The Future Interstate Study: Materials of Construction and their Impact

Narayanan Neithalath

Professor
School of Sustainable Engineering and the Built Environment
Arizona State University, Tempe, AZ

Narayanan.Neithalath@asu.edu

Ira A. Fulton Schools of Engineering
ARIZONA STATE UNIVERSITY

U.S. Transportation Infrastructure

Current State of U.S Infrastructure

Highway Bridges

260 M daily trips

13.1% Structurally Deficient

13.6% Functionally Obsolete

D+ Grade by ASCE

Roads

32 % Poor

Bridges - California

60 M daily trips

27 % Structurally deficient/ functionally obsolete

Bridges - Arizona

6% worse off since 2011

2 M daily trips on structurally deficient bridges

Future Impact

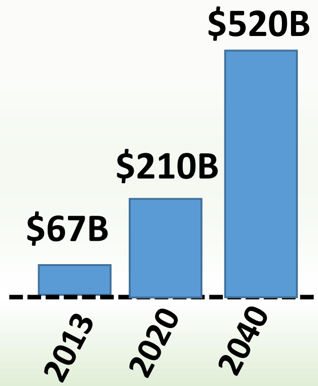
Next 30 Years

$37 Trillion

390 M

20% Population Growth

115% Economy Growth



Economic impact of deterioration

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N. Neithalath, Presented at the panel on Future Interstate Study, Austin TX, September 12, 2017

Urban Mobility and Infrastructure

- In the past 20 years, Urban vehicle miles of travel (VMT) has increased by about 80 percent while highway lane mile increases have been only about 4 percent, with little of that on the Interstate
- The amount of traffic experiencing congested conditions in the peak travel periods (three hours in the morning and three hours in the afternoon) in the Nation's largest urban areas has doubled in the last 25 years from 32 percent to over 67 percent in 2003.
- Currently congestion is causing nearly 4 billion hours of annual travel delay and over 2.3 billion gallons of wasted fuel.
- The nation is already paying nearly $170 billion per year for congestion and unreliability; the cost is growing at more than twice the rate of growth of the overall economy [USDOT Chief Economist].

Projected Needs

- Needed investment of $1.7 trillion over the next ten years to maintain, improve and expand our interstate system [Conditions and Performance Report, published annually by FHWA].
- As per AASHTO and ASCE, $2 trillion, including railroads

Table 1: Present and Future Interstate Systems

Present and Future Interstate Systems						
	Interstate			Non-Interstate NHS		
	Miles	Lane miles	VMT	Miles	Lane Miles	VMT
Existing system	47k	212k	24%	115	347K	20 %
Future Interstate	62K	385k	37%	100*	289*	10%*

