Facilitated Sessions @ BBD 2017 Summary Report

Abstract: At the Bridging Big Data (BBD) 2017 workshop, a total of 8 working sessions were conducted. All attendees were assigned to one of four focus area themes related to SMArt big data pipeline for Aging Rural bridge Transportation Infrastructure (SMARTI). The first four working groups focused on *challenges* and the last four working groups focused on *solutions*. This document summarizes the findings of these working group for each focus area. The working groups were facilitated using the Nominal Group Technique. This method is summarized at the end of the report.

BBD Team:
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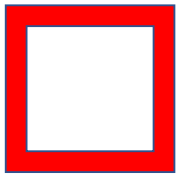
Dan Linzell, Chungwook Sim – University of Nebraska – Lincoln



Next-Generation Health Monitoring

Challenges:

What are the **challenges** with Next-Gen Health Monitoring of bridge health in rural areas?

1. **Category: Goal, Purpose, Objective of Monitoring**
   - What do we want to learn? (Load information in rural area)
   - What are you going to do with sensors?
   - What will you do with data? What is the purpose?
   - Do you really need real-time data?
   - Information that can be digested (fundamental information) not detailed information
   - To predict failure? Or try to extend the service life? To avoid scour?
   - How and where to place sensors
   - Which rural bridge to monitor
   - Early crack detection
   - Predictive deficiency models
   - Real-time discussion making during harsh conditions
   - Select best method that is easy to maintain
   - Service limit states (durability) or strength limit states (infrequent heavy loads)
   - Load enforcement, unknown loads

2. **Category: Data Analysis, Data Management**
   - Believing what you don't see
   - Bridge ownership (private vs public)
   - Very slow changes over time
   - Failure modes can be sudden and sensors might not pick this up
   - Is data open shared?
   - What data formats
   - Central public data center
   - Data use agreements/licensing
   - Quality of bridge metadata
   - Monitoring system (feature extraction, correlate features to physical damage)
   - Robust data analysis
   - Collected data reduction
   - How to identify damage

3. **Category: Rural Location**
   - Mostly old
   - Lack of traffic data
   - Lack of design plans

- Accessibility to rural areas
- Internet
- Maintenance
- Theft/Vandals
- Available trained people
- Weather events
- Gravel/dust
- Infrastructure power
- Poor internet connection
- Rough conditions in environment
- Rural access

4. **Category: Sensors Issues**
   - Wireless sensor power
   - Durability of monitoring hardware
   - Cheap sensing devices
   - Development of ease of use
   - Self-deployed, autonomous, robotic sensors platforms that can carry sensor arrays that detect bridge health characteristics
   - Sensor stability and calibration
   - Durability
   - Maintain power demand and cost for long term monitoring
   - Seasons effect monitoring and performance
   - Knowing when system malfunctions
   - How to install sensors to prevent falling

5. **Category: Cost and Social issues**
   - Money
   - Lack of funds
   - No money, no politics, No people, no voters
   - Lack of technical support
   - Hidden cost
   - Sensor cost
   - Social issues (accepting new tech)
   - I think we should finish the current generation first (there are too many aspects that need solutions before moving forward)

Solutions:

What could be **solutions** for **Next-Gen Health Monitoring** of bridge health in rural areas?

1. **Category: Optimization, data analysis**
   - Need a robust strategy that connects measurement types and frequency that provides…?
   - Informative path planning
   - Model constraints and relative SLAM data
   - Multi modal fusion and adaptive resolution occupancy map representations
   - I think we should find optimal sensors placement which includes number and place first – then how to process the collected data
   - More frequent historical traffic data collection
   - Power consumption and costs of operation can be optimized by developing triggering mechanism
   - Scour – this phenomenon changes vibration characteristics (vibration sensors + automated FDD + supervised learning)
   - Any prediction based on accumulated methods
   - Utilize data analytics algorithms and technology to predict 1. Bridge health, and 2. Bridge Maintenance schedule
   - Do targeted bridge repair
   - Using google earth? – or public image database
   - Use Possible existing datasets
   - Understanding collective data to use it in an effective way
   - With respect to rural bridge inspection, 1. Cost optimization is important. A physical worker still must travel to the location. That costs money still., 2. How is this saving money?
   - We know what we are looking for
   - We can use targeted sensors
   - It is not always better to have more data – can get lost in the way

2. **Category: Sensors Use for Inspection**
   - UAV application for inspection
   - Fixed robot deployment stations
   - Real time instrumentation for loads and vibration
   - Early detection of scour, early detection of delamination
   - Non-contact is preferable on existing bridges – no drilling!
   - Cameras can detect semi trucks to trigger the sensors
   - Adaptive, smart sensor networks, multi-modal, while operational 24/7/365 – only_ while useful data can be provided

- Reduced costs (human training, operation costs, maintenance costs) by using autonomous monitoring and inspection with 1. UAVs, 2. Wireless/Satellite comms, 3. Wireless power and charging, and 4. Non-contact sensors and passive sensors
- Arm inspectors with better technology – they know what they want and what will help aid inspection

Data Management

Challenges:

What are specific **challenges** with bridge health **data management** in rural areas?

