Infrastructure Monitoring with Digital Twin Technology: Lessons from the I-90 Homer M. Hadley Memorial Bridge

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What Makes Managing Modern Bridge Infrastructure So Challenging?

Aging Infrastructure

39% of U.S. bridges are already over 50 years old, exceeding their original design life [1].

Growing Demands

More than 42,000 bridges remain in poor condition, with an estimated $319 billion repair backlog [1].

Climate-Related Stresses

More frequent extreme weather events accelerate deterioration and increase uncertainty in asset performance [2].

Limited Funding & Resources

The U.S. still faces a $3.7 trillion infrastructure investment gap over the next decade despite recent federal investments [2].

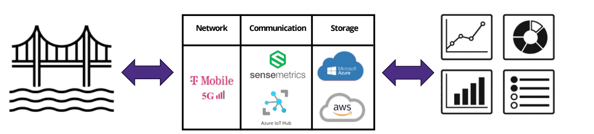
Reactive Decision Making

Most bridge inspections still rely on periodic inspections rather than continuous condition awareness [1].

A Promising Solution: Digital Twins for Infrastructure

What are Digital Twins

A digital twin of an asset is a fit-for-purpose and intelligent virtual representation of it synchronized at specific frequencies, with an existing or planned connection between the virtual and physical twin that may include analysis and the ability to actuate physical changes from the virtual twin [3].



Digital Twins Can

- Connect fragmented data
- Monitor infrastructure continuously
- Predict future performance
- Support better decisions

How Do You Make a Digital Twin?

1. Proposal Phase

The I-90 Homer M. Hadley Memorial Bridge was selected as the pilot project because of its unique floating-bridge design and the emerging operational challenges associated with carrying light-rail traffic.

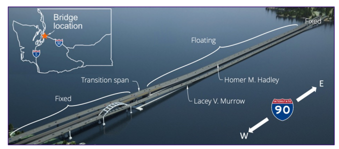


Fig 1. I-90 Homer M. Hadley Memorial Bridge (Courtesy: WSP)

Fig 2. I-90 Bridge Light Rail Test

2. Design Phase

The research team developed the system using commercially available, off-the-shelf products and deployed selected sensors based on end-user needs identified through stakeholder interviews. Sensors installed include GPS, a weather station, strain gauges, and water pressure sensors.

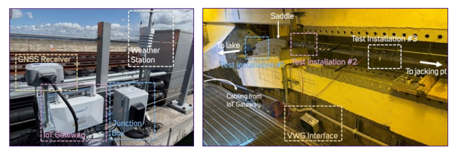


Fig 3. Installed Sensors on the Bridge

3. Operation Phase

The Bentley iTwin IoT platform serves as the primary user interface, enabling real-time sensor visualization, customizable dashboards, automated alerts, and report generation.

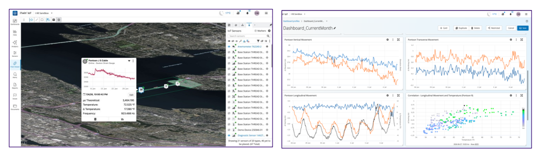
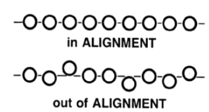


Fig 4. Bentley iTwin IoT Dashboard and the Sensor Data Visualization

Digital Twin Use Cases in Our Project

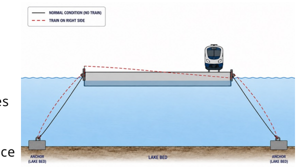
Bridge Pontoon Alignment

Unlike conventional bridges, floating bridges rely on anchor cables to restrain lateral movement and maintain structural stability. Bridge movement is continuously influenced by changing lake levels, seasonal variations, wind, waves, and traffic loads, causing cable forces to vary over time. Traditionally, engineers have relied on periodic visual inspections to assess cable conditions, providing only snapshots of bridge behavior. By integrating real-time pontoon position data with cable strain measurements, the digital twin enables continuous monitoring of the relationship between bridge movement and cable response, supporting early anomaly detection and more proactive maintenance decisions.



Anchor Cable Health Monitoring

Anchor cables are critical components of the floating bridge, providing the lateral restraint necessary to maintain structural stability. With the introduction of light rail service, understanding how train loading influences cable response has become increasingly important. The installed strain gauges collect high-frequency measurements that capture the cable response during each train pass-by. By correlating these measurements with pontoon movement and other operational data, the digital twin enables engineers to better understand cable behavior, identify abnormal responses, and support more proactive maintenance planning.



What's Next? Expanding Data Integration and Decision Intelligence

Phase 1 was supported by WSDOT to develop and evaluate a proof-of-concept digital twin for the I-90 Homer M. Hadley Memorial Bridge. Following the successful demonstration of its feasibility and operational value, Sound Transit committed to expanding the platform by integrating its own monitoring systems. Beginning in July 2026, Phase 2 will integrate cathodic protection, stray-current, and traction-power sensor systems.

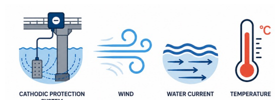
Level of Digital Twins

- Descriptive (what is happening?)
- Diagnostic (Why is it happening?)
- Predictive (what will happen?)
- Prescriptive (What should be done?)

We will strengthen the digital twin's descriptive capabilities while beginning to develop its diagnostic capabilities.

Exploring What Factors Influence Cathodic Protection Performance?

Early discussions with track bridge and electrical engineers suggested that cathodic protection performance may be influenced by environmental conditions, including temperature and wind speed. A key objective of the digital twin is to investigate and validate these potential relationships.



[1] Policy statement 208—Bridge safety. (2024). Retrieved July 3, 2026, from https://www.asce.org/advocacy/policy-statements/ps208---bridge-safety
[2] American Society of Civil Engineers. (2025). 2025 Report Card for America's Infrastructure. https://infrastructurereportcard.org/
[3] Ghorbani, Z., & Messner, J. (2024). A categorical approach for defining digital twins in the AECO industry. Journal of Information Technology in Construction, 29, 198–218. https://doi.org/10.36680/j.itcon.2024.010

Sound Transit; eScience Institute; Challenge Seattle; WSDOT; ARC UTC IBT; U.S. Department of Transportation Federal Highway Administration; Sierra Wireless is now Semtech; STIC; WSP; Microsoft Azure; T Mobile; COMPASS; Bentley