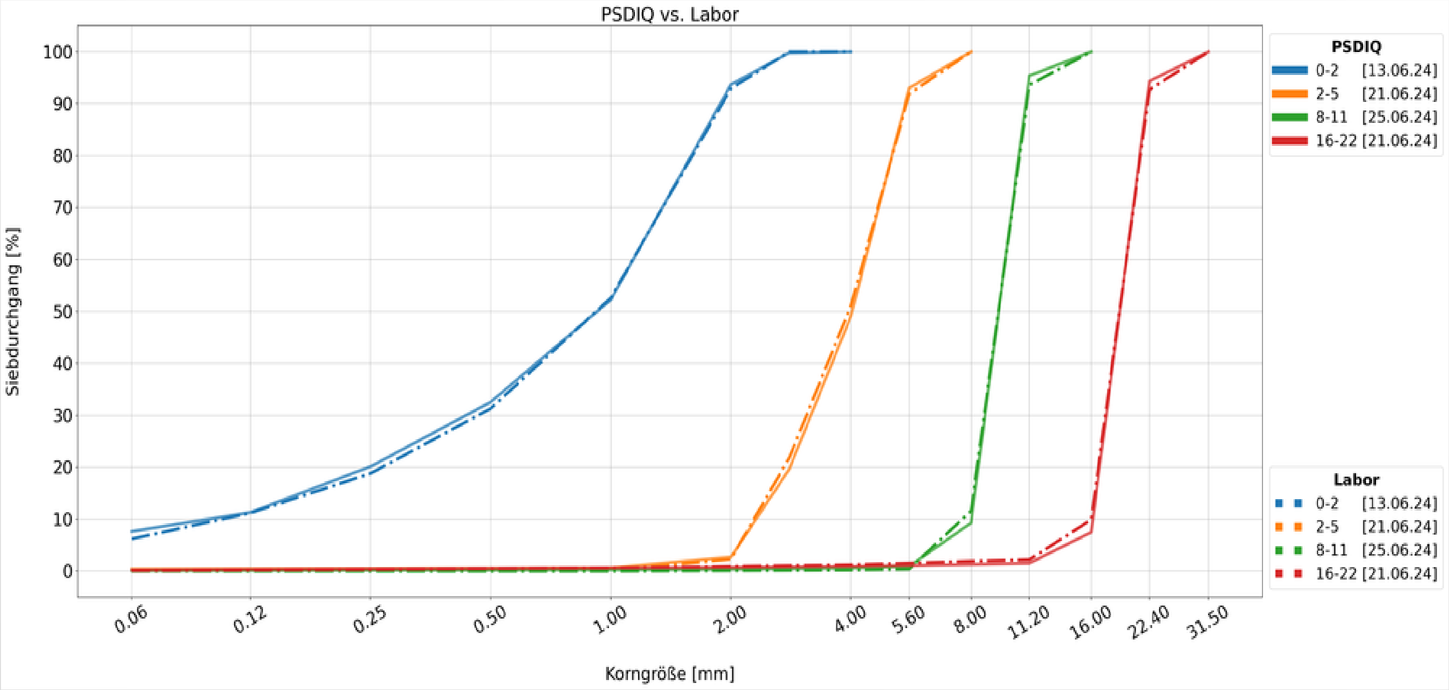
Figure 6. Asphalt Meter Calibration Tank

