OPTIMIZING EMERGING TECHNOLOGIES FOR SMARTER BRIDGES

BRIDGE-ING

BIG DATA WORKSHOP

OMAHA, NE • OCT 8-9, 2015

Workshop Steering Committee

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Overview

The *BRIDGE-ing Big Data Workshop* was held at the CenturyLink Center in Omaha, Nebraska on October 8 and 9, 2015. This Workshop provided an opportunity for substantive discussion related to the influence of Big Data and technology on civil – starting with bridges – infrastructure management. It also helped to develop a roadmap focused on utilizing public-private partnerships to effectively leverage Big Data technologies and expertise to improve management of infrastructure assets. While the Workshop largely focused on bridges, relevant topics related to all components of the built environment were also discussed.

The event was developed, planned and supported by a collaborative group from the University of Nebraska-Lincoln's (UNL) College of Engineering and the University of Nebraska at Omaha's (UNO) College of Information Science and Technology. Other key partners supporting the effort included the Durham School, NEBCO, HDR and Union Pacific Railroad.

A broad collection of individuals attended and included academia, industry from all sectors related to transportation infrastructure and the built environment and prominent Big Data and technology experts. Over 120 individuals participated in the event, with participants coming from the state and region, other locations across the United States, and overseas. These individuals represented diverse organizations, including, but not limited to: the Nebraska Department of Roads; Union Pacific Railroad; NEBCO; Johnson Controls; DLR Group; Olsson Associates; eConstruct.USA; Scry Analytics; Datafloq.com; Microsoft; the New York Times; and faculty/staff from UNLs College of Engineering and UNOs College of Information Science and Technology.

The Workshop kicked-off with a roundtable discussion entitled "Big Data and Bridges – Successes to Date, Challenges We Face, and Opportunities that Exist." This discussion involved transportation industry leaders representing current and former policymakers, owners, designers, fabricators along with developers of tools used to manage those assets. They spoke to the *need for expanded integration of Big Data and technology into both transportation infrastructure and the built environment* to ensure that effective management of resources continues.

The opening roundtable was followed by a technical session entitled "Big Data and Infrastructure – What We're Doing and How We're Succeeding," involving distinguished individuals from government organizations, academic institutions, and industry located in the

U.S. and abroad. Participants discussed specific applications, techniques, tools and projects that successfully demonstrated benefits of integrating technology and Big Data theory and techniques into bridge asset management and maintenance. It was recognized by all participants that, while exciting advances are occurring, *a multitude of basic and applied research opportunities still exist*.

Day 1 ended with a poster session and dinner presentation. The poster session featured a large suite of research projects focused on smart infrastructure and relevant technology and Big Data applications, with this work being presented by students and faculty from UNL and UNO and demonstrating that *expertise exists at both institutions* to make substantial contributions at the intersection of infrastructure and Big Data and technology. The dinner presentation, given by David Levitan from Microsoft, served as a link to Day 2 by providing a concise summary of the history and current status of Big Data and related technologies from a data science perspective.

Day 2 started with a Keynote Address by the Honorable Ray LaHood, former Secretary of the U.S. Department of Transportation. Mr. LaHood utilized his extensive transportation leadership experience to recognize the timeliness of the Workshop and to emphasize *the importance of integrating Big Data and technology into management of transportation assets*.

Immediately following this address, a group of national and international Big Data experts participated in a session entitled "Developing a Roadmap – Big Data Success, Vision and Implementation." This activity involved short, focused presentations on the state-of-the-art related to Big Data technology in the U.S. and around the world, technological advances related to transportation, and how those advances could affect future use and management of the built environment. A roundtable discussion followed. All participants recognized the *transformational period* we currently reside in with respect to technology's influence on transportation and the built environment.

The Workshop ended with breakout sessions focused on one of three interrelated components of a data-centric asset monitoring and management program:

- Modeling
- Sensors and data collection
- Analytics, decision making, and impact

These breakouts identified opportunities where leveraging Big Data and technology could beneficially impact management of transportation infrastructure and built environment assets.