1. **Category: Sustainability of Data**
   - ***Normalizing data*** and combining it. Data variety affects interoperability.
   - ***Work plans*** are submitted in non-consistent formats. They are not as consistent as inspection data.

2. **Category: Funding and Resources**
   - Lack of funding and resources in rural areas
   - Few people for many assets (bridges) can strain data management
   - Many barriers to data discovery
   - Cost of new technologies

3. **Category: Workflow/Implementation/Data Use**
   - Lack of collaboration between data scientists and policy makers
   - Lack of ability to justify decisions, lots of politics involved
   - Exposure to good and bad sides that comes with having access to data
   - Lack of experience in exposing data with licensing

4. **Category: Education/Training/Communication**
   - Many regulations and many people involved with different regulations can lead to issues. Have to be aware of a lot of regulations in different areas.
   - Lack of ways to support decision making from data and justify decisions to a lay person
   - Resistance to change from policy makers
   - Linking Data management to goals of the asset owners. Is data science advanced enough to do this yet?
   - What is in it for me? (How to educate people involved in the process)
   - Train and license UAV pilots
   - Train existing employees

5. **Category: Sparsity**
   - Lack of cell towers for communication
   - Lack of physical proximity strains resources
   - Detour routes are difficult in rural areas for 911 to re-route traffic when a bridge goes down for maintenance. Data management can help here.

6. **Category: Institutional dependency**

- Depends on the leadership. Who is the superintendent? Will they support data management efforts?
- Change in workflows. Who maintains data and associated responsibilities.

Challenge Category Rankings:

Lower the average rank, higher the priority.

Challenge Categories	Average Rank
Funding and Resources	2.00
Education/Training/Communication	2.14
Workflow/Implementation/Data Use	3.14
Sustainability of Data	4.00
Institutional Dependency	4.43
Sparsity	5.29

Solutions:

What could be **effective solutions** for bridge health **data management** in rural areas?

1. **Category: Funding and Access**
   - Access to a computer with email and internet in rural areas for a start.
   - Funds to collect data.
   - Limit overhead of data collection and maintenance.

2. **Category: Tools/Software**
   - Implement AASHTO BrM for smaller bridges that are off-system.
   - Tools that provide suggestions for making decisions. Based on BrM. Need an excel tool to support county bridge decision makers with data refreshed by BrM software.
   - Leverage AASHTO standards in the solutions. Software solutions.

3. **Category: Strategic Instrumentation**
   - When are certain thresholds crossed for fracture critical, i.e. low condition bridges. Fracture critical and greater than 50K average daily traffic bridges should be candidates for instrumentation.
   - Next-generation sensors should integrate with BrM.

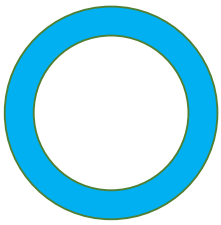
4. **Category: Understand data and apply it**
   - Work with local stakeholders to tailor data management solutions to them.
   - Have forms available for county highway superintendent to share tips and tricks related to asset management in rural areas.

5. **Category: Storage/Formats**
   - Access to datasets for existing bridges.
   - Inspection data format changes are upcoming.

Solution Category Rankings:

Lower average rank, the better.

Solution Categories	Average Rank
Funding and Access	2.125
Understanding data and apply it	2.25
Tools/Software	2.625
Storage/Format	3.375
Strategic Instrumentation	4.625



Decision Support Systems

Challenges:

What are specific **challenges** with bridge health **Decision Support Systems** in rural areas?

1. **Category: Barriers to DSS**
   - Every bridge is unique. How can you compare them?
   - Each state has different standards.
   - What are the key indicators?
   - Can we go from reactive to predictive maintenance?
   - What granularity level is acceptable?
   - Prioritization challenge: Bad, Good, Those in between
   - How to track bridges that are old?
   - Plug it before it becomes a hole.
   - Farm to market is important in rural areas.

2. **Category: Resources for DSS**
   - Fiscal and historical challenges.
   - Can the power and communication networks reach rural bridges?
   - Is there even an interest in decision support systems?

