A Summary of the 6th Quarterly Report for the Technical Activities Council

Bridge Condition Assessment Using Remote Sensors

Michigan Technological University

Cooperative Agreement No. DTOS59-10-H-00001

Principal Investigator:

Dr. Tess Ahlborn, P.E.
Associate Professor, Civil and Env. Engineering
Michigan Tech Transportation Institute
Michigan Technological University
1400 Townsend Drive
Houghton, MI 49931
(906) 487-2625; tess@mtu.edu

Program Manager:

Caesar Singh, P.E.
Lead Engineer/Program Manager
Research Development & Technology
RITA, U.S. Dept. of Transportation
1200 New Jersey Avenue, SE, E33-123
Washington, DC 20590
(202) 366-3252; Caesar.Singh@dot.gov

TABLE OF CONTENTS

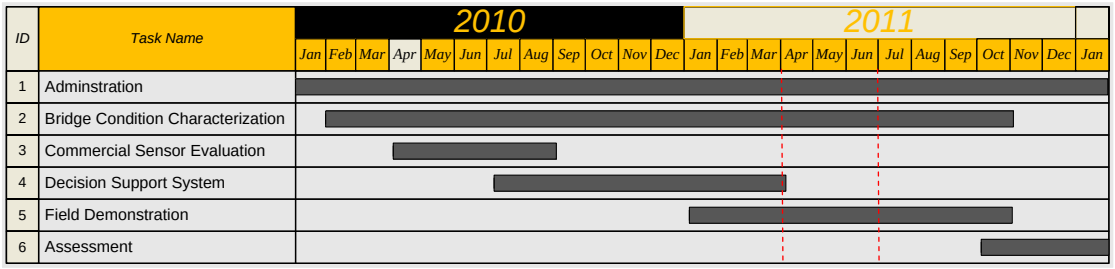
EXECUTIVE SUMMARY

This quarterly report documents progress for *"Bridge Condition Assessment Using Remote Sensors"* during the sixth quarter for the period of April 1, 2011 – June 30, 2011. Our Michigan Tech research team is investigating the use of remote sensing technologies to assess the structural health of bridges and provide additional inputs to bridge asset management systems. The project is exploring correlations between commonly used inspection techniques and remote sensing systems, and develop a decision support system to combine various inputs to create a unique bridge signature that can be tracked over time.

The primary goals of this project are to:

1. Establish remotely sensed bridge health indicators.
2. Develop a baseline bridge performance metric, the "signature," for benchmarking overall bridge condition.
3. Provide a system that enhances the ability of state and local bridge engineers to prioritize critical repair and maintenance needs for the nation's bridges.

The project schedule is shown below with Quarter 6 activities bounded by dashed lines; note that additional time was previously requested for the Decision Support System (Task 4) in order to incorporate field demonstration data results from Task 5:



Accomplishments for this quarter are discussed below and include progress on all tasks.

Also, according to the Revised Cost Proposal submitted June 26, 2009, and included as Attachment 2 of that cost proposal, the following deliverables were cited for Quarter 6. All technical memos are located at the end of this document and are discussed in the relevant tasks below.

- ✓ Technical Memorandum No. 19 describing further laboratory and modeling progress (full bridge models) and remote sensor correlations (Tasks 2.2, 2.3).
- ✓ Technical Memorandum No. 20 discussing field instrumentation installation and
- ✓ calibration and outlining the field deployment (Task 5.2).

TECHNICAL STATUS

Progress of each of the six tasks is documented below with references to the Technical Memos which are located at the end of this document.

Task 1: Administration

Several sub-tasks within the administration have been initiated and completed.

The project website continues to be updated: www.mtti.mtu.edu/bridgecondition . This website includes an overview of the project, information related to the project schedule, tasks and deliverables, the decision support system, project team partners, and key links for the project. All presentations, papers and reports are downloadable from our website under the "Tasks & Deliverables" link.