The final element of the workshop was an open dialogue involving all participants. This dialogue focused on interest in creating public-private partnerships to further advance and integrate Big Data and technology into civil infrastructure and built environment asset management. There was clear support to continue the dialogue, with more focused, smaller group, discussions related to identified opportunities as being the focus of future activities and partnership exploration.

Key outcomes of the workshop included:

i. Recognizing that we are currently *shifting from producing "Big Data" to producing "Smart Data"*. This shift is centered on to how data is produced and used and must be recognized and addressed by those that manage transportation infrastructure and the built environment.
ii. Understanding that *technology advancements will have a profound influence on future use of transportation infrastructure and the built environment*. Some influencing advancements include increased usage of social media as a predictive tool and the development of driverless vehicle technology. The influence of these advancements, and others, must be anticipated and addressed by those that manage transportation infrastructure and the built environment.
iii. Recognizing that *an extensive pool of transportation infrastructure data already exists and this data needs to be better mined* to manage assets and optimize future decisions related to sensor placement and data collection.
iv. Understanding that produced *data must provide non-technical asset managers with easy to interpret tools* that clearly identify safety and cost repercussions associated with decisions at multiple scales.
v. Ensuring *that industries associated with transportation infrastructure and the built environment clearly understand return on investment* offered by integration of technology and Big/Smart Data into their management processes.
vi. Developing *means for transportation and built environment industries to share important data between sectors* and for these industries to look to overcome privacy concerns to realize full benefits provided from the data.
vii. Developing proactive approaches to *standardize and integrate sensor technologies, platforms and Big/Smart Data management principles* into structural design and construction processes.
viii. Leveraging an opportunity to *redefine how models that help manage infrastructure are developed and used* within the decision-making process.
ix. Establishing better methods to measure, track and *share information on applied loads* across transportation networks.

Identified opportunity areas included:

1. *Better use and sharing of data that exists* coupled with *leveraging other industry sector expertise* that has been effectively utilizing Big Data to make operational decisions.
2. *Demonstrating realized returns on investment* via integration of Big Data and technology.
3. *Supporting and standardizing technologies*.
4. I*mproving models* and their integration.

Action items included:

1. Preparation of a Workshop summary report (University of Nebraska). *Draft completed*

2. Preparation of an accompanying video (University of Nebraska). *Draft completed*
3. Completion of a "data" gaps survey to augment and enhance Workshop discussions (University of Nebraska). Fall 2016
4. Forming and convening focus groups. Fall/Winter 2016
5. Initiating prioritized, exploratory, projects addressing identified opportunity areas. Winter/Spring 2016/17
6. Holding a second workshop, focused on Big Data and the entire Built Environment. Summer 2017

Background and Context

The *BRIDGE-ing Big Data Workshop* concept originated from a series of discussions and planning exercises focused on opportunities Big Data and technology offered to help advance the state-or-the-art in key engineering sectors and industries. Initial outcomes from these discussions, which involved individuals from UNL's College of Engineering and UNO's College of Information Science and Technology, consisted of development of whitepapers focusing on agreed upon opportunity areas and on distribution and discussion of these whitepapers with leaders in key industry sectors relevant to their topics. These discussions helped initiate initial development of UNL and UNO research strategies and collaborations.

A whitepaper entitled *Better Bridges Using Big Data* was developed from this effort. It focused on leveraging Big Data and technology to develop and implement "smart infrastructure" systems to assist with asset management, with an initial focus on bridges. This white paper spoke to a 3-pronged effort to address research needs in this area, with the areas focusing on (1) data collection and transmission, (2) data analysis, and (3) smart and safe management of bridge assets.

It was apparent during whitepaper development that providing a vehicle whereby individuals from industries involved with and affected by advances in these focus areas, having both engineering and Big Data backgrounds, could interact with visionaries and researchers in those areas would be enriching and beneficial. This was especially true when these interactions happened in an open forum so that innovative opportunities and concepts could be proposed, questioned, and discussed. As a result, a Workshop was planned with an intent on developing a shared understanding of the importance of investigating these concepts and establishing opportunities for exploration and advancement in a research environment that promoted public-private partnerships.

