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Research Paper**Sustainable smart city highway bridge-2****A.S mahinge****Pranali dattatray Khandar****Sanket Arun Vitonde****Chinmay Ravindra Wadhai****Anjali Vilas Mhala****Riyaz Beniwale**

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Abstract

Rapid urbanization, increasing traffic demand, climate change, and aging transportation infrastructure have created a need for highway bridges that are safer, more durable, environmentally responsible, and technologically intelligent. Conventional bridges are generally designed primarily for structural strength and serviceability, while modern smart-city infrastructure requires integration of transportation management, structural health monitoring, renewable energy, digital technologies, and life-cycle sustainability.

This research proposes an integrated framework for a Sustainable Smart City Highway Bridge (SSCHB). The proposed concept combines conventional structural systems with Internet of Things (IoT) sensors, Structural Health Monitoring (SHM), Artificial Intelligence (AI), Digital Twin technology, Intelligent Transportation Systems (ITS), renewable energy, energy-efficient lighting, sustainable construction materials, rainwater management, and predictive maintenance. The objective is to improve structural safety, traffic efficiency, environmental performance, resilience, and life-cycle cost.

Recent research indicates that intelligent transportation systems can improve traffic efficiency, safety, and environmental performance through real-time sensing, communication, traffic management, and predictive technologies. DOI Similarly, bridge-monitoring research demonstrates the potential of sensor networks to provide continuous information about structural behavior and support predictive maintenance. Federal Highway Administration+1

The proposed framework adopts a life-cycle approach in which the bridge is considered not only as a physical structure but also as an intelligent infrastructure asset connected to the wider smart-city ecosystem. The research concludes that integrating sustainability with digital monitoring and intelligent transportation can transform conventional highway bridges into resilient, low-carbon and data-driven infrastructure.

Keywords: Sustainable bridge, smart city, highway bridge, structural health monitoring, IoT, artificial intelligence, digital twin, intelligent transportation system, renewable energy, predictive maintenance, life-cycle assessment.

Expected Benefits

The proposed Sustainable Smart City Highway Bridge can provide the following benefits.

Structural Benefits

- Continuous structural monitoring.
- Early detection of deterioration.
- Improved reliability.
- Improved maintenance planning.
- Extended service life.

Environmental Benefits

Safety is a central component of the sustainable smart bridge.

The proposed system can detect:

1. Detect the incident.
2. Confirm the event using multiple sensors.
3. Alert the traffic-control center.
4. Notify emergency services.
5. Display warnings to road users.
6. Control affected lanes.
7. Recommend alternative routes.

This reduces emergency-response time and potentially reduces secondary accidents.

- Reduced embodied carbon.
- Reduced operational energy consumption.
- Renewable-energy generation.
- Reduced traffic emissions.
- Improved resource efficiency.

Transportation Benefits

- Reduced congestion.
- Faster incident detection.
- Better traffic management.
- Improved travel-time reliability.
- Integration with connected vehicles.

Economic Benefits

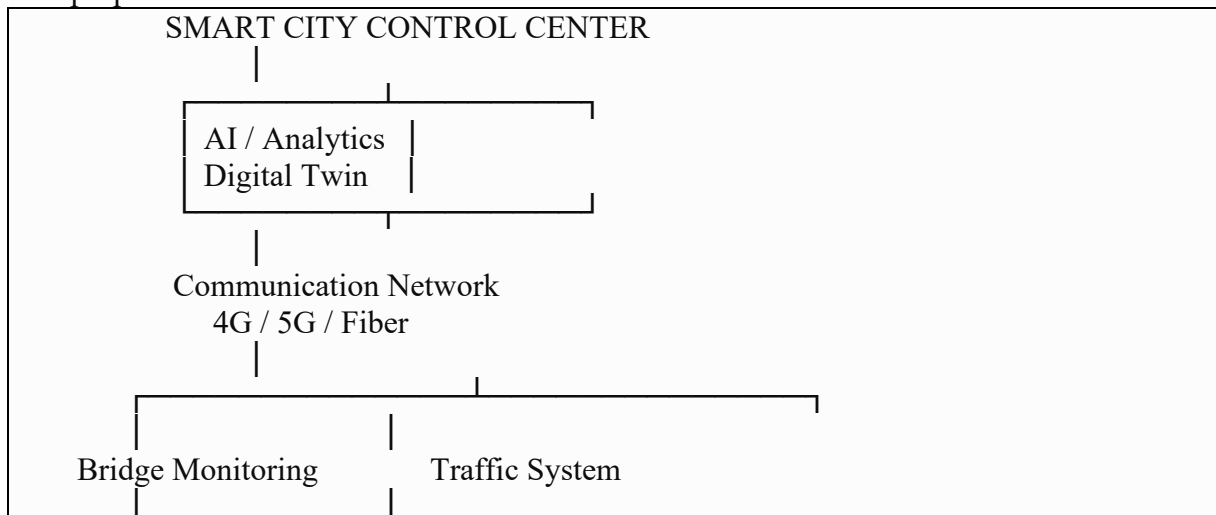
- Predictive rather than reactive maintenance.
- Reduced emergency repair costs.
- Reduced inspection requirements for selected tasks.
- Better asset-management decisions.
- Potentially longer service life.