Figure 7. Robotic Truck Sampler

KONTROLA JAKOŚCI UZIARNIENIA KRUSZYWA W KOPALNI W CZASIE RZECZYWISTYM

PROJEKT BADAWCZY TPA & TIPCO GMBH

ROZKŁAD WIELKOŚCI ZIARNA W DYNAMICZNYM STRUMIENIU MATERIAŁU NA ŻYWO I CYFROWO



AUTOMATYCZNA OPTYMALIZACJA PROCESU UKŁADANIA I ZAGĘSZCZANIA WARSTW NAWIERZCHNI

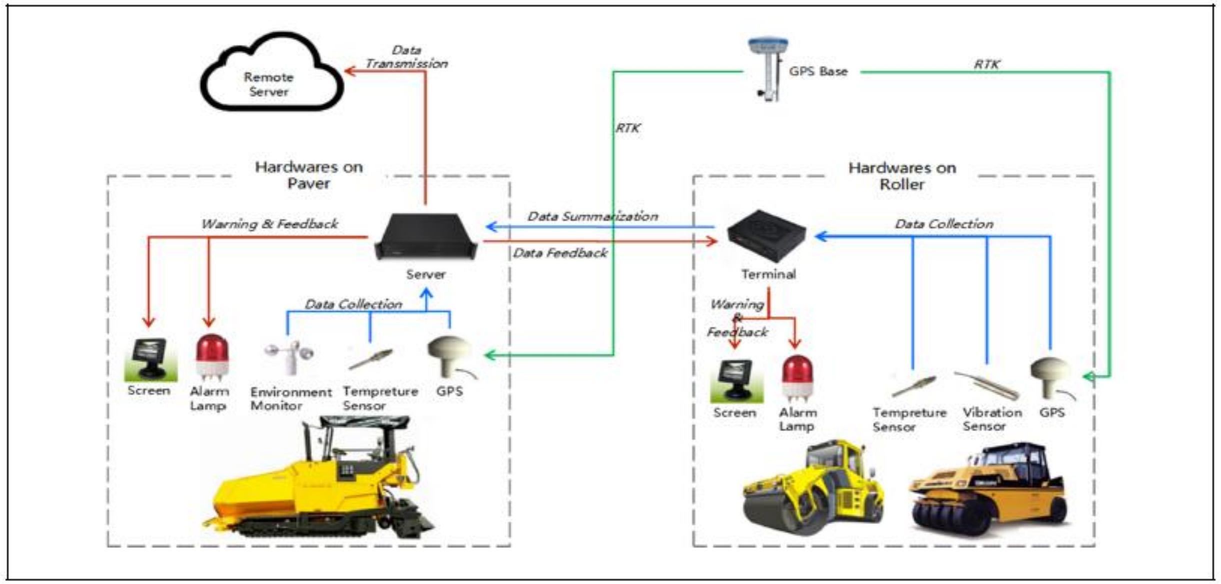


Figure 4. Composition of HMA paving and compaction quality check system.
Note: RTK = real-time kinematic.

