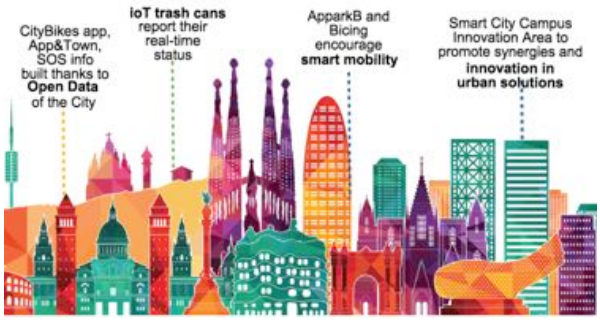
Vision for an Integrated and Active Digital Pavement Management System

Bill Buttlar
Professor and Glen Barton Chair in Flexible Pavements
University of Missouri-Columbia

What is a 'Smart City?'

"A smart city is an urban development vision to integrate multiple information and communication technology (ICT) solutions in a secure fashion to manage a city's asset, including: schools, libraries, transportation systems, hospitals, power plants, water supply networks, waste management, law enforcement, and other community services.

http://www.wsj.com/articles/singapore-is-taking-the-smart-city-to-a-whole-new-level-1461550026



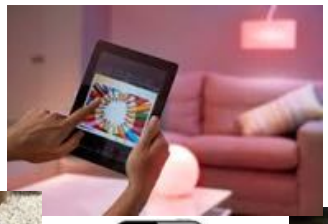
http://www.barcinno.com/smart-city-barcelona/

The goal of building a smart city is to improve quality of life by **using technology to improve the efficiency of services and meet residents' needs**. ICT allows city officials to interact directly with the community and the city infrastructure and to monitor what is happening in the city, how the city is evolving, and how to **enable a better quality of life**."

en.wikipedia.org/wiki/Smart_city

What is a 'Smart Service System?'

Service systems are socio-technical configurations of people, technologies, organizations, and information [1] designed to create value by fulfilling the needs of those participating in the system….




A ***"smart" service system*** is a system that amplifies or augments human capabilities [2] to identify, learn, adapt, monitor and make decisions. The system utilizes data received, transmitted, or processed in a timely manner, thus improving its response to future situations. These capabilities are the result of the incorporation of technologies for sensing, actuation, coordination, communication, control, etc.

[1] Spohrer, J., Maglio, P., Bailey, J., Gruhl, D. (2007). Steps towards a science of service systems. Computer 40(1):71-77. doi:10.1109/MC.2007.33

[2] Ng, I. (2015). The Internet of Everything and the Future of Service. Speech, 2015 Frontiers in Service Conf, San Jose, CA. http://hubofallthings.com/hat-in-the-usa/

Motivation Towards Smarter Ways to Monitor and Manage Pavements

Expensive and infrequent assessment

Rough pavements = more environmental harm

User delay, safety, low-tech/blue-collar image problem

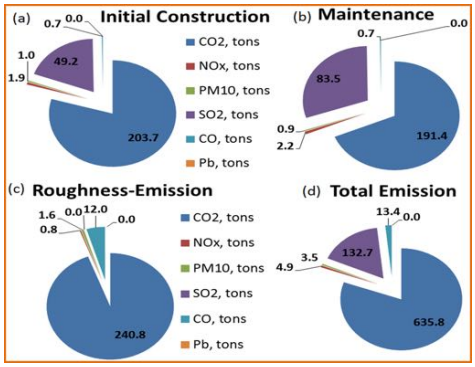
Potholes develop quickly; very damaging

Technological disruption will happen; … our community should lead it

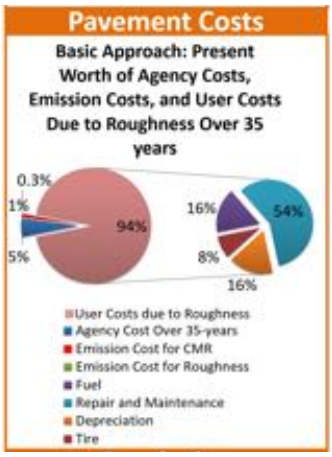
Dangerous and inefficient field data collection; disparate data sources

Return-on-Investment for Keeping Pavements Smooth

48-to-1 Return on Investment for Smoothening Rough Pavement!!!