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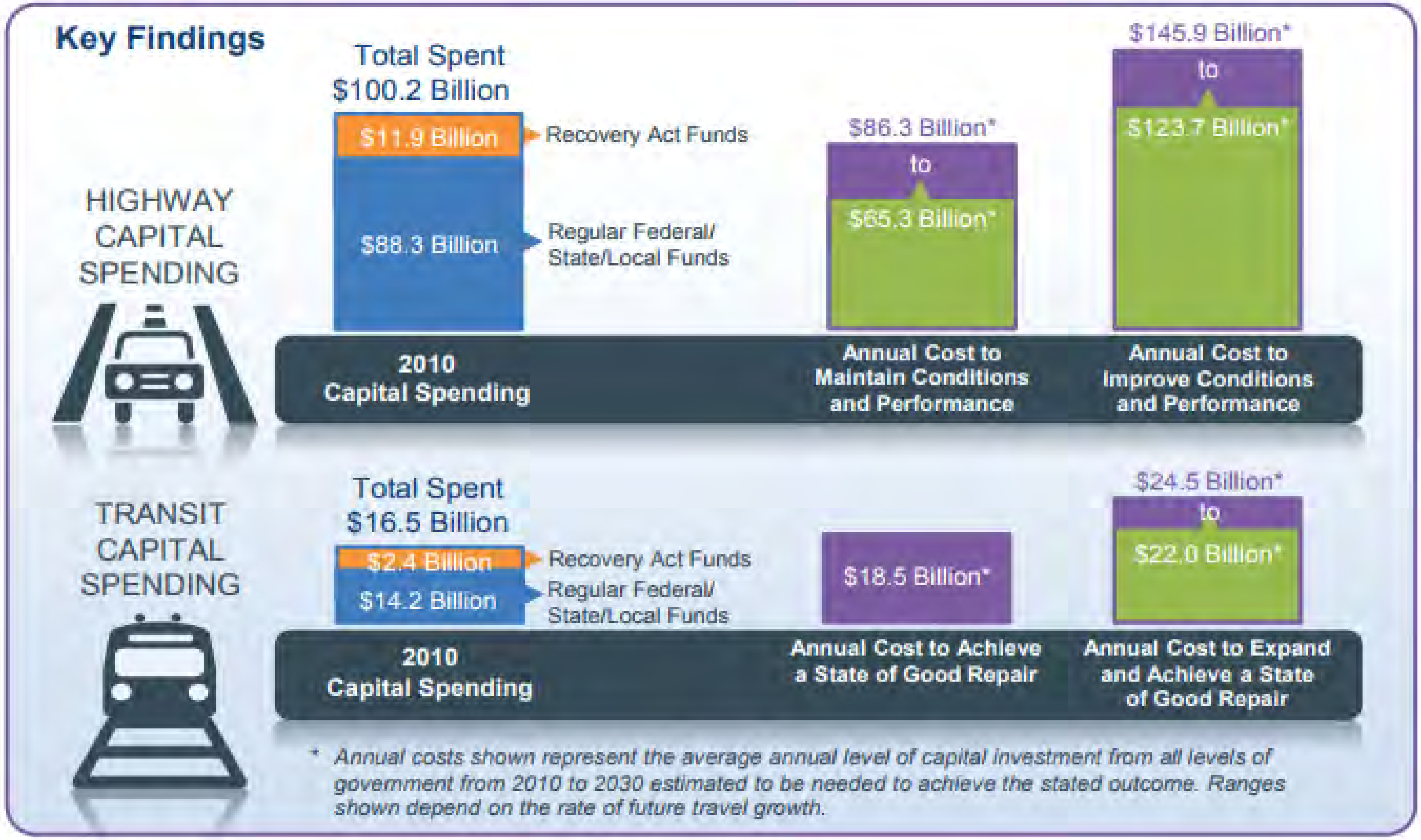
Projected Needs



2013 Status of the Nation's Highways, Bridges, and Transit: REPORT TO CONGRESS Conditions & Performance

Specific Materials/Design Comments

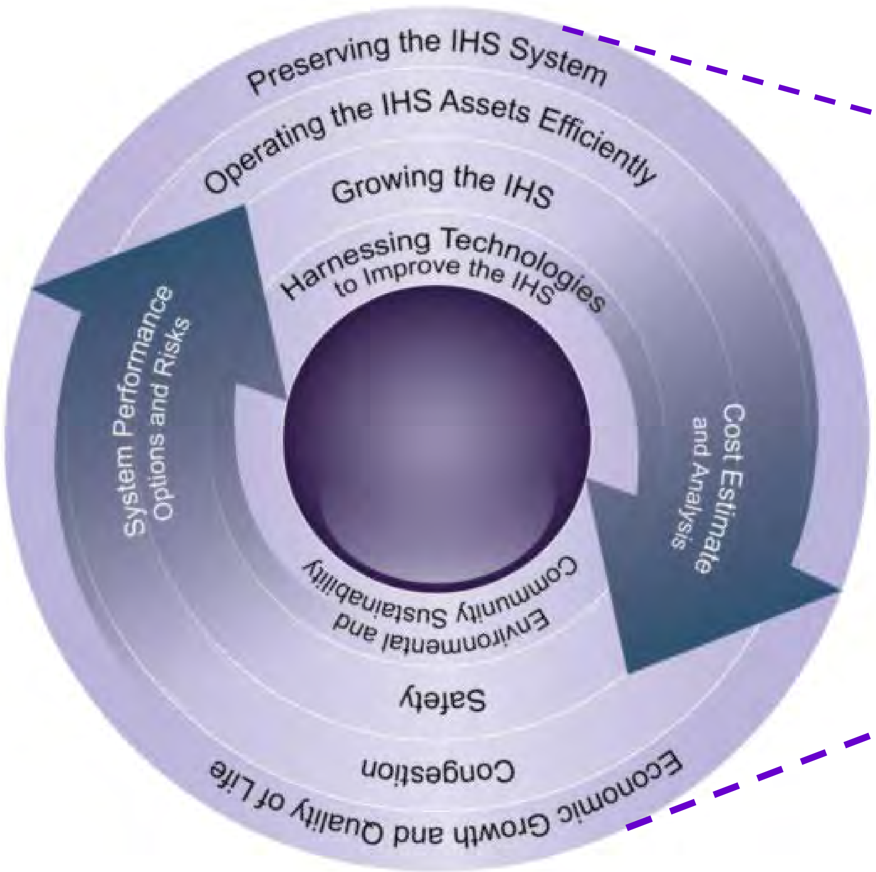
- Conservation of materials and energy by applying asset management principles that improve durability and minimize the frequency of maintenance and repairs [FUTURE OPTIONS FOR THE NATIONAL SYSTEM OF INTERSTATE AND DEFENSE HIGHWAYS TASK 10 FINAL REPORT (NCHRP and The National Academies)]
- ….features that would take advantage of technological capabilities to address modern standards of construction, maintenance, and operations, for purposes of safety, and system management, taking into further consideration system performance and cost [SEC. 6021. FUTURE INTERSTATE STUDY.]

