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The role of a load test in creating a bridge digital twin

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INTRODUCTION

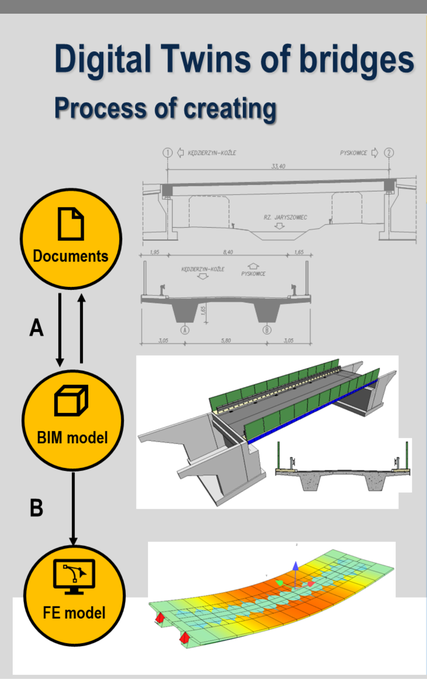
Digital Twins offer a major step beyond traditional BIM by enabling lifecycle management of bridges. However, in regions like Central and Eastern Europe, their potential is underused, with load tests often seen as formalities rather than opportunities for digital integration

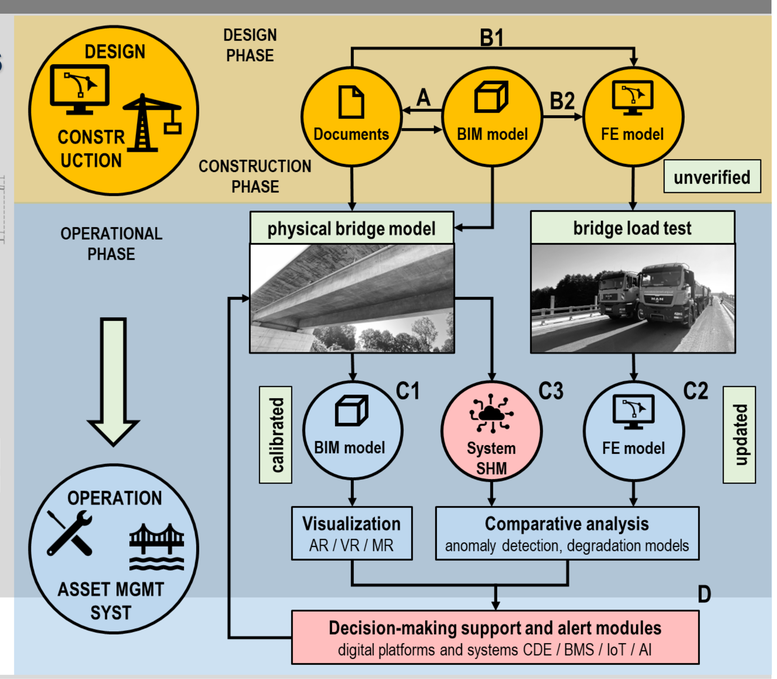
Bridge load tests are often underutilized, serving as mere formalities instead of key steps in creating accurate digital twins. Key stakeholders include infrastructure owners, bridge managers, engineers, and public authorities responsible for asset safety and lifecycle management

The research aims to establish a reliable method for creating bridge digital twins by integrating load test data with BIM and FE models. This approach is expected to enhance infrastructure management, improve safety assessments, and reduce maintenance costs

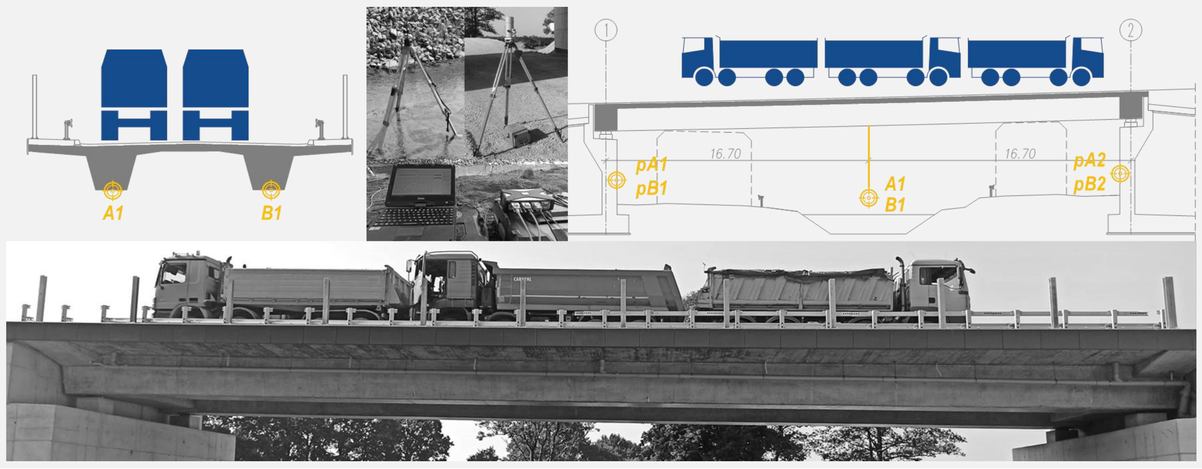
METHODOLOGY FOR CREATING A BRIDGE DT

The methodology for creating a bridge DT involves several integrated steps. It starts with building a detailed BIM model. This model accurately represents the bridge's geometry, material properties, construction elements, and their relationships, enriched with metadata and links to external databases. Simultaneously, a FE model is created, which captures the bridge's structural behavior under various loads and conditions. After construction, static and dynamic load tests are performed to validate and update the FE model, ensuring its accuracy by aligning simulations with real-world responses. Ideally, these two models are interconnected, enabling data exchange and synchronization between the physical characteristics and analytical simulations Once updated, the FE model is linked with the BIM model to form the digital twin. This twin is continuously refined using data from SHM systems, inspections, and maintenance records, supporting long-term performance monitoring and decision-making.