3. **Category: Data availability for DSS**
   - What is the right architecture to aggregate bridge health data?
   - How do we maintain trust between parties?
   - Cross-platform data aggregation.

Solutions:

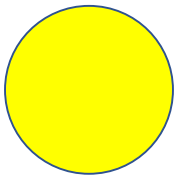
What could be **effective solutions** for bridge health **Decision Support Systems** in rural areas?

3 P's necessary for Decision Support Systems

1. **Category: Parameters**

2. **Category: Proactive**

3. **Category: Performance**



Socio-Technical Impact

Challenges:

What are specific **challenges** with identifying bridge health Social-Technological Impacts in rural areas?

1. **Category: Budget Constraints**
   - State/Local government resources are limited
   - Funding for repair/replacement

2. **Category: Usable Information for Agile and Effective Decision Making**
   - E.g., Sufficiency rating formula - deeply complex and doesn't do a great job establishing priority or replacement schedules.

3. **Category: Data Governance** (pass to DATA MANAGEMENT THEME)
   - Accuracy, quality, definition, ownership, licensing of derived products, etc.

4. **Category: Ethical/Social Issues**
   - Tradeoffs for replacement/repair of bridges
   - How do we evaluate and decide which bridges to replace or repair? The one in rural areas that serves 3-4 farms or some other? Is it always a tradeoff? How do we prioritize?
   - Impact on Citizens – a farmer needs the bridge for obvious reasons

5. **Category: Government Processes**
   - E.g., State/Local or Federal permitting paper work - Time to process is too long at this time

6. **Category: Cultural Issues relating to Big Data Instrumentation**
   - How do we prioritize instrumentation/monitoring?
   - Citizen engagement is essential (e.g., rural farmers pull barricades from repair zones to get their own work done ignoring directions… Needs enforcement)

7. **Category: Localization Issues**
   - Rural vs. urban
   - Variation in environmental factors and bridge details by location can impact solutions
   - Generalizability of approaches is difficult

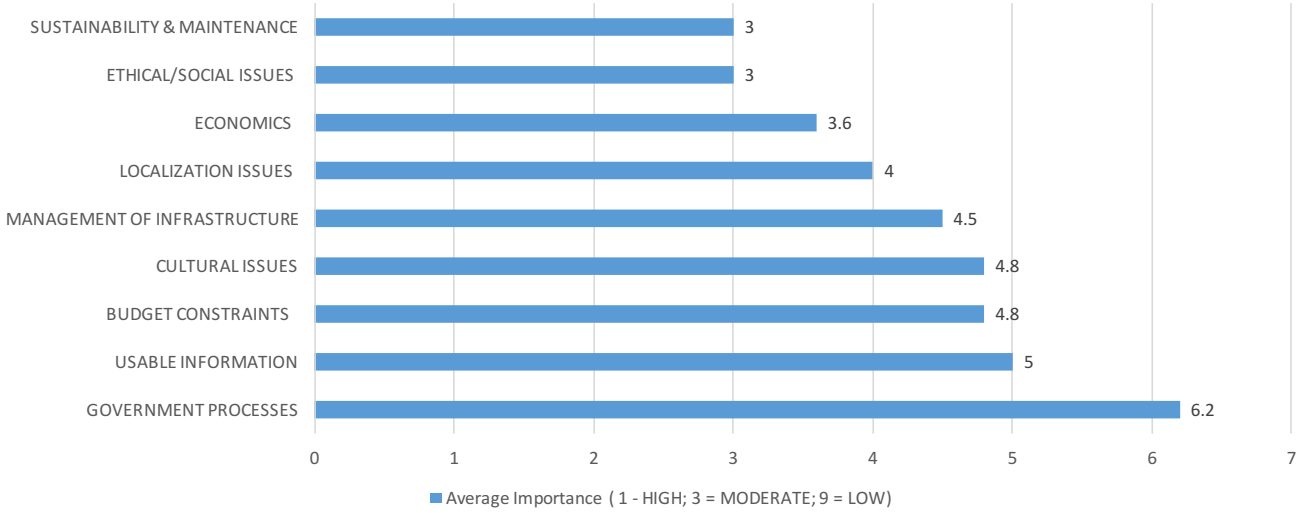
8. **Category: Economics of Instrumentation**
   - Implementation of instrumentation like UAVs, sensors, scour gauges and remote reporting carries a number of economic challenges

9. **Category: Sustainability and Maintenance**
    - Instrumentation can be a challenge
    - Battery life, replacement costs, monitoring of failure of sensors themselves

10. **Category: Management of Infrastructure**
    - Continuous monitoring for understanding traffic patterns, video monitoring, etc.