Life-Cycle Analysis

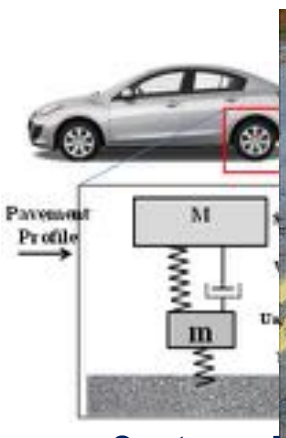


Islam, M.S., and W.G.Buttlar, "Effect of Pavement Roughness on User Costs," *Journal of the Transportation Research Board*, Vol 2285, Issue 1, pp. 47-55, 2012.

Islam, M.S., and W.G. Buttlar, "Assessment of Emission Costs due to Maintenance and Rehabilitations to Reduce Pavement Roughness," *Journal of the Transportation Research Board*, Issue: 13-5084, 2013.

Pavement Roughness

- Defined in engineering practice as surface unevenness which adversely affects ride comfort
- Expressed by a numerical scale called the International Roughness Index (IRI)



Quarter-car Model

Inertial Profiler

Roughness Capture App

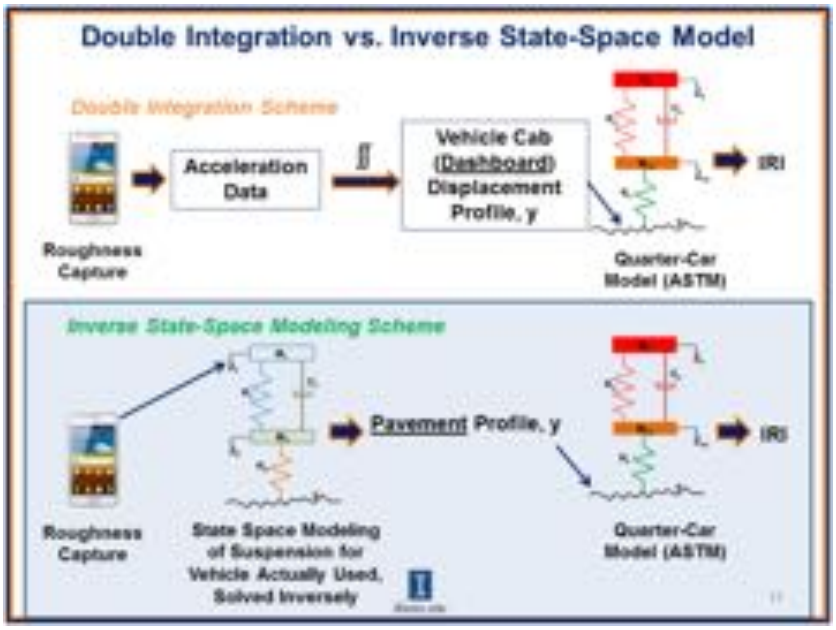
- Pavement surface irregularities causes the vehicle wheels to move up and down with respect to the road surface, causing the vehicle cab to accelerate (although cab movement is dampened by suspension)
- "Roughness Capture" has been used to collect vertical acceleration data in the vehicle cab - It is hypothesized that vehicle cab acceleration measured with smart phones can be combined with vehicle dynamics models to arrive at accurate measures of pavement IRI

