



Silesian  
University  
of Technology



RESEARCH  
UNIVERSITY

EXCELLENCE INITIATIVE

Ministry of Science  
and Higher Education

# DIGITAL TWINNING OF BRIDGES AND CIVIL INFRASTRUCTURES

BRIDGE TEAM AT THE FACULTY OF CIVIL ENGINEERING

---

# Contact persons

## Bridge team at Faculty of Civil Engineering



Piotr ŁAZIŃSKI, PhD

- steel bridges, FEM, DT, SHM
- bridge load tests

<https://omega.polsl.pl/info/author/PSL76ae4d22dcf24b698fb153fa3a95b34a/>



Marcin JASIŃSKI, PhD

- concrete bridges, FEM, BIM, DT, AI
- visual programming, machine learning

<https://omega.polsl.pl/info/author/PSL06ffdf077c34b629160e583c19937a6/>



Muhammad FAWAD, PhD

- bridge management, SHM, BIM, VR/MR
- immersive platforms, gamification

<https://omega.polsl.pl/info/author/PSL4722bacdf20245bd8eeaf3a1cd0a2fbf/>



Marek SALAMAK, Prof.

- concrete bridges, FEM, BIM, DT, VR/MR
- bridge load tests

<https://omega.polsl.pl/info/author/PSLdc1162ddf3c644538c3a3f4d8f322451/>



Mateusz UŚCIŁOWSKI

- 3D reconstruction, BIM, VR
- bridge inspections

<https://omega.polsl.pl/info/author/PSLd2c186c85795497fbd8c4e149f35ed69/>



Dawid PIOTROWSKI

- bridge designing, FEM, BIM, DT, SHM, AI
- visual programming, machine learning

<https://omega.polsl.pl/info/author/PSL53f4c7187a2647c68ebeacebd782016b/>



Duc Cong NGUYEN, PhD

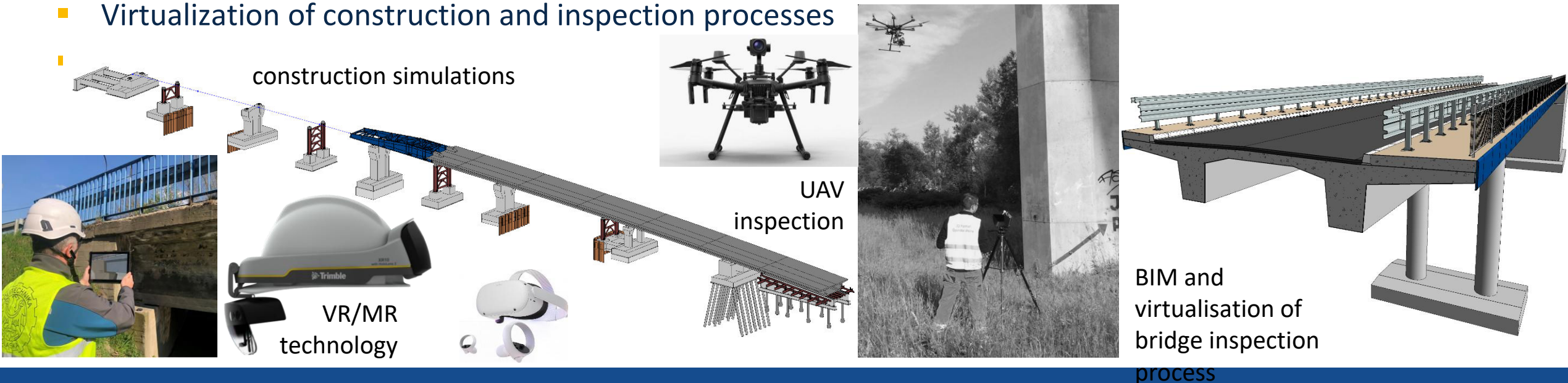
- bridge dynamics, signal processing, SHM
- bridge load tests, machine learning

<https://orcid.org/0000-0002-3393-0197>

# A comprehensive approach to critical infrastructure assets

## Digitisation of construction and inspection processes

- Open digital bridge structure description formats according to BIM methodology
- Optimizing design processes already in BIM environments
- Modeling and simulating construction processes in the context of their automation and robotization
- Definition of digital bridge twins taking into account the public needs of managers
- SHM bridge monitoring systems with new diagnostic methods and digitization of technical inspection process
- Virtualization of construction and inspection processes