Day 1, October 8, 2015

Session 1 - Kick-off Roundtable Discussion, *"Big Data and Bridges – Successes to Date, Challenges We Face, and Opportunities that Exist."*

Moderator: *Jay Puckett*

Participants: *David Connell, Vice President/Engineering, Union Pacific; Mark Lafferty, Vice President/General Manager, Concrete Industries; Hon. Raymond LaHood, former United States Secretary of Transportation; Raj Prasad, Chief Technology Officer, HDR; Paul Thompson, Consultant, Management Systems and Engineering Economics.*

Moderator Puckett opened the discussion and recognized that, while transportation is heavily invested in data driven asset management, and opportunities still exist to better utilize Big Data to improve the process, other sectors of the built environment, specifically buildings, could substantially benefit from monitoring and management techniques that better leveraged Big Data.

The timeliness of the event, given the age of our interstate highway system and current federal transportation funding allocation philosophy, was clearly apparent to Secretary LaHood. Effective creation and use of data related to transportation infrastructure demands and condition is of paramount importance for effective asset management and our federal representatives need accurate and timely information to make effective policy decisions.

Paul Thompson stated that those charged with managing transportation infrastructure often do not have engineering expertise. This renders information that is available "Expensive Data" rather than "Big Data," as its effective utilization has significant repercussions. Transportation asset managers currently do not trust infrastructure data that is available as it is viewed as being complicated, of questionable quality and difficult to justify as a value added component of the decision-making process. It is crucial for university researchers to strive to make data-centric tools simpler so they become an integral part of the management process. Expanding effective collection and utilization of bridge vehicular load data was identified as one area where data value could be demonstrated in the short term.

Extensive data is being collected that could assist with infrastructure management, according to Raj Prasad, but effective use of that data is still somewhat elusive to the industry. Focus should shift to collecting the "Right Data," which is data that is truly useful for effective decision-making. This strategy was developed by HDR since, for the most part, everyone has Big Data. Studying other industries who effectively share and utilize their data to make decisions, such as the medical and financial industries, would assist with developing means to collect the "Right Data." Opportunities to gather "Right Data" run the gamut between manual collection and effective use of developing "Internet of Things" technology. Privacy concerns associated with sharing data have been addressed by other industries, such as the mining industry, and

advantages offered by sharing data, both in developing and industrialized countries, have been demonstrated.

Context from an owner and operator's perspective was provided by David Connell, who indicated that, when the operation and maintenance of an extensive transportation network is a core business focus, adequate assessment of infrastructure condition is crucial to maintaining operability. Shifting from a "go look and see approach" to a technology centered management model has been shown to offer clear benefits to the rail industry, such as being able to accurately track and manage load data, while concurrently producing vast amounts of information. Challenges still exist related to managing this data as sensing densities and data storage capabilities expand.

Mark Lafferty indicated that, irrespective of what Big Data is defined to be in the transportation industry, it must ultimately be proven that this information will help better construct and maintain our infrastructure. To do this effectively, all entities involved in designing, building, owning and maintaining infrastructure must collaborate, with one area of immediate collaborative benefit in the bridge industry stemming from real-time reporting of structure position and loads, especially during construction.

Participant comments and the subsequent question and answer session identified multiple opportunities for public-private partnerships to have an impact. These included a need to:

- Identify data that helps non-technical transportation asset managers and policymakers make effective decisions.
- Develop means to securely share important data between traditionally "siloed" transportation industry sectors.
- Focus on developing better methods of tracking and measuring loads on transportation infrastructure assets.

Session 2 - Technical Session, "*Big Data and Infrastructure – What We're Doing and How We're Succeeding"*

Moderator: *Daniel Linzell*
Participants: *Paul Barr, Professor and Interim Head, Department of Civil and Environmental Engineering, Utah State University; Brett Commander, Co-Founder, Bridge Diagnostics, Inc.; Aldo De La Haza, Manager, Nondestructive Testing Services, Dynasty Group, Inc.; Chuck Farrar, Director, The Engineering Institute, Los Alamos National Laboratory; Rory O'Rourke, CEO, DATUM; Duane Otter Director, Association of American Railroads' Transportation Technology Center*

Various examples and philosophies related to Big Data and information technology and their use as tools to assess and manage infrastructure assets, focusing on bridges, were shared in this session. Presented information ranged from specific projects and applications to general techniques and technology that utilized data-centric methodologies to assess performance and condition and make decisions.