(a) Cellphone App Capturing Vertical Acceleration

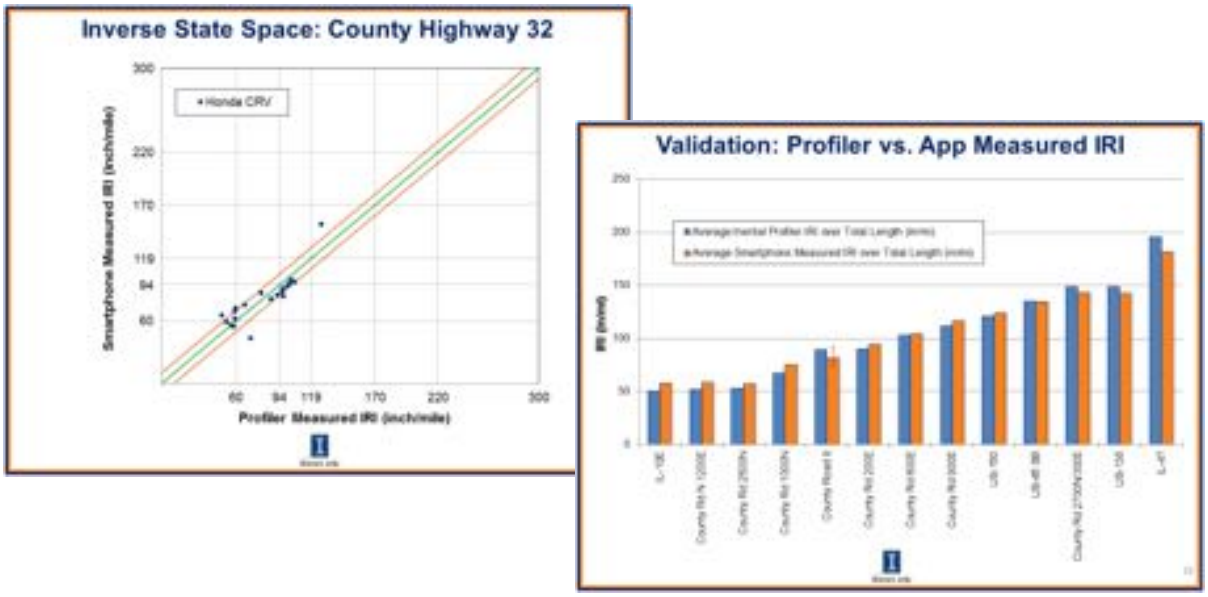
(b) Roughness Capture Interface

(c) Acceleration Data Capturing

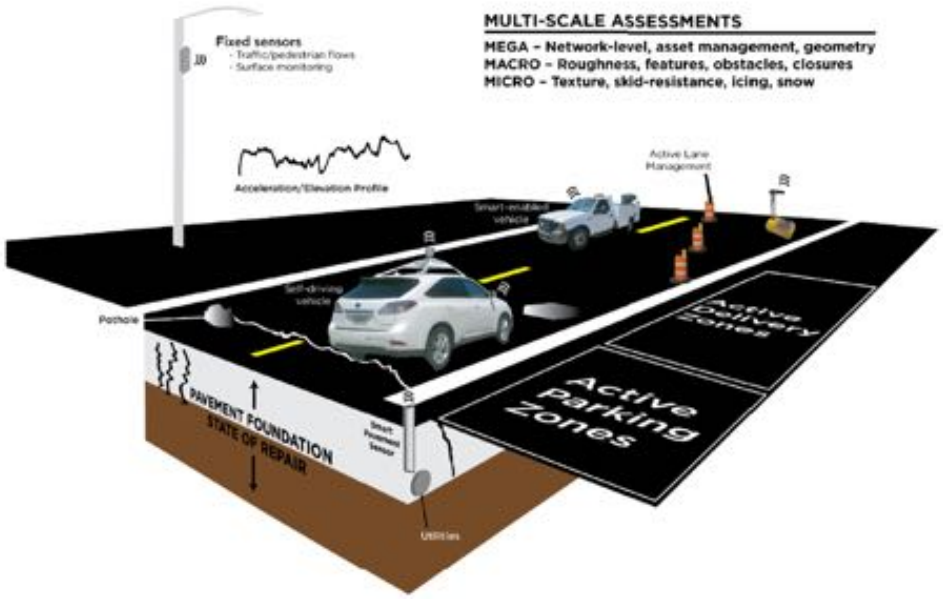
Roughness Capture App



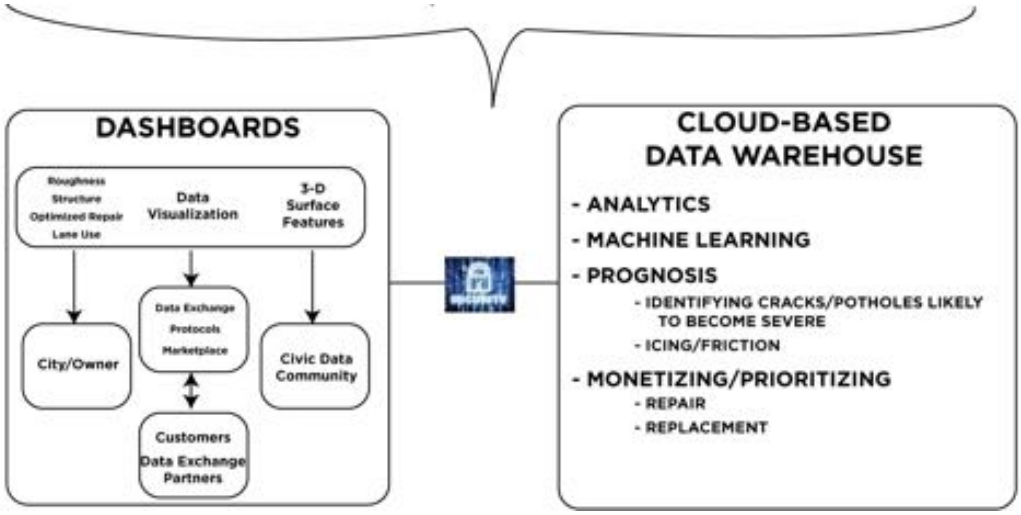
Roughness Capture App



Vision: Active Digital Asset Management System (1/2)