Specific Materials/Design Comments

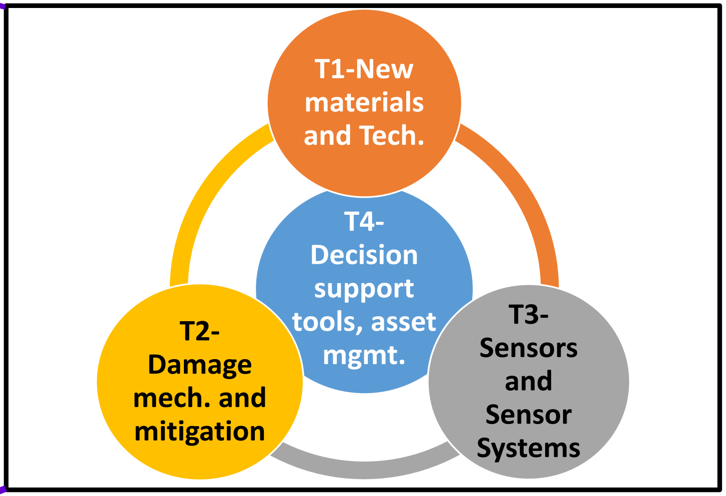
- Advanced design and life cycle construction involving long-life cycle pavement, rapid setting materials and high speed construction techniques will minimize traffic disruptions and provide long term savings
- Both the existing interstate and all improvements will incorporate the best available technology and procedures in two key areas: Advanced design and life cycle construction.
- The future Interstate will embody significant advances in design configuration, pavement and construction technology. <u>The impact of long-life cycle pavement, rapid setting materials and high-speed construction techniques will minimize traffic disruptions due to both initial construction and preservation cycles, and will provide cost-effective approaches.</u> Context sensitivity in design will also play a key role—not just in Interstate expansion, but also in reconstruction of the current Interstate, as it reaches the end of its useful life that can be extended through conventional 3-R strategies

A Robust and Resilient Infrastructure

The BIG picture



Engineer's perspective



Innovations in Materials for Construction

- New materials, systems, and sensing tools for pavements and bridges that will improve their design, performance and management – thereby extending their service-life, in spite of the damaging influences of traffic and climate
- An effort like Future Interstate can catalyze a number of inventions and innovations in this field
  - Economic impact
  - Environmental impact

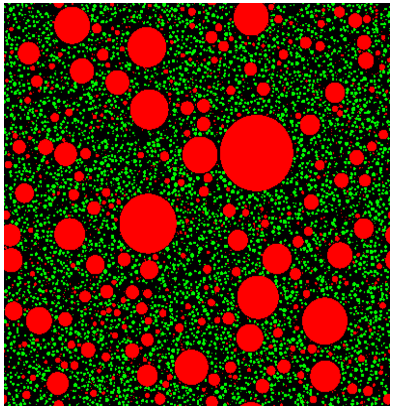
Extending Service Life

- New materials – stronger, tougher, built faster
  - Ultra high performance concrete
  - Self-diagnosing structural components
  - Innovations in steel
- Crack control strategies
  - Materials and design innovations
- Corrosion mitigation and management
  - Coatings and treatments
  - Advances in novel corrosion resistant alloys for construction