# Laboratory – tools from the area of digital technologies



Trimble XR10  
HoloLens2



photogrammetry  
camera



Leica BLK360  
laser scanner



gogle VR  
Oculus  
Quest 2



tablet for  
inspection



DJI Matrice 210 RTK



Trimble  
Site Vision



mobile  
skanner ZEB 1

# Digital infrastructure asset management

## New methods of bridge inspections



yesterday



tomorrow





# Bridge damage detection

## Pillar of the border bridge between Poland and Czechia

- Detection of cracks
- UAV platform
- Real time
- Machine Learning



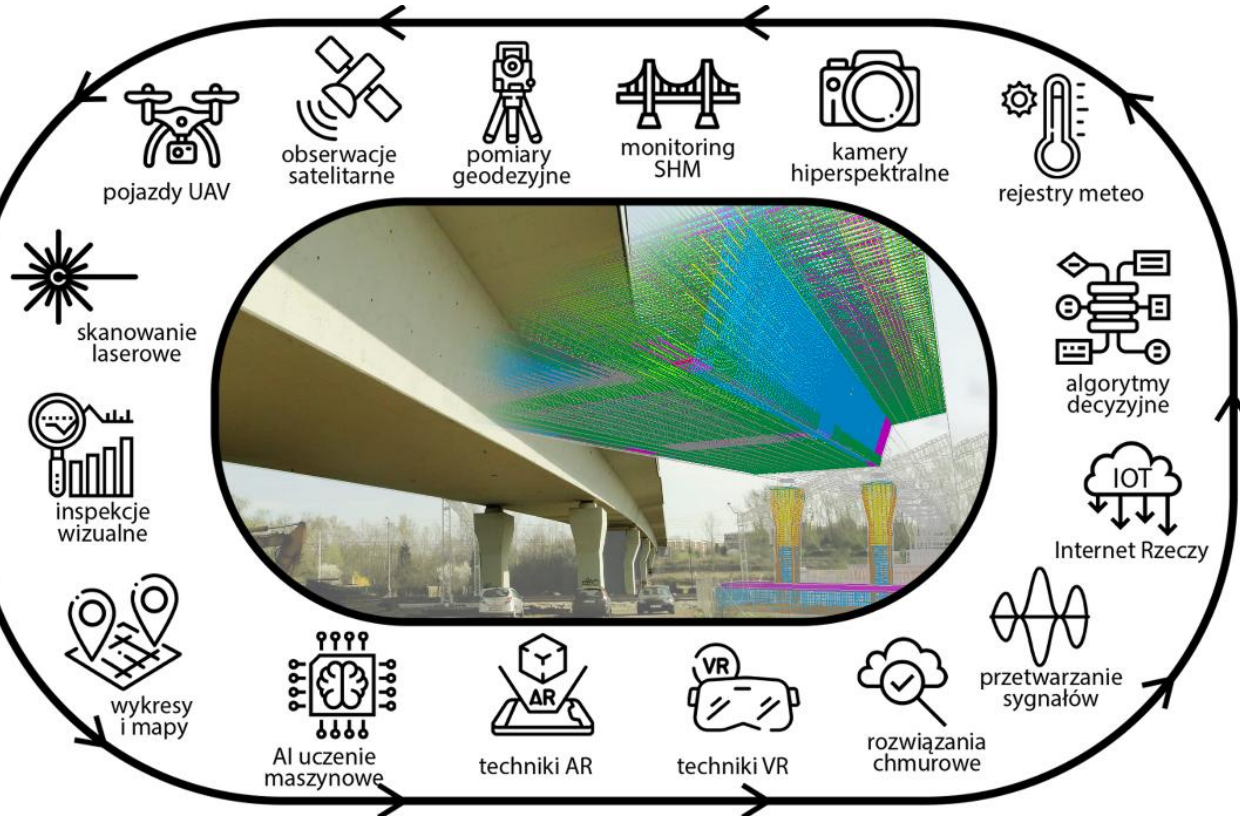


# Digital twins of bridges

## Diversification of data sources, with acquisition and processing methods



Data sources and ways of acquisition

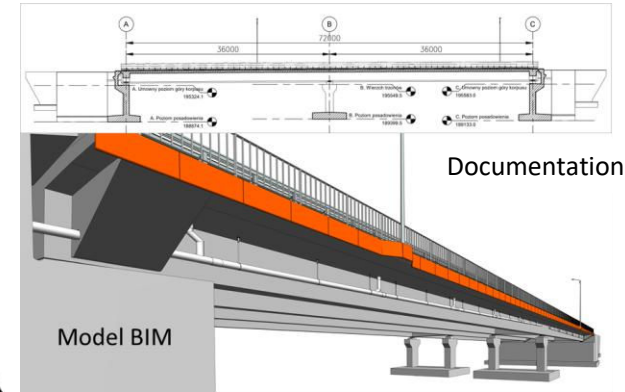


Data processing tools and digital technologies

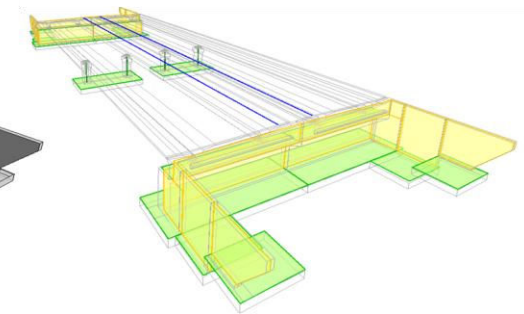
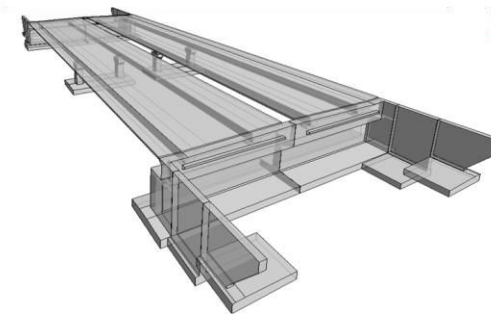
Digital Twin Model (DTM)



Reality Twin Model (RTM)

