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BIM4CE Solution Outlook: Integrated Bridge Monitoring System

Bridge Monitoring Using Real-Time Data and Digital Twins for Central Europe

Executive Summary

The BIM4CE project has successfully developed and deployed a comprehensive, integrated bridge monitoring solution across three pilot sites in Germany, Slovenia, and Italy. The solution combines novel leakage sensor foils developed by TU Dresden with existing partner-provided sensors — including accelerometers and Weigh-in-Motion (WiM) systems — all connected via a purpose-built IoT data transfer infrastructure for real-time cloud-based monitoring. A Digital Twin platform provides each pilot site with a live, data-driven virtual model of the bridge, enabling predictive maintenance and informed decision-making by bridge owners and authorities.

1. Project Background, Partnership and Objectives

BIM4CE (Bridge Information Modelling for Central Europe) is a three-year Interreg Central Europe project with a mission to advance the state of bridge monitoring in the region. Bridges are critical infrastructure assets, and their deterioration — particularly due to moisture ingress, structural vibrations, and heavy traffic loads — poses significant safety and economic risks.

The project was structured around three Work Packages (WP1–WP3), covering stakeholder engagement and site selection (WP1), technical development and deployment (WP2), and digital twin integration (WP3). The 30th Consortium Meeting was held in Ljubljana, Slovenia in March 2026, marking a key milestone in the project's progress review.

Partnership

The BIM4CE partnership brings together eight organizations from Germany, Slovenia, and Italy, forming a well-balanced and complementary consortium. The partnership collectively covers all key areas required for the development and implementation of a standardized monitoring and maintenance solution for European bridges, as well as transnational stakeholder engagement via. It integrates expertise in data collection, digital technologies, and infrastructure management and stakeholder involvement and networking within a single collaborative framework. Advanced capabilities in data transmission, analysis, and storage are combined with strong knowledge in digital modelling and visualization. With extensive experience in infrastructure planning and management, the partnership ensures a holistic and practical approach. This integrated structure

enables efficient development of innovative, reliable, and applicable solutions at the European level. Further information on partners avaliable at https://www.interreg-central.eu/projects/bim4ce/

Key Objectives

- Identify and classify representative bridge types across partner countries based on an analysis of the available bridge databases
- Develop novel leakage sensing technology to detect moisture infiltration in bridge structures
- Integrate partner-provided sensors into a unified monitoring platform
- Deploy a cloud-based IoT infrastructure for real-time data transfer and storage
- Build Digital Twin models for three pilot bridge sites to enable predictive and condition-based maintenance

2. Novel Leakage Sensor Foils

One of the core innovations of BIM4CE is the development of **novel leakage sensor foils** by TU Dresden (Dresden Integrated Center for Applied Physics and Photonic Materials — IAPP). These flexible, thin-film sensors are designed to detect moisture and water ingress at critical points in bridge structures, such as expansion joints, deck surfaces, and bearing areas.

Key Features

- **Thin-film flexible form factor** — conformable to complex bridge geometries
- **Early-warning capability** — detects moisture before structural damage occurs
- **Low power consumption** — compatible with IoT energy budgets for remote deployment
- **Durable for outdoor environments** — engineered to withstand harsh weather conditions

Leakage and moisture infiltration are among the most common causes of reinforced concrete bridge deterioration. The sensor foils fill a critical gap not addressed by existing commercial monitoring products, making them a novel contribution to the field.

3. Integration of Partner-Provided Sensors

BIM4CE adopted an integration-first philosophy, combining the novel leakage sensor foils with existing, proven sensor technologies supplied by consortium partners. This multi-sensor approach enables comprehensive structural health monitoring from a single unified platform.

Sensor Types Integrated

Sensor Type	Parameter Monitored	Purpose
Accelerometers	Structural vibrations, dynamic loads	Detect anomalies based on the change in natural frequencies
Bridge Weigh-in-Motion (B-WiM) sensors	Vehicle gross and axle weights; bridge response	Monitor traffic loads and traffic-induced stress; support load management decisions
Leakage Sensor Foils (novel, TU Dresden)	Moisture / water infiltration	Early detection of water ingress into structural elements

The integration of these complementary sensor modalities allows the platform to correlate events — for instance, correlating heavy vehicle loads with vibration signatures and moisture exposure — providing a far richer picture of bridge condition than any single sensor type could offer alone.

4. Data Transfer and Cloud Infrastructure

A data-transfer solution was developed to transfer sensor data in real time from the pilot bridge sites to a centralized cloud platform. The cloud infrastructure was set up early in the project and serves as the backbone for data aggregation, storage, processing, and visualization.

- On-site edge nodes collect data from all sensor types (leakage foils, accelerometers, B-WiM) and transmit via secured wireless and/or wired EtherCAT communication protocols, thus transmiting it securely to cloud platform
- Cloud platform receives, stores, and processes the incoming data streams, enabling remote access for bridge owners, project partners, and stakeholders
- Real-time dashboards present live sensor readings, alert thresholds, and historical trends through a web-based interface
- Data security and redundancy ensured through standard industrial IoT best practices

The cloud infrastructure setup was completed during the early phase of WP1/WP2 and has been operational across all three pilot sites during the monitoring period. Real-time access to bridge data represents a significant upgrade over traditional periodic inspections, enabling condition-based rather than time-based maintenance strategies.

5. Digital Twin Solution

A **Digital Twin** was developed for each of the three pilot bridge sites, creating virtual representations that mirror the physical bridges in real time. The Digital Twin models integrate live sensor data feeds with structural models, allowing for continuous condition assessment, anomaly detection, and simulation of future deterioration scenarios.

Digital Twin Capabilities

- **Real-time synchronization** with sensor data streams from the cloud platform
- **Structural health visualization** — live status overlays on 3D bridge models
- **Anomaly detection** — automated alerts when sensor readings exceed defined thresholds
- **Predictive analytics** — modelling of deterioration trends to support maintenance planning
- **Stakeholder reporting** — accessible reports and dashboards for bridge owners and authorities

The solution was deployed and validated at three geographically distributed pilot sites across Central Europe, each representing a different bridge typology and operating environment.

6. Pilot Bridge Sites

6.1 IDA-KI Bridge — Germany

Partner: TU Dresden

The IDA-KI bridge is an openLAB bridge in Bautzen, Germany and was constructed as a full-scale research and validation structure within the IDA-KI project. It serves as an experimental platform for the systematic investigation of monitoring systems, damage assessment methods, and structural behaviour in prestressed concrete bridges. TU Dresden's proximity to this site enabled close integration of the novel leakage sensor foils and iterative refinement of the Data Transfer and Digital Twin systems. The bridge represents a typical Central European Road bridge subject to heavy traffic and seasonal moisture exposure.

6.2 Tomačevo Bridge – Slovenia

Partner: Cestel & ZAG

The Tomačevo bridge in Ljubljana, Slovenia, was the host site for the 30th Consortium Meeting and serves as a key demonstration site for the project. The Slovenian site provided valuable data on structural behaviour under the specific loading and environmental conditions of the Alpine region.

6.3 Sant'Ambrogio Bridge — Italy

Partner: SINA

The Sant'Ambrogio bridge in Italy represents the southernmost pilot site, providing data under specific climate conditions - moderately continental with Mediterranean influences. Its inclusion ensures the solution's applicability across diverse environmental contexts within Central Europe.