Materials Innovations – Stronger/Tougher

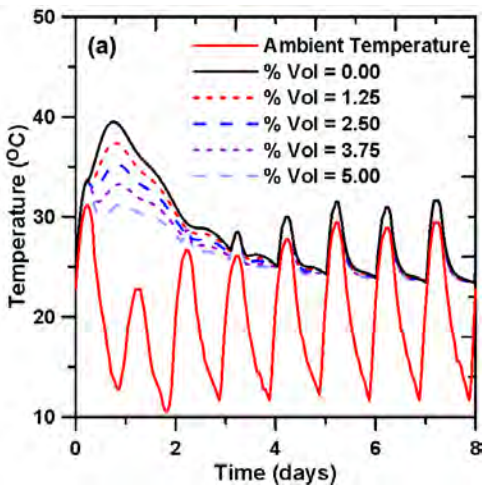
- Ultra-High Performance Concrete
  - Develop economical designs for concrete with very high strengths and other desirable properties

  - Necessary to move away from traditional approaches in selecting raw materials
  - Fiber reinforced systems for ductility



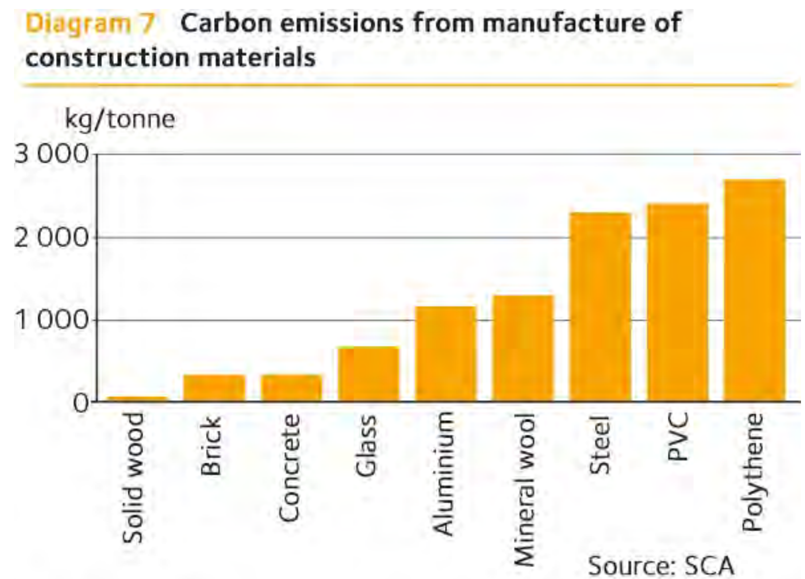
Materials Innovations – Crack Resistance

- Strategies for more active crack control in concrete (not at the rebar level, but at a materials level)
  - Better mixture proportioning
  - Controlling temperature through heat sinks in the material – allowing for phase transitions within
  - Reduce pavement/bridge deck temperature and fluctuations



Materials Innovations - Sustainability

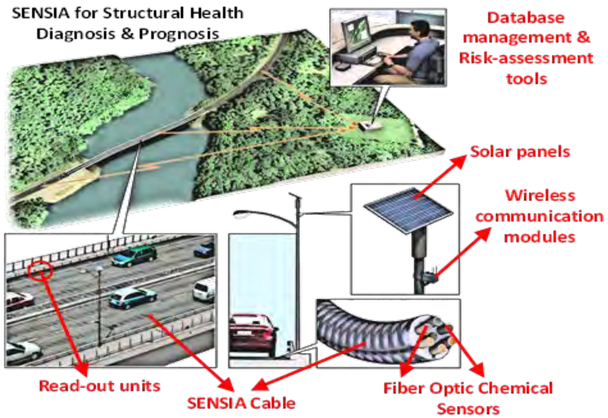
- Resource conservation and recycling
- Inventory of available resources (considering the shift in conventional sources of sustainable materials – e.g., shift in fuel mix for energy production)