The following presentations were documented for this quarter:

- Colin Brooks updated partner MDOT on *"Bridge Condition Assessment Using Remote Sensors"* at Bridge Inspection Calibration Meeting on April 12, 2011.
- Colin Brooks and Arthur Endsley presented initial Decision Support System (DSS) findings to partner MDOT and Decision Support Focus Group in Lansing, MI on April 18, 2011.
- Devin Harris and Colin Brooks updated the University of North Carolina Charlotte USDOT RITA team and Technical Advisory Council on progress to date of *"Bridge Condition Assessment Using Remote Sensors"* project, May 26, 2011.

Task 2: Bridge Condition Characterization

This task consists of several sub-tasks including feasibility studies (through laboratory and small scale field investigation and demonstration) and structural modeling. Progress has been completed on these sub-tasks through several activities.

Previous quarter activities related to Task 2 focused primarily on narrowing down the suite of sensors to be evaluated and performing preliminary assessment of their capabilities. The efforts of Q6 have included further laboratory assessment of digital image correlation (DIC), LiDAR, and radar to confirm applicability as a field tool to enhance bridge inspection. Our other selected remote sensing technologies that have proven success in the laboratory environment and will be included in our field demonstration. The suite of technologies most suited to assess the condition state of a bridge have been found to be

- Thermal IR
- 3-dimensional optics (including photogrammetry)
- Digital Image Correlation

- Radar –
  - GPR (Ground Penetrating Radar)
  - SAR (Synthetic Aperture Radar)
  - InSAR (Interferometric Synthetic Aperture Radar)
- Electro-optical airborne and satellite remote sensing
- StreetView-style high-resolution digital photography
- LiDAR (Light Detection and Ranging)

In addition to the refined sensor assessment, additional focus has been given to how these sensors/technologies will be integrated into the Decision Support System (DSS).

- ✓ **Technical Memorandum No. 19** describes further laboratory and modeling progress made on full bridge models and remote sensor correlations found as required in Tasks 2.2 and 2.3.

Task 3: Commercial Sensor Evaluation

The commercial sensor evaluation was completed during Quarter 3 and is documented in the report *An Evaluation of Commercially Available Remote Sensors for Assessing Highway Bridge Condition*. The report can be downloaded from www.mtti.mtu.edu/bridgecondition by clicking on "Tasks and Deliverables" and "Deliverable 3-A". It continues to inform our study and has served a steady reference during project work.

Task 4: Decision Support System

Progress on the Bridge Condition Decision Support System (DSS) has continued steadily since the previous quarter. Many bugs in the early version, which was available during the last DSS Focus Group meeting, have been fixed. Map marker symbology can now be classified by any NBI rating or sufficiency. Multiple selections in the metrics table can now be made and the map will fit to any number of selected bridges. Driving directions to a given bridge are also now available through a pop-up utility that accepts an MDOT regional office, street address or latitude-longitude coordinate pair as an origin. Query-building utilities have also been built to allow arbitrary sorting and filtering of the database from within the application. These fixes were done based on DSS Focus Group feedback and internal review with the project team. Figure 1 shows an example screenshot of the current version of the DSS. Additional details on the progress of the DSS development are presented in Technical Memorandum No. 16 and Technical Memorandum No. 17.

The next features to be developed include some essential improvements such as the ability to perform spatial queries (e.g. find bridges in a given area) and to synthesize and integrate multiple data sets, particularly the remote sensing datasets that will soon be

available from the field demonstration and other deployments. The database for the DSS was recently converted to a geospatial database to support these and other features. During the transition, many improvements to the existing data were also made such as setting null NBI rating fields to 'N' in compliance with the schema established by MDOT and also relating bridges to their MDOT regions. This will improve and expand the summary of NBI ratings in the inventory which now may be viewed for a particular region.