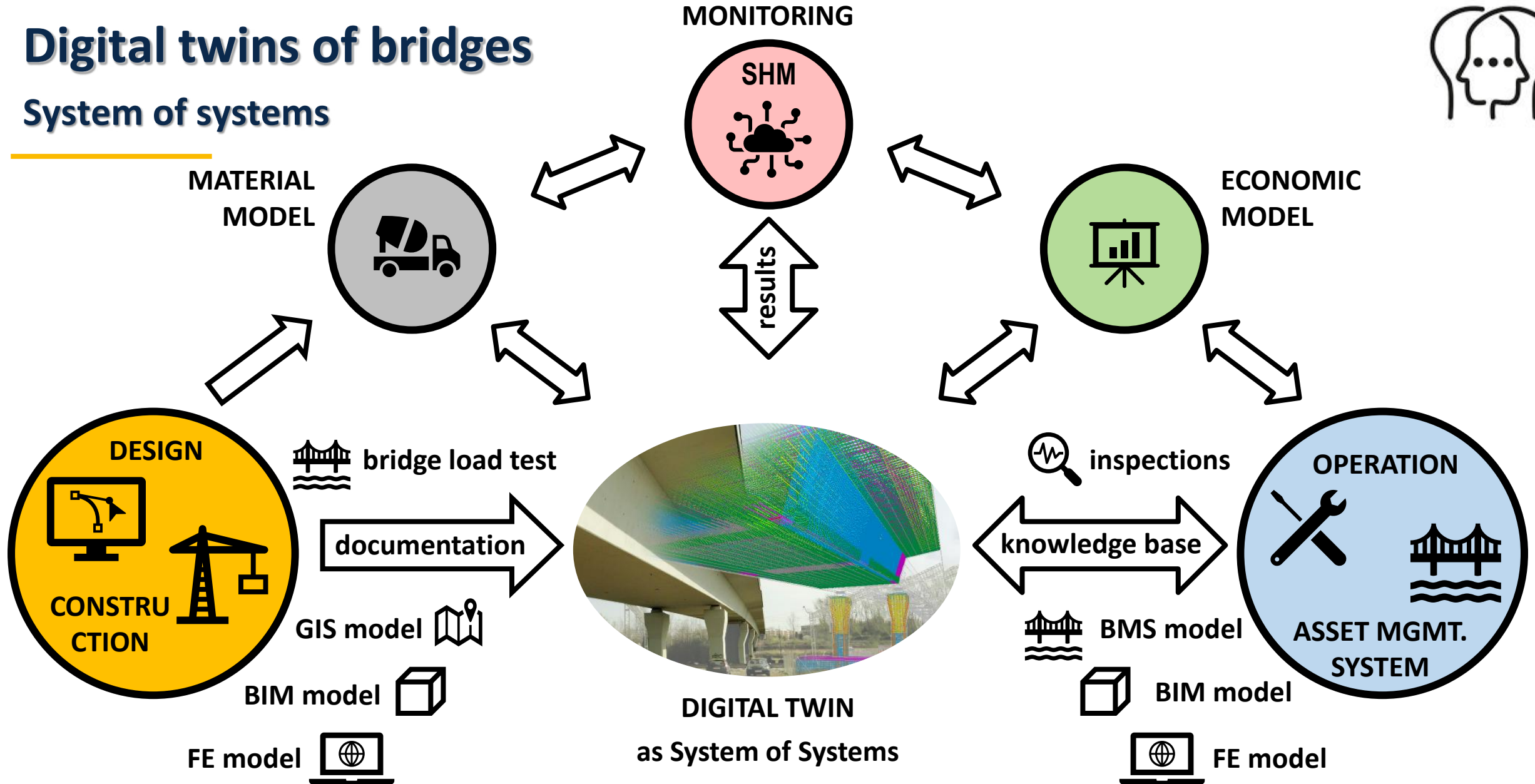


Analytical FE Model (FEM)



# Digital twins of bridges

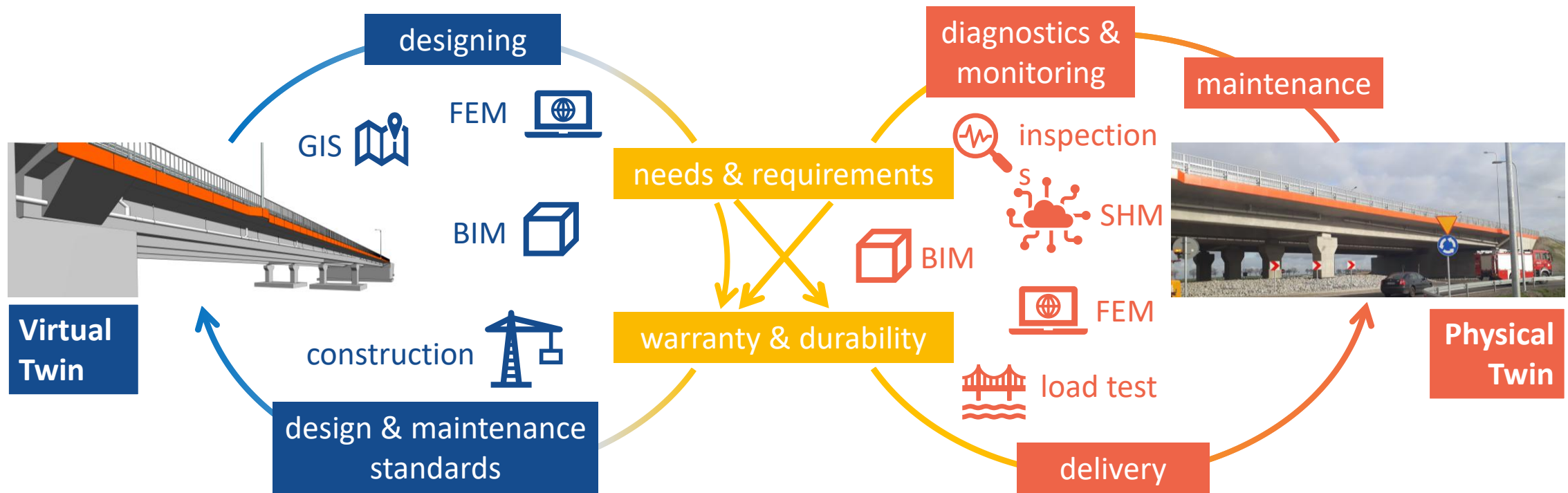
## System of systems





# Digital twins of bridges

## Life Cycle Approach



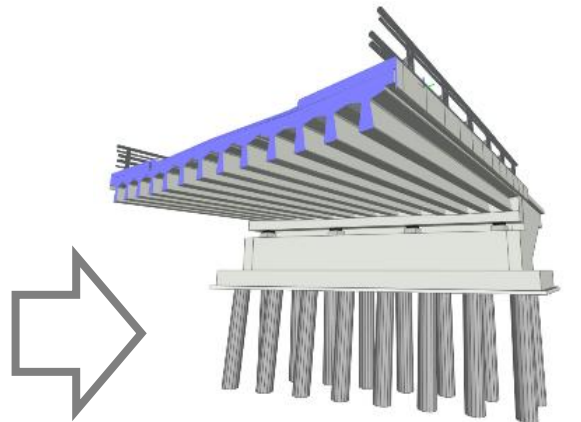
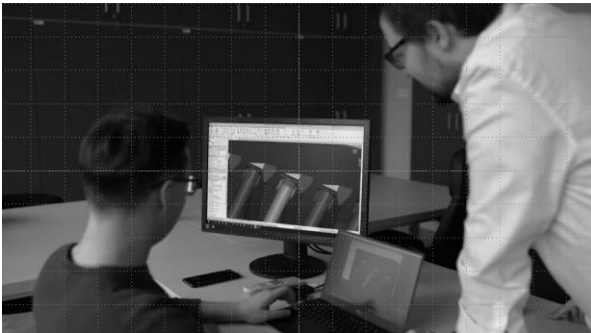
# Digital twins of bridges