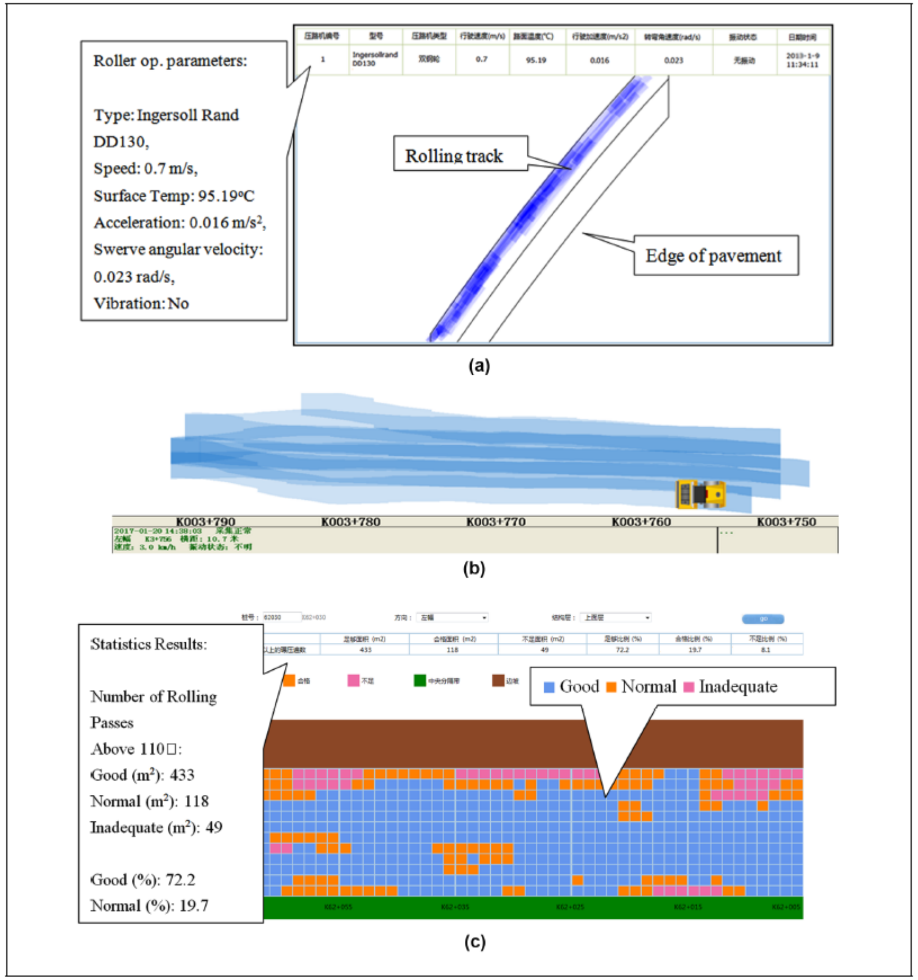


Figure 6. (*a*) Web-based roller real-time working status; (*b*) roller driver working status user graphic interface; and (*c*) graphic display of rolling quality statistics.

CYFROWA, INTELIGENTNA I ZRÓWNOWAŻONA BUDOWA

WALZGEN & InfraROB

PROJEKTY BADAWCZE Z UDZIAŁEM STRABAG NAD W PEŁNI AUTONOMICZNYMI SYSTEMAMI UKŁADANIA NAWIERZCHNI ASFALTOWYCH

AUTOMATYCZNA INSPEKCJA BUDOWY ZA POMOCĄ DRONÓW

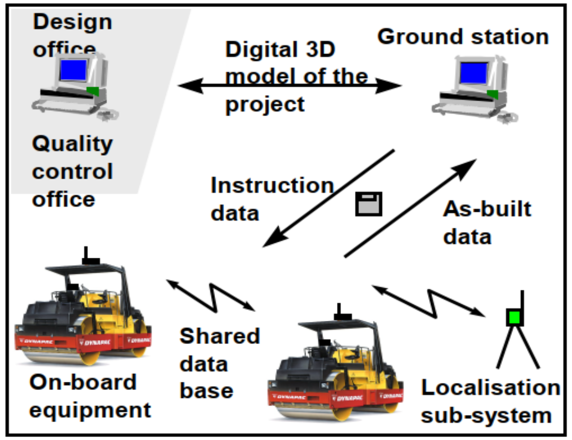


Figure 1: general architecture of a CIRC system

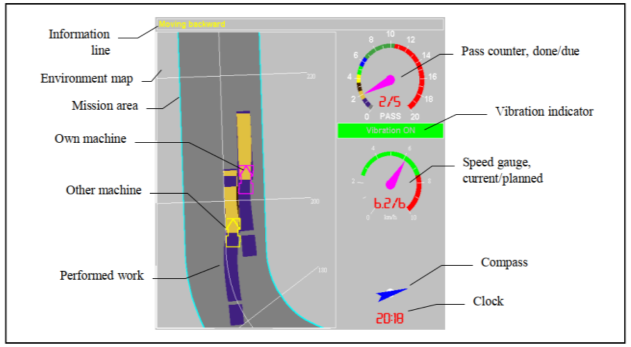


Figure 3: CIRCOM on-board sub-system MMI

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)).