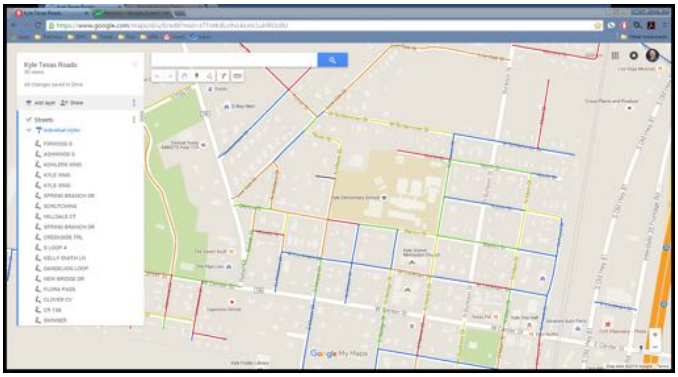
Vision: Active Digital Asset Management System (2/2)



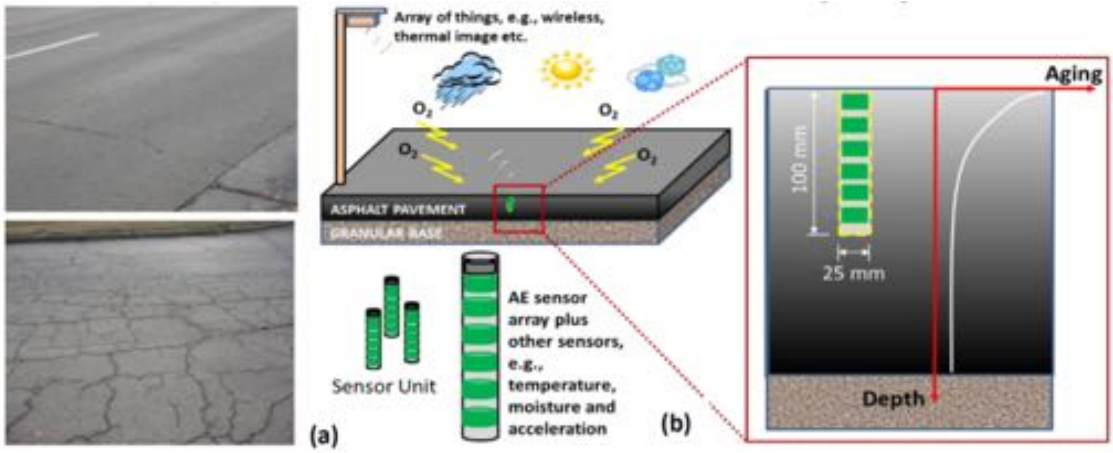
Imagine a City Where…

Transportation engineers use PCs, tablets and smartphones to collect and view roadway information in an intuitive, graphical format, anywhere, anytime:

- To view roughness/feature 'hot spots' (potholes, blowups…) in ***real time*** from varied data sources (acceleration from fleet vehicles and apps, image feeds, 311 reports…), to dispatch maintenance crews, and to assess/monitor road repairs.
- To view data geographically and temporally, i.e., similar to online weather maps, where pavement condition can be scrolled between past-present-future, where future condition is predicted using an ever-evolving, intelligent pavement prognosis system fueled by data fusion, advanced analytics and machine learning.



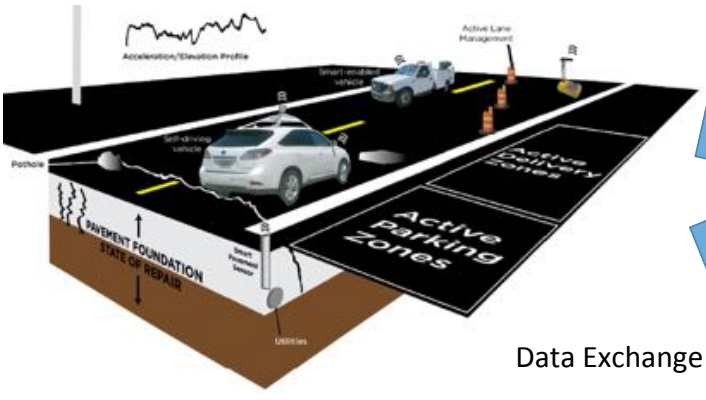
Smart Instruments



…Imagine a City Where…

Auto makers and navigation apps can access 3D roadway profile and feature data, and purchase/exchange data regarding precise pavement geometry and profile, roughness features and obstacles, lane closures, and dynamically-assigned parking and loading zone locations

- Navigation-aided and autonomous vehicles can then safely navigate around rough routes, dangerous/damaging pavement features, and request/reserve special digital-only lanes, parking, and loading zones in urban centers



Data Exchange Opportunities

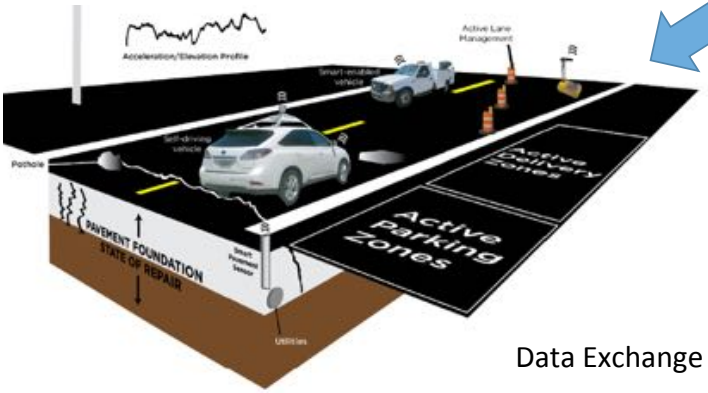
Smart Vehicle

Self-Driving Vehicle

…Imagine a City Where…

Auto makers and navigation apps can access 3D roadway profile and feature data, and purchase/exchange data regarding precise pavement geometry and profile, roughness features and obstacles, lane closures, and dynamically-assigned parking and loading zone locations

- Navigation-aided and autonomous vehicles can then safely navigate around rough routes, dangerous/damaging pavement features, and request/reserve special digital-only lanes, parking, and loading zones in urban centers