## Two scenarios for creating a digital twin

- BIM 3D solid modeling in the design process
  - Newly designed facilities
  - Digitization of the design process itself
  - Introducing requirements in the infrastructure
  - Reconstruction may require 3D reconstruction

parameterization of 3D solid models

solid modeling in the design process

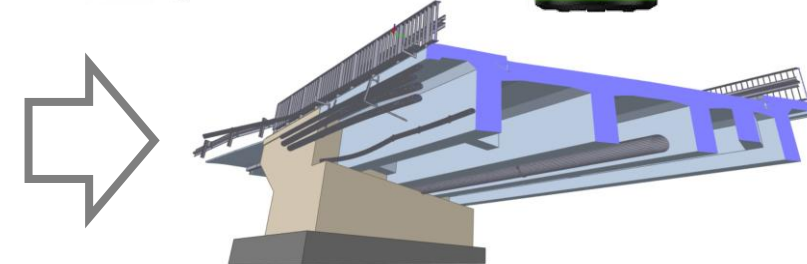


model of the designed bridge

- Modeling with the 3D reconstruction techniques
  - Facilities already constructed and in use
  - Mainly scanning techniques and photogrammetry
  - Object inventory in the form of a 3D point cloud
  - It is necessary to process the cloud into a solid model

3D reconstruction and drones

scanning of an existing bridge



model of an existing bridge