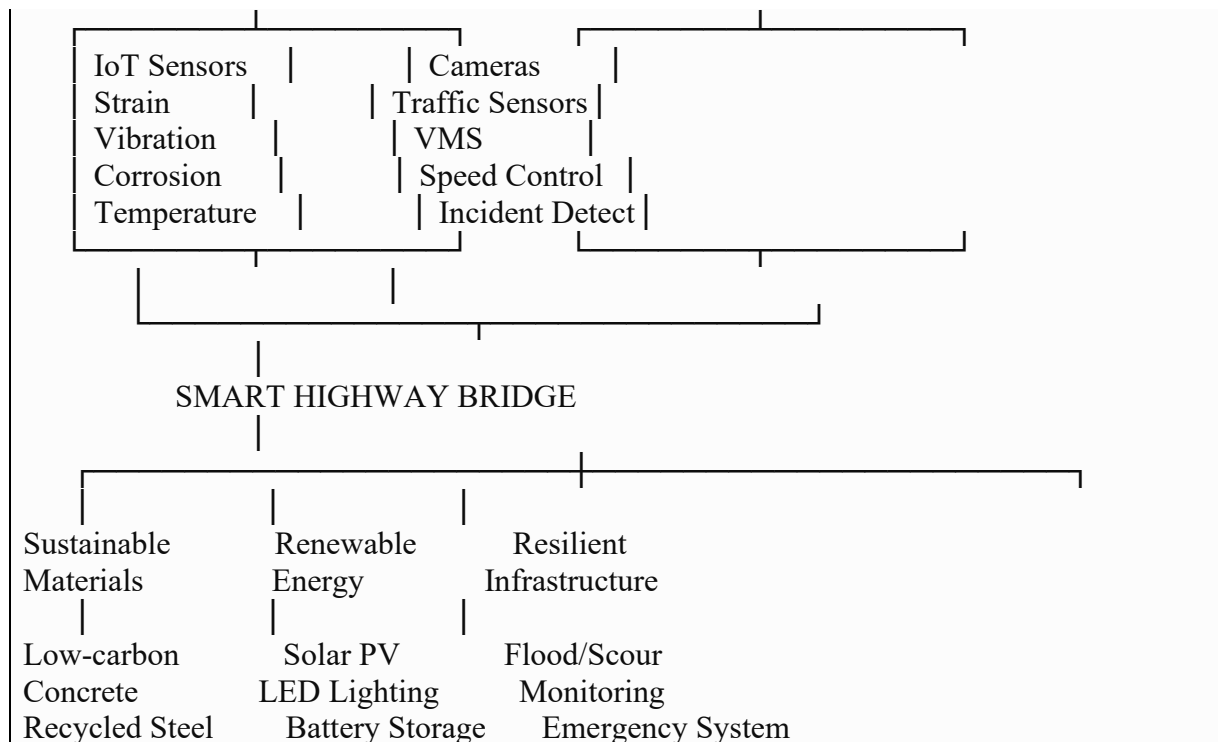
Social Benefits

- Improved road safety.
- Faster emergency response.
- Better accessibility.
- Improved reliability of urban transportation.
- Increased public confidence in infrastructure.

Proposed Sustainable Smart Bridge Architecture

The proposed architecture can be summarized as follows:





Safety and Emergency Management

Safety is a central component of the sustainable smart bridge.

The proposed system can detect:

- Vehicle collisions.
- Stopped vehicles.
- Wrong-way driving.
- Fire or smoke.
- Structural abnormalities.
- Flood conditions.
- Dangerous wind conditions.

An emergency-management system can then:

1. Detect the incident.
2. Confirm the event using multiple sensors.
3. Alert the traffic-control center.
4. Notify emergency services.
5. Display warnings to road users.
6. Control affected lanes.
7. Recommend alternative routes.

Digital Twin of the Highway Bridge

A Digital Twin is a continuously updated digital representation of the physical bridge.

The proposed Digital Twin would contain:

- BIM model.
- Structural geometry.
- Material properties.
- Construction records.
- Inspection history.
- Sensor data.
- Traffic data.
- Environmental conditions.

- Maintenance history.
- Structural-analysis models.

Real-time sensor information can be compared with the expected behavior of the digital model.

For example:

Physical	bridge:
Measured vibration = 4.2 mm/s	
Digital	model:
Expected vibration = 2.8–3.5 mm/s	
AI	system:

Potential abnormal behavior → generate inspection alert.

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