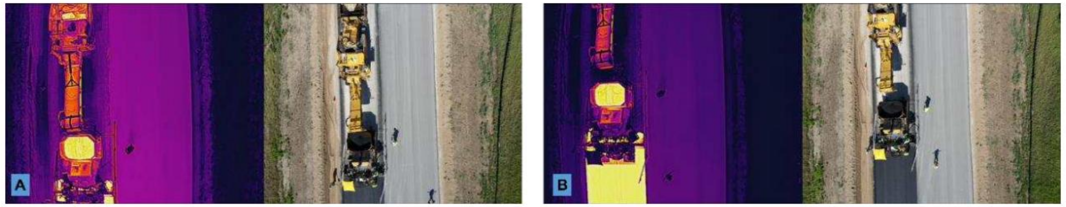


Figure 9. Thermal profile of HMA in the hopper (**A**) and behind the paver (**B**).

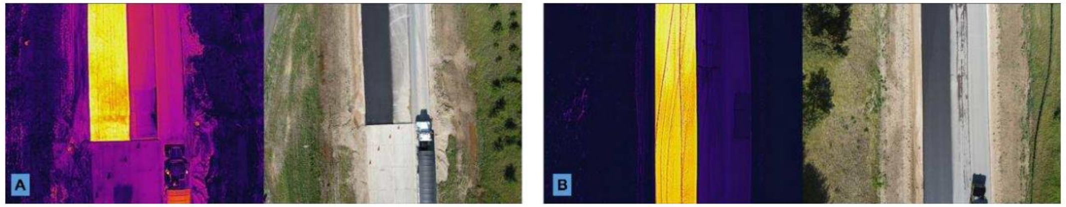


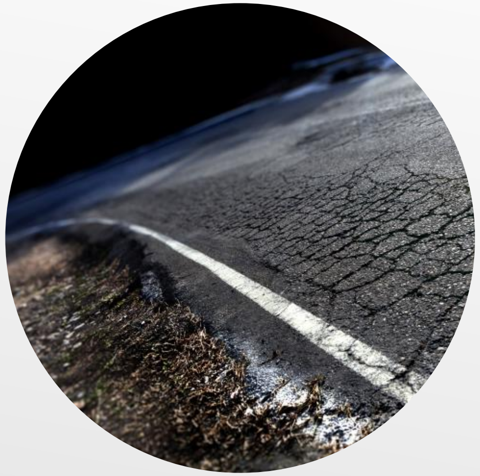
Figure 10. Differential cooling on the freshly placed HMA at the very beginning of the paving (**A**) and along the roller tracks (**B**).

SYSTEMY EKSPERCKIE

WIRTUALNY TECHNOLOG LUB EKSPERT

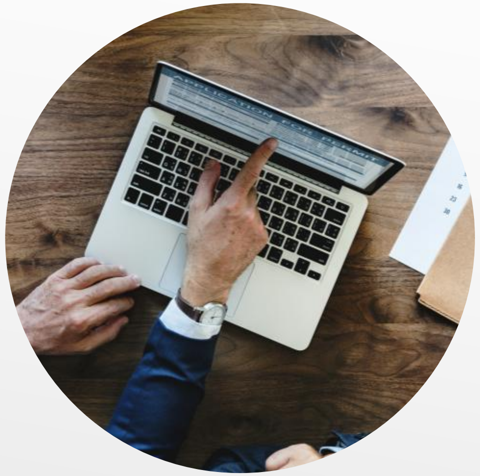
MMA / PCC BADANIA TYPU

przyspieszenie procesu projektowania receptur i osiągnięcie optymalnych składów



OCENA PRZYCZYN USZKODZEŃ

identyfikacja i ocena przyczyn przedwczesnych uszkodzeń nawierzchni lub konstrukcji budowlanych w oparciu o połączone informacje dotyczące parametrów materiałów, jakości wykonania i warunków eksploatacji



PRZEWIDYWANIE I REKOMENDOWANIE

możliwość przewidywania (Analiza Predykcyjna) i zapobiegania błędom (Analiza Preskryptywna) na etapie projektowania, produkcji i realizacji w czasie rzeczywistym (online) w oparciu o stale napływające dane i informacje

DZIĘKUJĘ ZA UWAGĘ!

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TPA