# Mobile devices with Mixed or Augmented Reality

## Research on virtualization of bridge inspection process



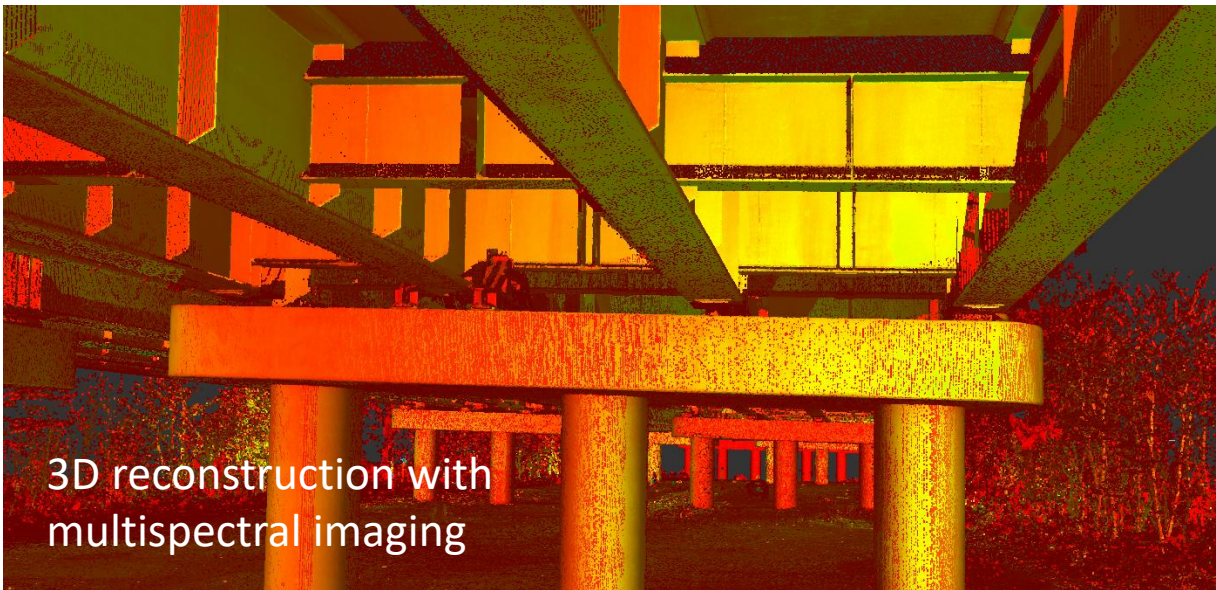




Testing different types of drones for bridge inspection



Trimble XR10 helmet with HoloLens 2



3D reconstruction with multispectral imaging



inspection with UAV platform





Trimble XR10 helmet  
with HoloLens 2



mobile application supporting  
the bridge inspection



Trimble SiteVison  
with GNSS receiver

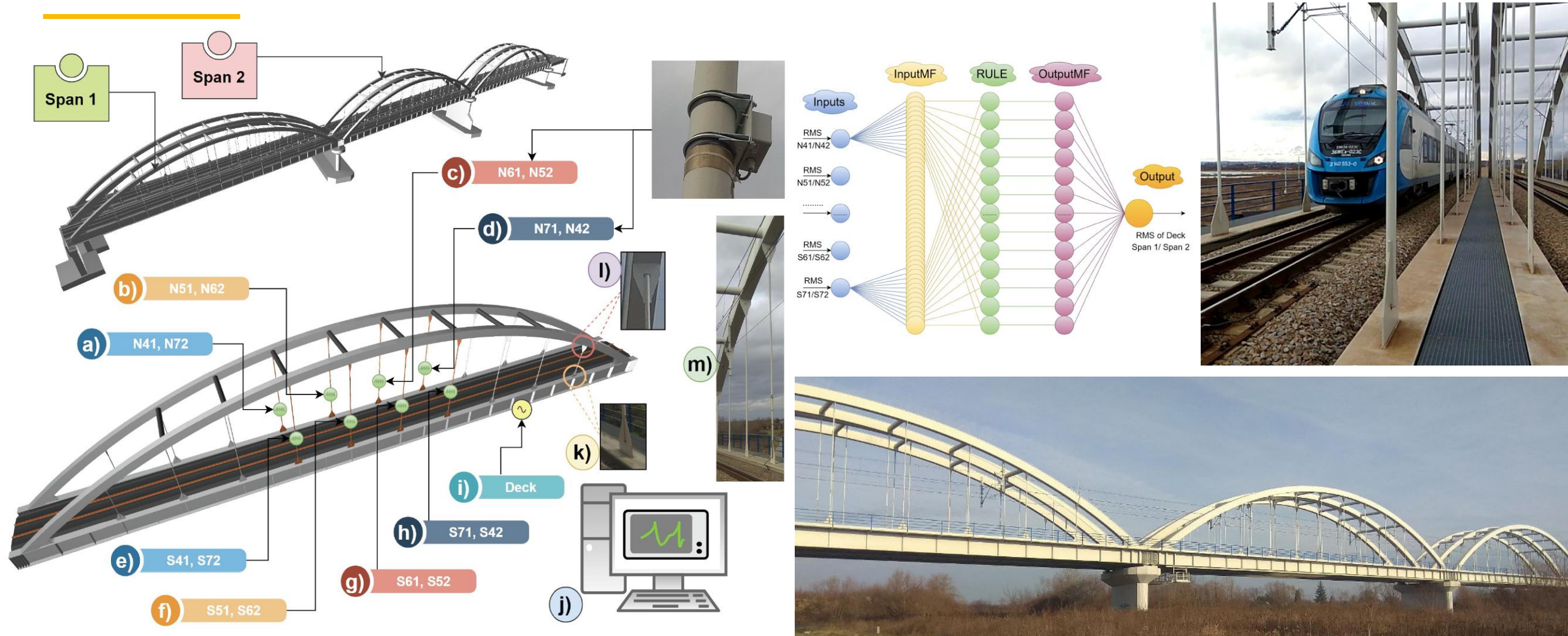


Smart probe with  
a mobile application



# Railway arch bridge with SHM system

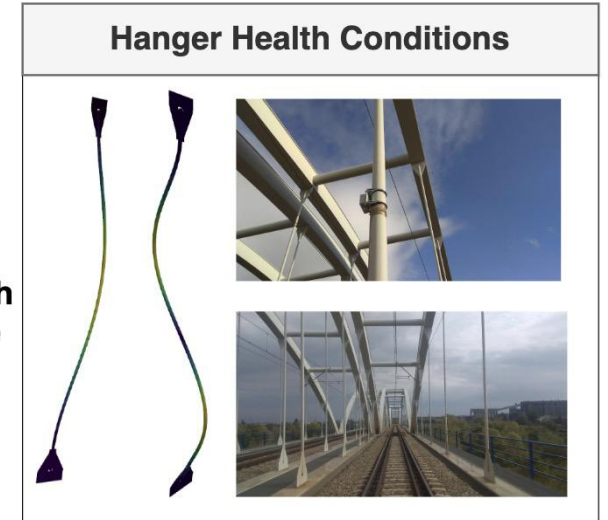
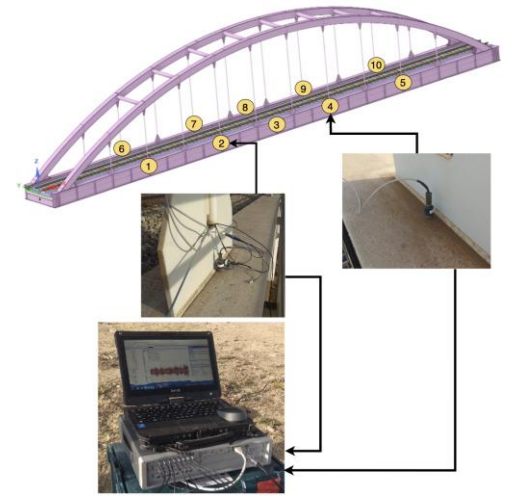
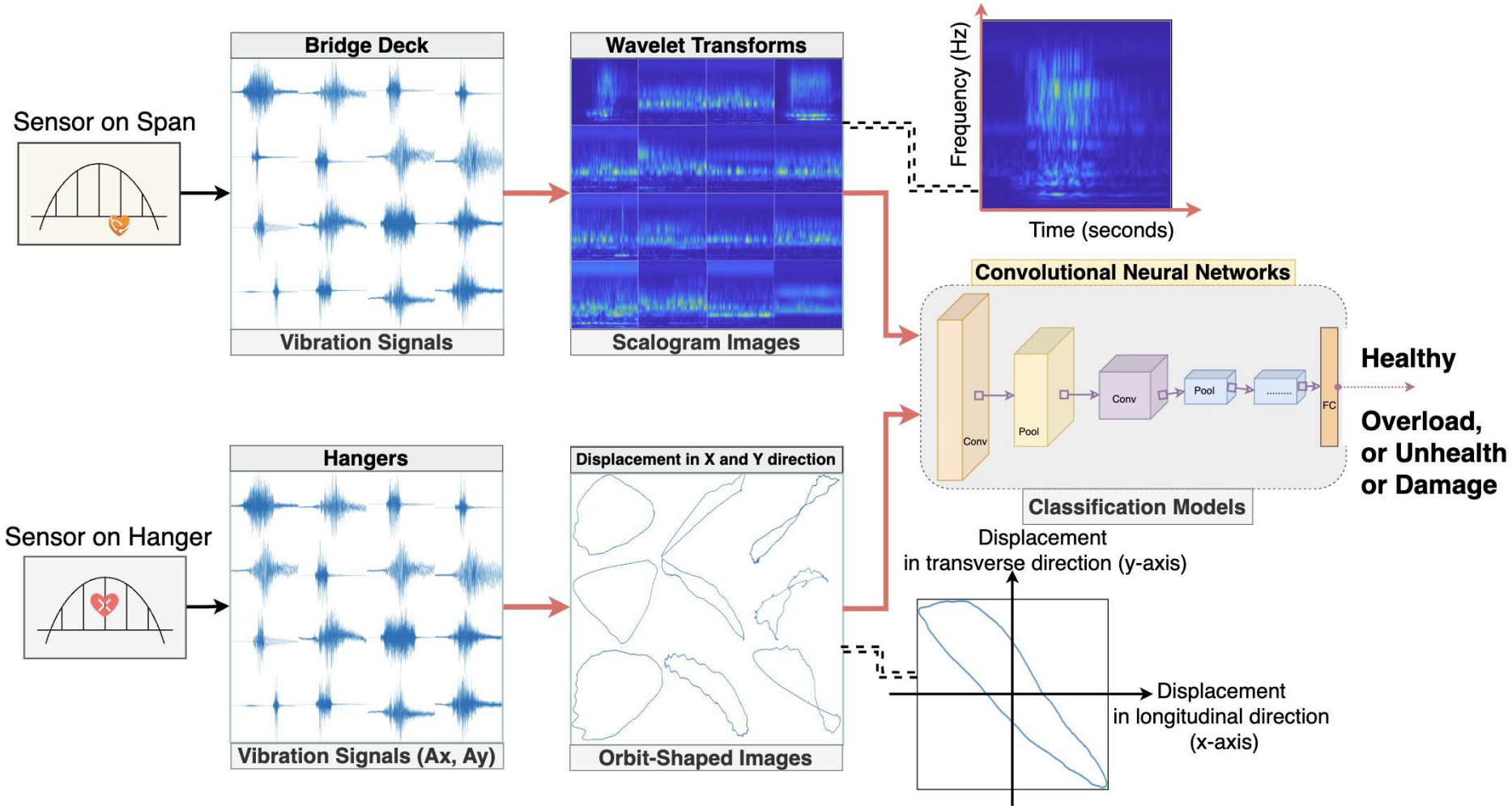
## Hangers vibrations assesment with Machine Learning based signal processing