Specific research efforts that focused on how data can assist bridge performance and, ultimately, asset management were provided by Paul Barr. The first example focused on establishing causes for deterioration in structural elements in an in-service bridge with the intent of developing preventative measures for future designs. The second focused on using controlled testing of a deteriorated bridge element to improve capacity predictions. The discussion ended with a summary of the Federal Highway Administration's ongoing Long Term Bridge Performance project, a national effort focused on developing accurate deterioration models for bridge structural elements.

Brett Commander and his firm are typically involved with projects that utilize in-situ monitoring and controlled testing to evaluate current condition and, ultimately, service-life. Experimental and computational data are used to address questions related to restricting or relaxing load limits or for evaluating effects of deterioration or accidental collisions on capacity and service life. It is believed that an opportunity exists to utilize archived data from the U.S. inventory to further leverage load test results and structural monitoring data. It would be impractical and cost prohibitive to instrument every bridge, but it is reasonable to infer measured performance results from detailed testing or monitoring to a range of structures with similar design and characteristics.

An innovative transportation asset management technology tool was introduced to the group by Aldo De La Haza. The tool is cloud-based and acts as a data repository that uses online mapping information in conjunction with a large database containing information on transportation network items to assist asset managers with real-time decisions.

An overview of structural health monitoring, one that included a snapshot of active research activities and the discussion of potential opportunities, was provided by Chuck Farrar. Structural health monitoring has four components: operational evaluation; data acquisition and networking; feature selection and extraction; and probabilistic decision making. Big Data is an

integral component and ultimately, monitoring "health" is a pattern recognition problem that depends on adequately detecting damage. More robust and easily integrated sensors need to be developed so that damage can be detected at the right resolution and throughout the structure's life. Research is attempting to augment human, visual sensing, still an important monitoring component, to incorporate other senses to monitor health. Owners are currently reluctant to invest in structural health monitoring technology until a clear return on investment is demonstrated, and, with no widely accepted procedure demonstrating the return on investment, the technology is not being broadly integrated.

An international viewpoint related to bridge and infrastructure asset management, predominantly from a railway perspective, was provided by Rory O'Rourke. Confusion regarding how data is used to make effective infrastructure management decisions also exists abroad and, as a result, experts are hired to produce and interpret data in a form that asset managers can utilize more readily.

Duane Otter stated that the U.S. railway industry has shifted from a reactive to a proactive maintenance philosophy, where data is a key component. A large amount of information related to demands, maintenance and condition is produced by the industry but not all data is effectively shared. Enhanced data sharing would be beneficial to the industry, along with advancements in inspection techniques and tools. The industry would like for Big Data to cost effectively provide appropriate and actionable information that can help prevent or prepare for unplanned service outages.

Opportunities for Big Data to assist with infrastructure asset management identified from this session and accompanying discussion included:

- Developing proactive and data-centric approaches that integrate sensor technology and, subsequently, Big Data, into representative structures to help manage these assets in the future.
- Clearly demonstrating the return on investment Big Data integration offers when managing infrastructure assets.
- Advancing and standardizing sensing technologies and platforms and data management and manipulation techniques.

Evening Presentation, “Big Data – What It Is and Why You Should Care”

Moderator: *Deepak Khazanchi*
Presenter: *David Levitan, Data Scientist, Microsoft Customer Data and Analytics Team*

David Levitan provided a precursor to Day 2 of the Workshop by providing a data science perspective on the history and current state of Big Data. The industry has shifted from focusing on producing extensive data to producing high quality and impactful data. This requires that data sets that are produced are clearly understood and associated with desired outcomes, recognizing that correlation does not imply causation . A number of publically available tools exist to assist with improving the quality of data sets in the context of desired outcomes.

Day 1, October 9, 2015

Session 1 – Keynote Presentation, *"Importance of Integrating Big Data into Infrastructure/Bridge Management*

Moderator: *Kyle Schneweis, Director, NDOR*

Presenter: *Hon. Raymond LaHood, former United States Secretary of Transportation.*

Director Schneweis introduced the Keynote Speaker. Prior to the introduction Director Schneweis emphasized the importance of mining existing transportation infrastructure data to enhance management of transportation assets.