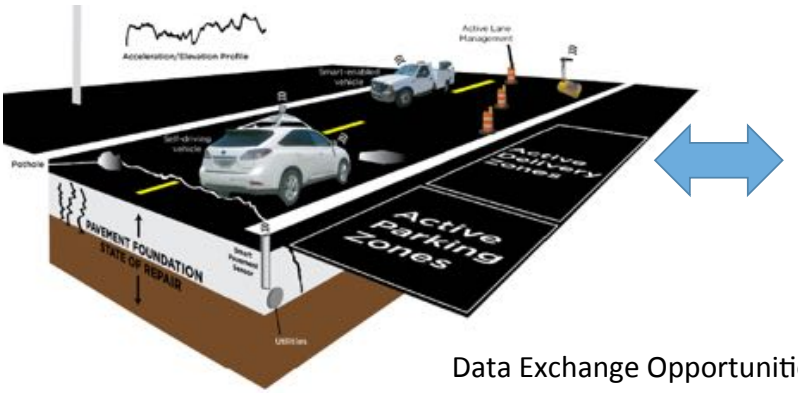
Recent software upgrade in Tesla Model S gives it a "location-based air suspension," allowing it to "remember" potholes, rough routes, etc. It also allows the car to automatically re-adjust as required to minimize damage to the vehicle.

Data Exchange Opportunities

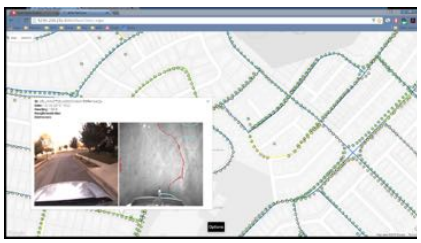
…Imagine a City Where…

Transportation engineering firms can lower the cost of pavement evaluation and management, by:

- Using the smart pavement service system as a complement to their existing pavement assessment and management systems.
- Exchanging high-resolution and high-accuracy pavement profile and feature data in the digital marketplace for access to high-volume, multi-source data feeds and pavement condition prognosis tools. This will also enable calibration of algorithms and sensors in the smart service system.



www.ara.com/projects/**PaVision**-automated-pavement-condition-assessment-system



Data Exchange Opportunities

City Digital at UI Labs

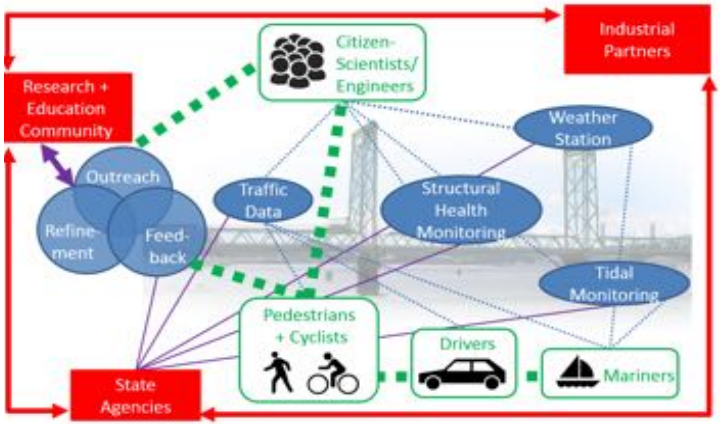
CITY DIGITAL

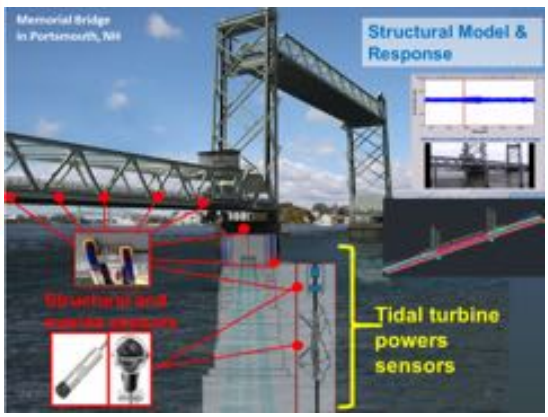
UI LABS

DMDII
DIGITAL MANUFACTURING AND DESIGN INNOVATION INSTITUTE

The Living Bridge Project @ UNH

"The Future of Smart, Sustainable, User-Centered Transportation Infrastructure"