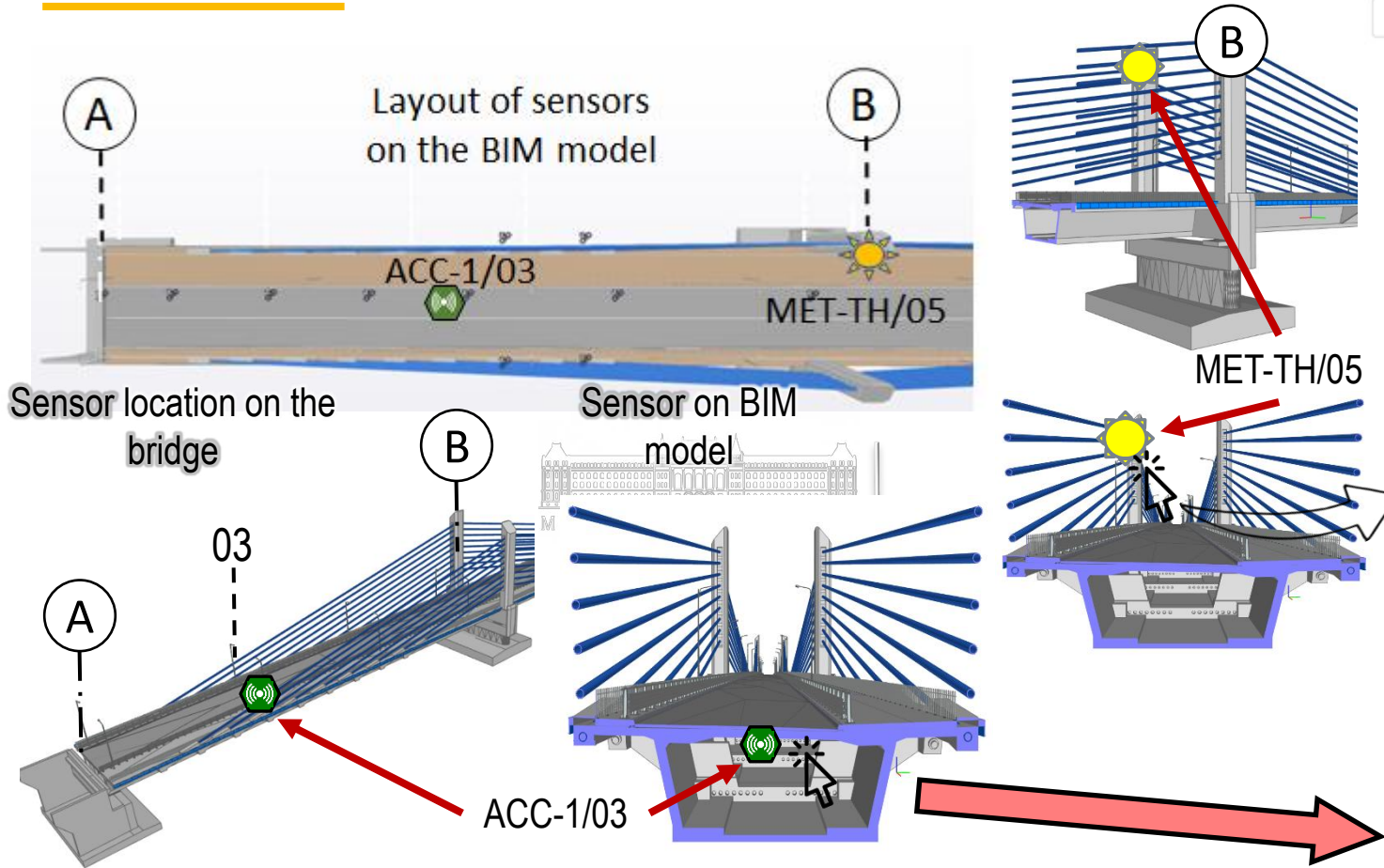
# Railway arch bridge with SHM system

## Wavelet analysis and deep learning



# Integration of BIM and IoT for smart SHM

## BIMification of SHM system



Kurow Bridge SHM System Online

Dashboard Timeline Device Info Metadata Actions Log

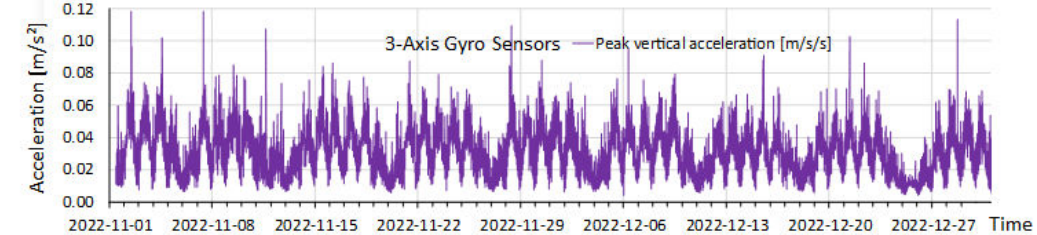
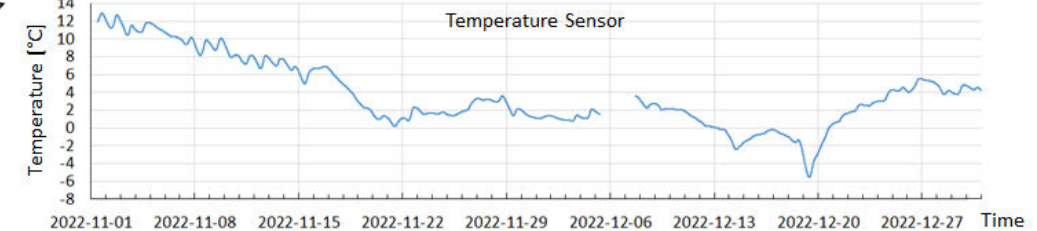
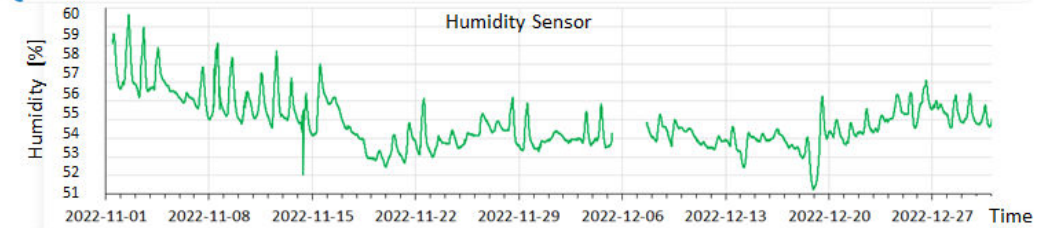