Mr. LaHood, in turn, emphasized that effectively utilizing transportation data is essential to bridge the gap between transportation asset needs and funds that are available. Workshop attendees were strongly encouraged to help influence how important data is identified, created, manipulated and presented so that federal government decision makers easily understand the influence various management and resource allocation decisions have with respect to advancing and sustaining our transportation infrastructure. Participants were strongly encouraged to reach out to other important transportation groups, such as trucking and automobile associations, to help identify needs and develop a cohesive voice.

Session 2 - Short Presentations and Roundtable Discussion, *"Developing a Roadmap – Big Data Success, Vision and Implementation"*

Moderator: *Robin Gandhi*
Participants: *Alok Aggarwal, Founder and CEO, Scry Analytics; Nick Bilton, Columnist, New York Times; Jack Uldrich, Global Futurist and Best-Selling Author; Mark van Rijmenam, Founder Datafloq.com; Don Voelte, Former CEO, Seven Holdings Group*

Further examination of the concept of Big Data and technology and the influence these concepts will have on use and management of transportation infrastructure and built environment assets, both now and in the future, occurred in this session. Leaders and innovators working in areas related to Big Data and technology provided varied perspectives on this topic.

Big Data is underpinned by four concepts, or "pillars," according to Alok Aggarwal, and include: obtaining raw data; cleansing and harmonizing data using human input and decision-making; asking the right questions based on subject matter expertise; and applying math and computer science principles to address these questions. Research effort is now focused on these concepts in the context of optimizing links between data sources and improving tools to analyze linked data.

Nick Bilton discussed the future of technology and Big Data and their influence on infrastructure and transportation and indicated that these items ultimately enhance system efficiency and user experiences. Examples where enhancement is occurring include: buildings that adapt to occupant usage; utilization of online activity data from social media to predict traffic movement and reduce congestion; harnessing digital imaging to predict growth and future transportation needs; and driverless cars influencing transportation patterns and demand. It should be recognized, however, that human intelligence still outpaces data intelligence, with purposeful manipulation of traffic pattern data being provided as an example.

Application of the AHA (Awareness, Humility, Action) concept to transportation and the current and future potential for Big Data to beneficially influence transportation thinking and action were the focal points for Jack Ulrich's discussion. Using Big Data to track current traveler trends and subsequently utilizing this information to positively impact future trends was an example of increased Awareness. Humility as it relates to transportation requires that individuals adjust their norms and expectations so that they will be more open to technological advances. Four technology components need to become better integrated for appropriate Action to occur:

- computer processing power and supporting sensors and technologies;
- local and cloud data storage capabilities;
- wireless capacity and bandwidth;
- and location technologies.

Integrating these components requires that researchers are open to engaging in strategic experimentation.

Mark van Rijmenam offered an international perspective on the current state of Big Data and its relationship with civil infrastructure, specifically bridges. The amount of data being produced is expanding exponentially and raw data needs to be better managed and integrated, especially as the “Internet of Things” continues to grow. We are now in the 'Mixed Data' era, where it is vital that organizations combine and mix different type of data sources, structured and unstructured data and internal and external data to gain valuable insights.

Specific examples of other industries effectively utilizing data and technology to make decisions and improve processes, namely the media and mining industries, were provided by Don Voelte. The media industry has been using and sharing data to drive decision making for an extended period of time while the mining industry has more recently recognized the benefits of technology integration and data sharing. Both industries have overcome legacy concerns related to data sharing and privacy.

Follow-up discussions indicated that, in the context of transportation infrastructure and the built environment, we are headed to an era focused on better utilization of Big Data that is produced. The current data and technology landscape offers a number of potential opportunities for research impact, including expanding 3D-printing and ubiquitous technology integration from other industries and allowing technology to make the public better aware of the impact of transportation infrastructure on their lives. Privacy concerns related to providing and sharing data were viewed as issues that can be effectively managed.

As a result of this discussion, the following takeaways and prospective research opportunities were identified:

- Recognizing and responding to influence social media and driverless vehicle technology will have on travel patterns and subsequent management of transportation assets.
- Recognizing that we are shifting from producing Big to Smart Data, data being produced by many sources, and that advancing means and methods to produce and integrate this data is of paramount importance.
- Understanding that concerns related to data privacy being better managed and other industries have developed means and methods for sharing beneficial information.