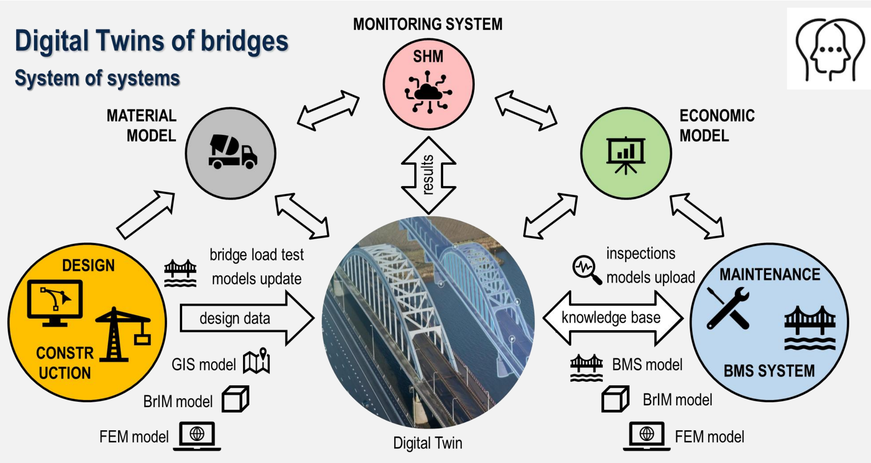
BRIDGE LOAD TESTS



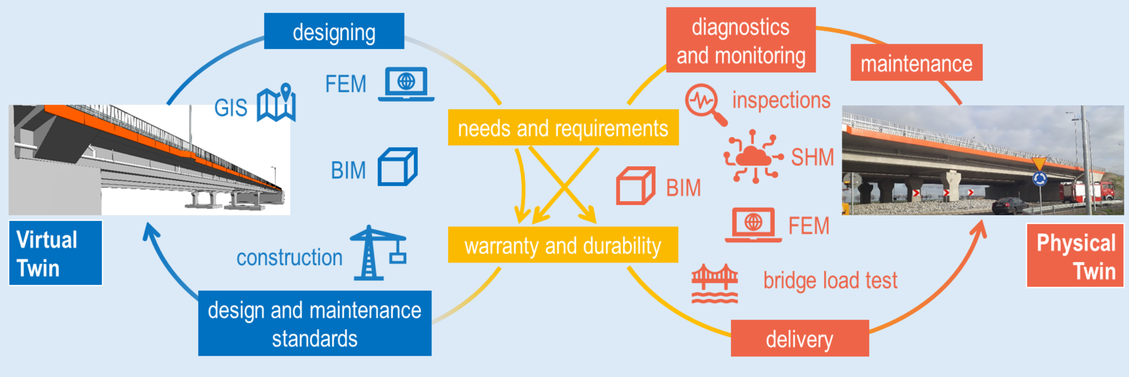
Bridge load tests are crucial for assessing how a structure behaves under real-life conditions. They involve applying static and dynamic loads - often using heavy vehicles - to measure key responses such as deflections, vibrations, and stiffness. These measurements are then compared with simulations from the FE model, allowing engineers to update and calibrate the model for greater accuracy. This process ensures that the digital representation of the bridge reflects its actual performance. Load tests help detect potential weaknesses and provide valuable data for ongoing maintenance and lifecycle management making them a foundational step in developing a bridge digital twin.

DIGITAL TWIN OF BRIDGE AS A COMPLEX SYSTEM

The digital twin of a bridge is not just a single model but a complex, evolving system composed of multiple interconnected elements. It integrates Building Information Modeling (BIM), Finite Element (FE) models, Geographic Information Systems (GIS), and Structural Health Monitoring (SHM) data to create a comprehensive digital replica of the physical structure. This system enables real-time and historical data to be analyzed together, supporting simulations, condition assessments, and maintenance planning. The digital twin continuously evolves by incorporating new data from inspections, repairs, environmental impacts, and material changes. As a result, it becomes a powerful tool for infrastructure owners and operators to manage bridges more effectively, optimize costs, ensure safety, and extend service life through informed decision-making.



CONCLUSION



In conclusion, the creation of a bridge digital twin offers a transformative approach to infrastructure management by linking physical structures with their dynamic digital counterparts. When supported by BIM, FE models, and load test data, the digital twin becomes a reliable and evolving tool for monitoring, analysis, and decision-making. It enhances safety, reduces maintenance costs, and extends the lifespan of bridges. To fully realize these benefits, it is essential to treat load tests and digital model updates as integral parts of the bridge lifecycle, not just formal requirements. Such an approach improves planning accuracy, helps prioritize maintenance, and supports budgeting by assessing long-term cost-effectiveness. Ultimately, digital twins contribute to extending the service life of bridges, enhancing user safety, and optimizing public infrastructure investments throughout the asset's entire lifecycle.