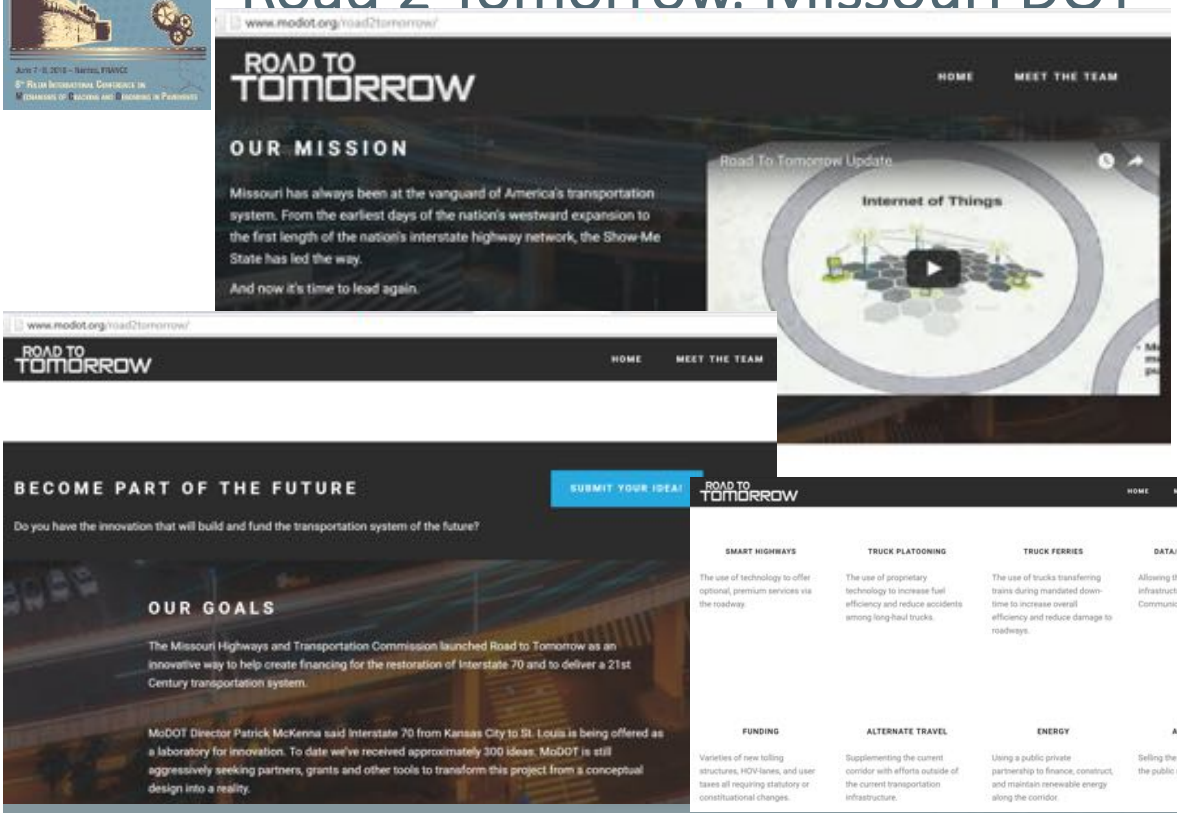




Acknowledgement: Dr. Erin Bell, University of New Hampshire

memorialbridgeproject.com

Road 2 Tomorrow. Missouri DOT



Kansas City, Missouri

Moving Forward…

- Disruption wave – don't run, ride!
  - In addition, will attract new talent to our field
- Need to standardize:
  - New roughness, pavement condition, user cost and sustainability parameters/indices from active data streams
  - Cloud storage data structures
- Get industry and citizenry involved
  - Crowd sourcing – 311 reporting, social media sentiments, repair funding ('GoFundMe' pothole repair funding)
  - Data exchange marketplace standards and business model