Towards the Smart Railway:

Interactive Wireless Smart Sensors for Structural Health Monitoring of Railroad Bridges

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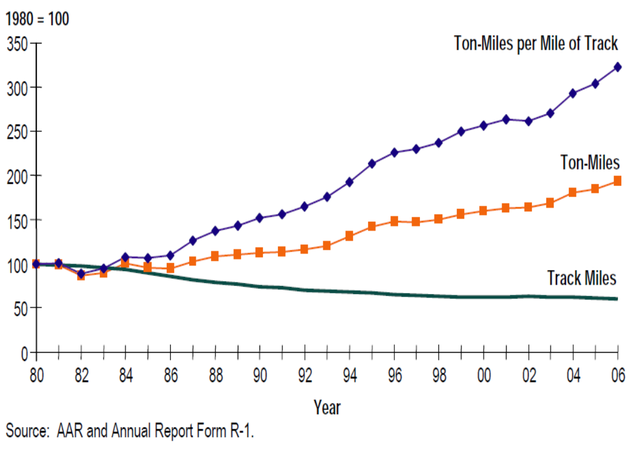
Background and Motivation

- **Railways in the U.S are old**: Over 40 % of privately owned railway tracks are over 100 years old (GAO, 2007)
- **Railroad Bridges are critical component**: One railroad bridge within every 1.4 miles of a railway.
- **Increased demands on freight trains**: Growing demand for freight transportation is also pressing the capacity of railway system (increased over three times).
- **Catastrophic consequence of a railroad bridge failure**: One bridge failure incurred $26 Million of damage to railroad facilities, cars, and locomotive (approximately 18% of the annual damage loss).
- **New Government announcement for High Speed Railways**: The intercity plan for expansion of railway networks, as well as upgrading of exiting railways to support higher speed passenger trains.
- **New FRA regulation standards to inspect railroad bridges**: New monitoring strategies to ensure structural integrity of railroad bridges

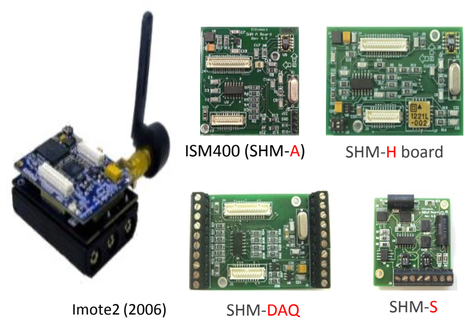


Source: AAR and Annual Report Form R-1.


Mississippi River, AL., Amtrak accident (barge impact) (1993)

Current Technology

- **Existing regulations on inspection of railroad bridges:** Rely on periodic visual inspection.
- **CPS-based structural health monitoring (SHM)**: Recent advances in low-cost wireless sensing and data acquisition technology have made it possible to instrument large civil structure with dense array of wireless smart sensors (WSS).

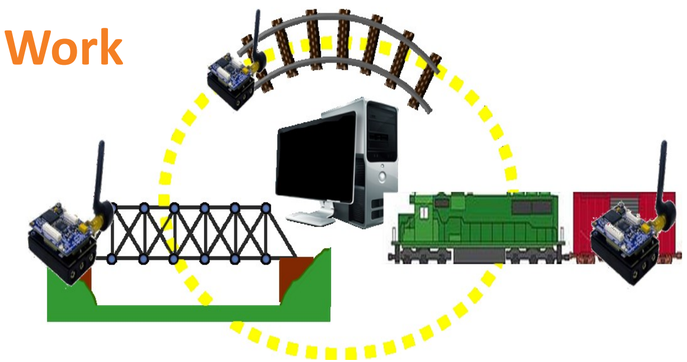


- **Existing applications on CPS-based SHM system:** A limited number of full-scale deployments exist, focused mainly on highway bridges (Due to hardware and software limitation).
- **Lack of systematic CPS-based SHM system** : A sustainable system yielding user-friendly information from real-time interaction between the WSSs on a structure and railway network.


Jindo Bridge, Korea, full-scale SHM with 113 WSSs (2008 – 2012)

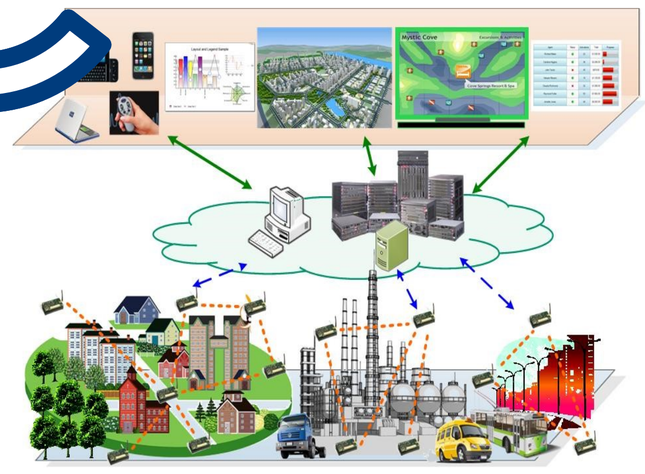

Calumet Bridge, IL., Railroad Bridge SHM with multi-metric WSSs (2013)

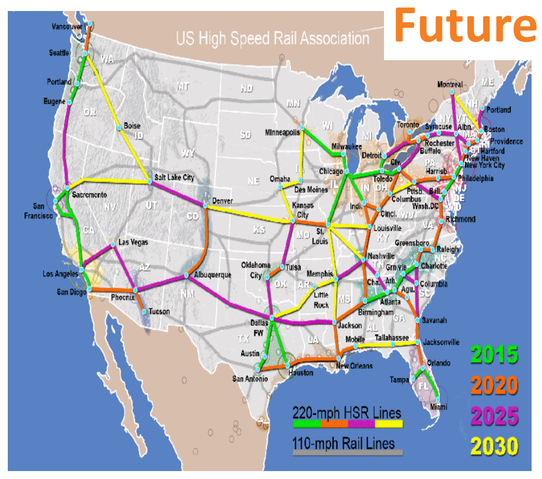
Proposed Work



- **Objective:** Develop CPS envisioned SHM system on each components of railroad bridges to establish early warning and detection of damage
- **Train WSS network:** Self characterize its load distribution, speed, and geographical information using a limited number of WSSs
- **Bridge WSS network:** WSS at the key locations estimates expected behavior of upcoming train loads.
- **Track WSS system:** WSS at key location diagnose its deterioration and acknowledge the maintenance considering environmental effects.
- **WSS system**: Provide real-time computing and communication among three sub-networks (train, bridge, and track). Require reliable, sustainable and cost-effective design.
- **Target Scenario**:
  1. Train informs the bridge of its characteristics beforehand.
  2. Bridge estimates its health through real-time computing using the train information and the interactions and inform the anomalies
  3. WSS system: Control the traffic, close the bridge, request the bridge owner for replacement of bridge elements, or redistribute the train loads

Future





- **The smart railway system impact on CPS**: interrelating infrastructure, smart systems, and users/operators.
- **Expected outcomes**:
  1. Optimize and redistribute the limited sources with increased safety.
  2. Bridge retrofit focusing on the elements with the problems, instead of entire bridge rehabilitation.
  3. Extend track life with increased serviceability
  4. Trains at faster speeds with increased safely

- Smart sensor technologies will evolve to offer required information in reliable, robust and cost-effective ways.
- The users will benefit from increased safety, fast services from unified railway network.
- The new railway systems equipped with CPS will further benefit the design of dynamic living of next era.

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