Latest Last Hour 6 Hours 1 Day 1 Week 1 Month **3 Months** Custom

Temperature

20.8 °C

Humidity

56.1 %

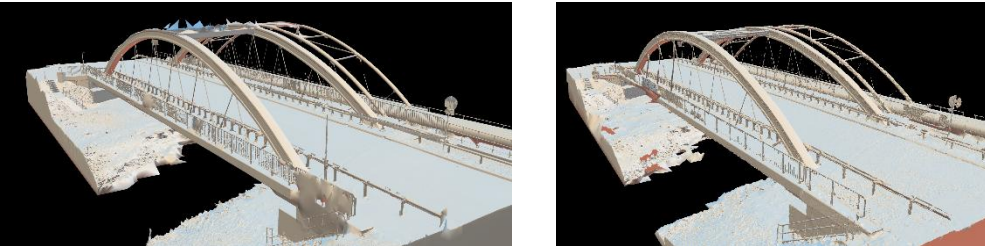




# Development of Immersive Bridge Digital Twin Platform (IBDTP)

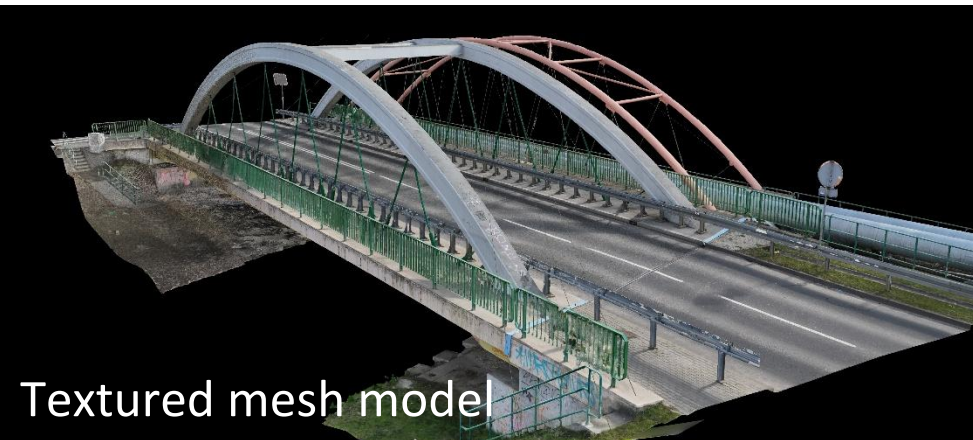
## Reality capture and BIM model update

3D reconstruction



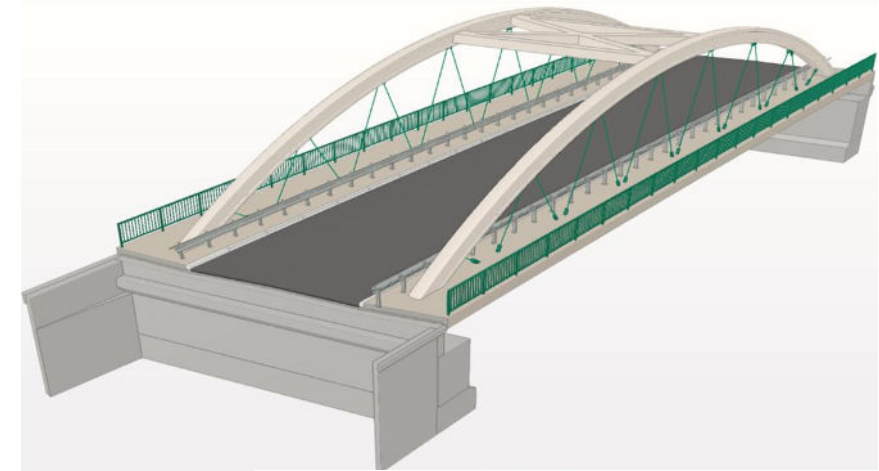
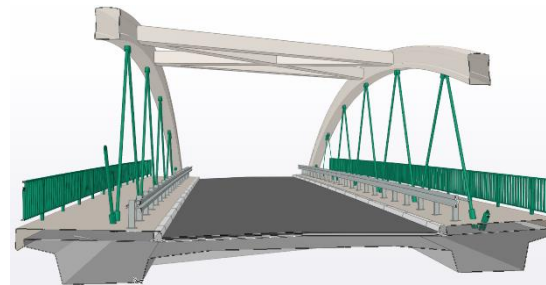
Laser scanning