Challenge Category Rankings:

Rank Range: 1 (Very important) to 9 (Least Important). "3" is moderate.



Challenges: Raw ideas and quotes

- Budgetary constraints related to state and local government.
- How to get usable to information with which to make decisions. *Sufficiency rating formula - deeply complex and doesn't do a great job establishing priority or replacement schedules.*
- Any data analytics project intersects with data governance. Governance meaning many different pillars including high-quality data on multiple dimensions, data definitions are consistent across. Also the ethical and sociological implications of doing all of this.
- One of the biggest problems is permitting from army corps of engineers.
- Cultural thing: we just don't monitor bridges now. Policy change, culture change on doing any of this. "It's too late now - we should have been monitoring 50 years ago".
- "If you had twenty near the end of their life, you can't replace all of them" using instrumentation to help make those decisions.

- People don’t understand the posting signs, or care. Farmers will pull the posts and open the bridge regardless. Zero enforcement.
- Citizen engagement.
- Rural mentality differing from urban mentality.
- A lot of data will be collected. Who owns that data? Who stewards/curates?
- Generalizability, variation between states, variation between rural and urban regimes of policy.
- Derived products from data. Handling those issues. *They want to make it all open-source*
- 600k bridges in the country, but little knowledge of railroad bridges. *Pretty clear trail of accountability from local to county to state to national.*
- Whole different set of details for rural bridges. More spread fittings, more recycled bridge parts. More frequently overloaded. Bridge details are not even close.
- What communities hold political sway.
- UP (Union Pacific). Access to one bridge that they can instrument. Working with a senior engineer. What is the value proposition for the business?
- Engaging the Midwest Hub around the issue of rail. Railroad is instrumenting bridges much faster than road bridges. Federal govt has required failsafes so it’s a mandate. Spending $100 million on building software to predict the possibility of railroad failure. Positive Train Control (PTC).
- “I tried to get more stream gauges to monitor scour critical structures and was told its $10k to install”
- Sustainability and maintenance of sensors. Who checks for and repairs failed sensors? Alternatives to instrumentation. Instrumentation is interesting to engineers.
- Accuracy of data and effectiveness of sensors. They all collect but quality is at question.
- Continuous monitoring to understand traffic patterns.
- “I don’t know why they don’t do more cameras”

Solutions:

What could be **effective solutions** for identifying bridge health Socio-Technical Impacts in rural areas?

1. **Category: Localization**
   - Automating Inspection? Smart Traffic Counters.
   - 6 inspectors/3000 bridges
   - What is the overload frequency?
   - Repair Strategy

2. **Category: Sustainability and Maintenance**
   - Budget
   - Scour sensing?
   - Communication?
   - Quality of Data
   - Redundant Instrumentation
   - East of maintenance
   - Frequency of data collection

3. **Category: Ethical and Social Issues**
   - Engage citizens?
   - Citizen science a priority?

4. **Category: Economics**
   - Nebraska 15000 bridges, 7 % structurally deficient
   - Poor preservation of average bridge
   - Small bridges: Video cameras can cause privacy issues, overloading of bridges, Farm equipment is not plated.
   - Relevance of data to decision making
   - Convey that technology is different?

Facilitation Script and Protocol

Facilitated Working Session 1:

Theme (**Challenges**):

9:45 to 10:30 a.m.

1. Data Management (Robin Gandhi)

What are specific **challenges** with bridge health **data management** in rural areas?

Some prompts:

- Lack of access of expertise
- Lack of centralized collection
- Varying data formats
- Lack of budget
- Access control, anonymity needs
- Access to technology
- Example cases
- Shortage of skilled labor

Ranking/Poll: As a community what should we address first?

2. Decision Support Systems (Dan Linzell, Brian Ricks)

What are specific **challenges** with bridge health **Decision Support Systems** in rural areas?

Some prompts:

- Distance from subject matter experts?
- Lack of data?
- Lack of interest
- Access to technology
- Turning raw data into actions
- Lack of budget

Ranking/Poll: As a community what should we address first?

3. Social-Technological Impact (Deepak Khazanchi)

What are specific **challenges** with identifying bridge health Social-Technological Impacts in rural areas?

Some prompts:

- Cultural norms
- Communication infrastructure
- Lack of understanding
- ....

Ranking/Poll: As a community what should we address first?

4. Next-Gen Health Monitoring (Chungwook Sim)

What are specific **challenges** with Next-Gen Health Monitoring of bridge health in rural areas?