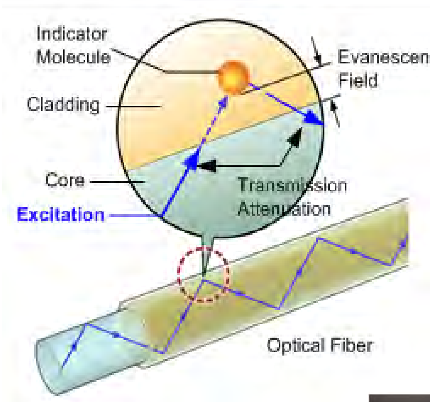


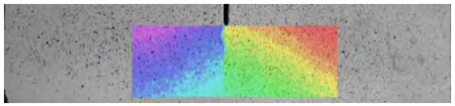
The values above may vary depending on numerous factors, including energy type, transport and production methods. A Life Cycle Analysis (LCA) usually compares functional units such as kg/m2 floor area in a floor structure. Carbon storage in wood is not reported in this diagram.

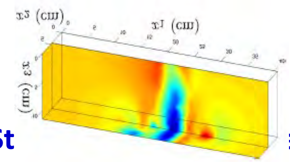
Self Diagnosing Structures

- Robust monitoring systems with real-time feedback for transportation infrastructure
- High fidelity sensor systems coupled with big data
- Off-the-shelf sensors for displacements, strain etc. provide real-time data through wireless messaging, screened data implemented into high fidelity models for performance states, for structural safety and performance









Advances in Structural Design

- Advances in both new design and strengthening and retrofitting designs
- Designs incorporating principles of sustainability and resilience
- Designs that can take advantage of very high strength materials
- Shape and size optimization
- Multi-use transportation structures

Corrosion resistant materials

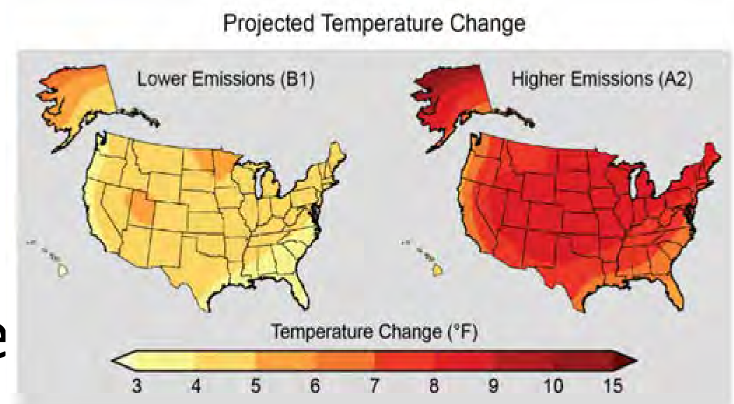
- Corrosion of steel bridges costs the nation an estimated $500 million on an annual basis (FHWA)
- Alloying to improve the weather ability of steel
  - E.g. modifying ASTM A710 Grade B steel by adding Ti, Al, P etc. which are not usually found in steels
- Stainless steel in infrastructure
  - Macau, China: River delta crossing
  - Duplex stainless steel in bridge

Coatings and Surface Treatments

- Corrosion of steel bridges costs the nation an estimated $500 million on an annual basis (FHWA)
- Need for coatings compatible with the substrate
- An interdisciplinary area – electro-chemistry, materials science, civil engineering, processing

Future Interstate and Climate Change

- Climate change is altering how transportation systems will need to be planned, designed, operated, and maintained
- Climate change impacts concrete structures by increasing rates of deterioration
- New design models for carbonation and corrosion, new service-life extending strategies



Future Interstate and Climate Change

- Increasing severe weather events
- Design and construction of interstate along coastal areas to account for this
- Facilitate fast and efficient movement of people away from severe events such as hurricanes
- Design to mitigate early flooding

Summary

- Advances in materials are being brought to the marketplace
- Life cycle approach to material selection and design for future interstate infrastructure
- Long life structures a must
- Adaptability to extreme events
- Design timeframes as well as design capacity require careful consideration
  - 50 years vs. 100 years life
  - Projected capacity increase over time