+ Photogrammetry



Textured mesh model

BIM model



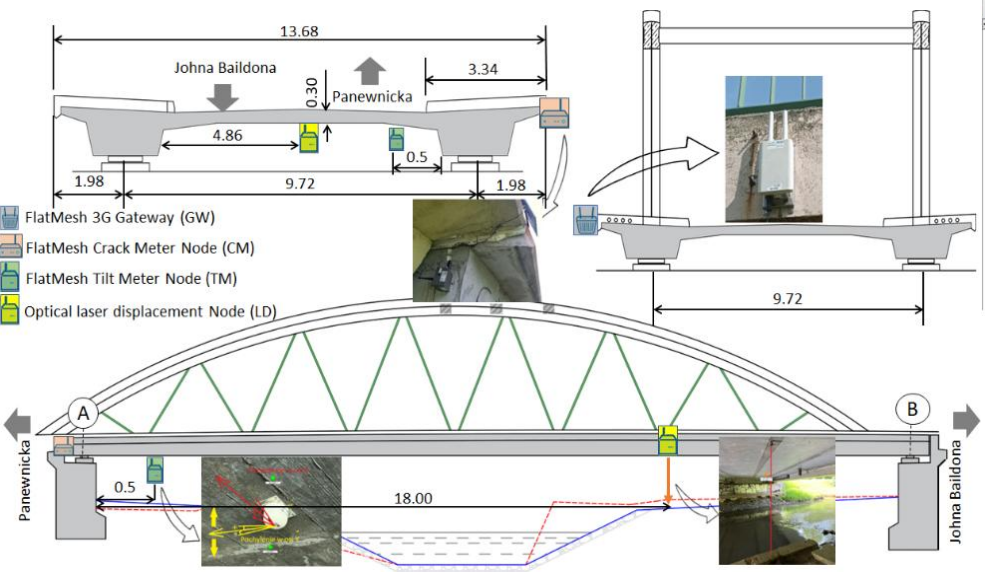
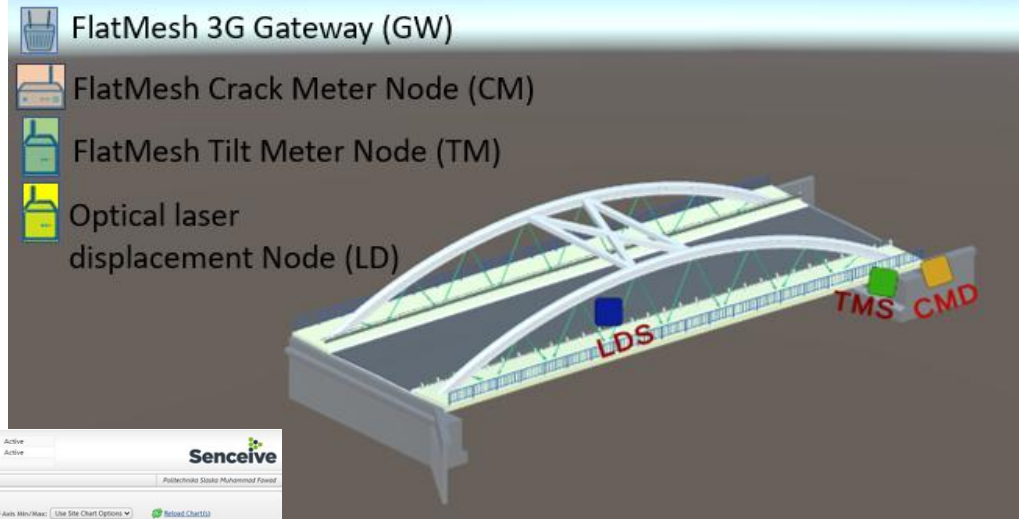
BIM model  
update



# Development of Immersive Bridge Digital Twin Platform (IBDTP)

## Digital Twin of the SHM system

- GW for the communication of sensors
- TMS for the measurement of rotation angle
- LDS for the measurement of vertical displacement
- CMD for longitudinal movements of spans
- Built-in temperature sensors



Screenshot of the Senceive digital twin platform interface. It displays data reports for Displacement (mm) and FMS Onboard Temperature (°C) over time. The interface includes a navigation menu, a data table, and a code editor showing C# code for a NewBehaviourScript.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

@ Unity Script (2 asset references) | - references
public class NewBehaviourScript : MonoBehaviour
{
    public string Url;
    - references
    public void Open()
    {
        Application.OpenURL(Url);
    }
}
```



Reports





# Development of Immersive Bridge Digital Twin Platform (IBDTP)

## MR-enhanced Digital Twinning of bridge of bridge SHM



synthesis of a virtual model with a real image



physical sensor IoT

virtual sensor

onsite data signal visualization

The composite image shows a worker in an MR headset. Overlaid on the scene is a virtual interface. On the left, a 3D model of a bridge structure is shown with a 'virtual sensor' icon and a hand cursor pointing to it. On the right, a 'physical sensor IoT' is shown as a small white cylindrical object. Below the 3D model, a 'Microsoft Edge' browser window displays a line graph titled 'onsite data signal visualization' showing a fluctuating signal over time.

# Multi-threaded case study of the Wolin Bridge Digital Twin