Some prompts:

- Lack of access of expertise
- Varying data formats
- Lack of budget
- Cost of instrumentation
- Access to technology
- Shortage of skilled labor

Ranking/Poll: As a community what should we address first?

Facilitated Working Session 2:

Theme (**Solutions**):

9:45 to 10:30 a.m.

1. Data Management (Robin Gandhi)

What could be **effective solutions** for bridge health **data management** in rural areas?

Some prompts:

- Centralized data collection
- Tech extensions agents
- Training and workshops
- Hosted services
- Reference implementations
- Google maps for bridges

Ranking/Poll: As a community what should we address first?

2. Decision Support Systems (Dan Linzell, Brian Ricks)

What could be **effective solutions** for bridge health **Decision Support Systems** in rural areas?

Some prompts:

- Google maps for bridges
- Remote monitoring techniques?
- User-friendly access to the data?
- Automatic suggestions from deep learning software?
- Tech extensions agents
- ...

Ranking/Poll: As a community what should we address first?

3. Social-Technological Impact (Deepak Khazanchi)

What could be **effective solutions** for identifying bridge health Socio-Technical Impacts in rural areas?

Some prompts:

- Mine expertise/dataset in sociology and political science across the region
- Resilient communities
- Low-tech crowd sourcing (Talking to people)
- Promoting technology for improving productivity, not replacing jobs.
- Case studies of benefits from technology

Ranking/Poll: As a community what should we address first?

4. Next-Gen Health Monitoring (Chungwook Sim)

What could be **effective solutions** for Next-Gen Health Monitoring of bridge health in rural areas?

Some prompts:

- Sensors families
- Common ontology
- Cheap, effective sensors
- Demonstrate ROI of sensing
- Citizen science
- Automate the data collection

Ranking/Poll: As a community what should we address first?

Nominal group technique (NGT)

The following material is reproduced and adapted from: *http://asq.org/learn-about-quality/idea-creation-tools/overview/nominal-group.html which is excerpted from Nancy R. Tague's The Quality Toolbox, Second Edition, ASQ Quality Press, 2004, pages 364–365*

NGT a structured method for group brainstorming that encourages contributions from everyone.

Materials needed: paper and pen or pencil for each individual, flipchart, marking pens, tape.

Procedure:

Idea Elicitation (15 minutes)

- State the subject of the brainstorming. Clarify the statement as needed.
- Each team member silently thinks of and writes down as many **ideas** as possible in a set period of time (5 minutes).
- Each member in turn states aloud one idea. Facilitator records it on the flipchart. NO COMMENTS. Be sure suggestor agrees what is written reflects his/her idea. Continue around the group until all ideas are exhausted. A member may "pass" his or her turn, and may then add an idea on a subsequent turn. (10 minutes Maximum)

Idea Categorization (15 minutes)

- Solicit 5-7 categories for the Ideas. Create a numbered list on a flipchart. Try to reduce any category overlaps through discussion. (5 minutes)
- Discuss each idea in turn and assign the appropriate category number to the idea. Wording may be changed only when the idea's originator agrees. Ideas may be stricken from the list only by unanimous agreement. Discussion may clarify meaning, explain logic or analysis, raise and answer questions, or state agreement or disagreement. (10 minutes)

Idea Prioritization (10 minutes)

- Once categorization is complete. Each member will vote for five top categories.
- Working individually, each member selects top five actions, 5= most important, 1=least important of the important issues, 4=next most important; 2, then 3.
- Tally votes then record on a flipchart
    - The easiest way to record votes is for the scribe to write all the individual rankings next to each choice. For each item, the rankings are totaled next to the individual rankings. If a decision is clear, stop here. Otherwise, continue with a brief discussion of the vote. The purpose of the discussion is to look at dramatic voting differences, such as an item that received both 5 and 1 ratings, and avoid errors from incorrect information or understandings about the item. The discussion should not result in pressure on anyone to change their vote.

RECORD ALL FLIPCHARTS BY TAKING PICTURES.

When to Use Nominal Group Technique

- When some group members are much more vocal than others.
- When some group members think better in silence.
- When there is concern about some members not participating.
- When the group does not easily generate quantities of ideas.
- When all or some group members are new to the team.
- When the issue is controversial or there is heated conflict.

Nominal Group Technique Considerations

- Discussion should be equally balanced among all ideas.
- The facilitator should not allow discussion to turn into argument.
- The primary purpose of the discussion is clarification. It is not to resolve differences of opinion.
- Keep all ideas visible.
- When ideas overflow to additional flipchart pages, post previous pages around the room so all ideas are still visible to everyone.