Breakouts - *"The Big Data 'Wheel' and Civil Infrastructure/Bridge Management: Influence/Challenges/Opportunities"*

<u>Moderator:</u> *Dan Linzell*

Workshop participants were assigned to one of three breakout sessions focusing on a component associated with data-driven infrastructure asset management depicted in Figure 1. After each breakout developed a shared understanding related to the relationship between their component and asset management was developed, that component's influence on the management process was discussed along with challenges and opportunities associated with improving that component by leveraging Big Data.

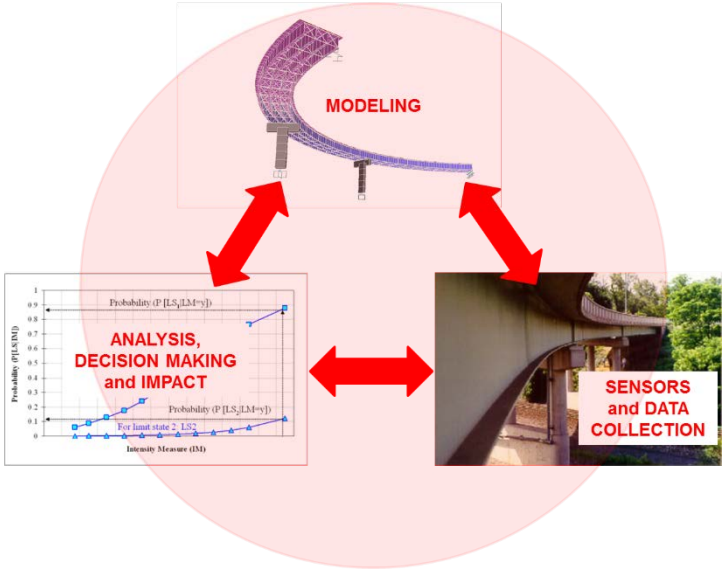

Figure 1. Breakout Diagram.

The Modeling breakout recognized that "modeling" exists in many forms and that correctly constructing appropriate physics or statistical models is a key component to good asset management and decision making. An opportunity exists to "reset" the modeling paradigm for civil infrastructure using Big Data so that models better address client needs and better associate management decisions with costs. Legacy privacy, security and data ownership concerns in the industry must be addressed in association with this opportunity.

The Sensors and Data Collection breakout recognized that other industries, such as the aircraft industry, better integrate sensors and technology into their operations and the public has accepted this integration. The human element is recognized as being very important to data collection and the interpretation process, but, its elimination could be considered if reliable systems could be developed at reduced cost. This would require research advancements in a number of areas, including development of faster and more reliable non-destructive

assessment methods and development of sensor technologies that are more easily integrated into infrastructure systems.

The Analytics and Decision-making group recognized that technologies that better utilize sensors in an integrated support system need to be developed along with improved computational tools to assist with analytics and decision making. An opportunity also exists to explore and leverage other industries' research work in this area.

Closure –

The final element of the workshop was an open dialogue involving all participants. This dialogue focused on interest in creating public-private partnerships to further advance and integrate Big Data and technology into civil infrastructure and built environment asset management. There was clear support to continue the dialogue, with more focused, smaller group discussions related to identified opportunities as being the focus of future activities and partnership exploration.

Opportunity areas that could be addressed included:

1. Better use and sharing of data that exists coupled with leveraging other industry sector expertise that has been effectively utilizing Big Data to make operational decisions.
2. Demonstrating realized returns on investment via integration of Big Data and technology.
3. Supporting and standardizing technologies.
4. Improving models and their integration.

Specific action items included:

1. Preparation of a Workshop summary report (University of Nebraska).
2. Preparation of an accompanying video (University of Nebraska).
3. Completion of a "data" gaps survey to augment and enhance Workshop discussions (University of Nebraska).
4. Forming and convening focus groups.
5. Initiating prioritized, exploratory, projects addressing identified opportunity areas.
6. Holding a second workshop, focused on Big Data and the entire Built Environment.