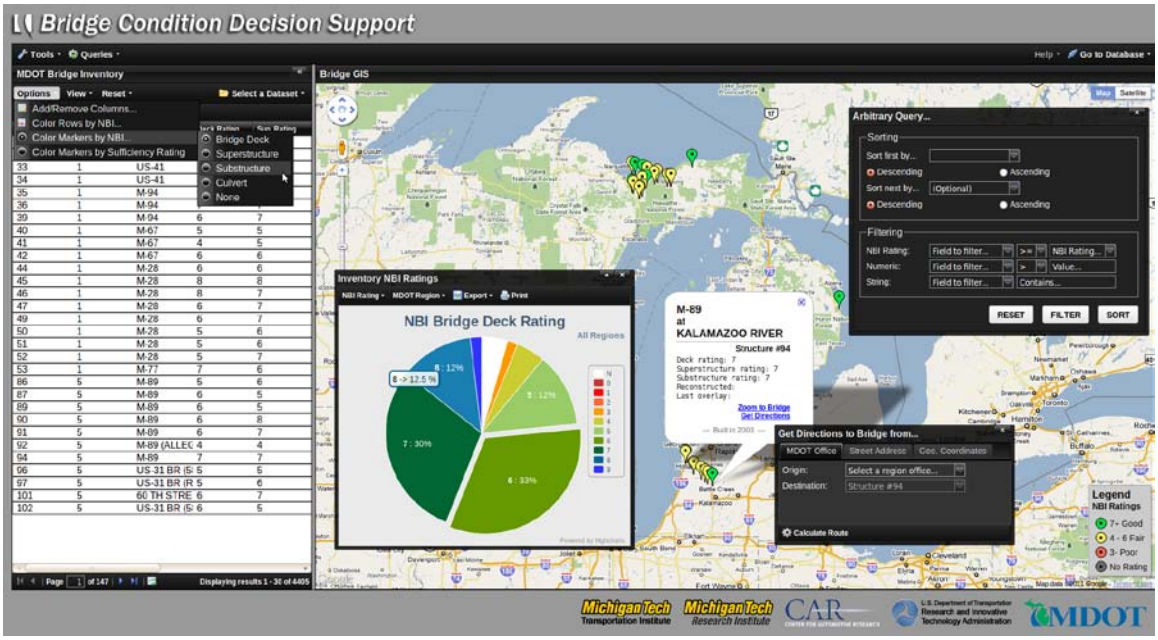


Figure 1: An example screenshot of the current Quarter 6 version of the Bridge Condition Decision Support System. *Note the availability and integration of data from MDOT's Bridge Management System with querying and display tools; integration of remote sensing results is planned next due to the upcoming field demonstrations.*

The first meeting of the DSS Focus group occurred on April 18, 2011 in Lansing at the MDOT Construction and Technology Office, with key representatives attending, including MDOT staff Steve Cook, David Juntunen, Richard Kathrens, and Jason DeRuyver. TAC member Amy Trahey of Great Lakes Engineering Group provided input representative of a firm that inspects bridges for MDOT. Their input helped the project team understand key desired features (such as the ability to display color-coded markers representing NBI ratings and information showing MDOT progress towards strategic goals); the list below consists of 13 specific decision criteria and attributes that the focus group would ideally like to see in a DSS. Not all will be possible within the scope, budget, and timeline of the project, but the development team is appreciative of having these goals to aim for in developing the DSS.

Below is the list of decision criteria and desired additional functionality received from the April 18, 2011 DSS Focus Group meeting:

1) Color-coded markers on map classifying bridge NBI ratings
2) Scatter plot for any two bridge condition parameters
3) Pie-charts showing distribution of NBI ratings in the inventory
4) "Zoom" and "Directions" links available in Google Maps InfoWindows
5) Tool showing (graphically, through histograms) progress towards MDOT strategic goal of 95% freeway and 85% non-freeway bridges at Good/Fair
6) Distribution of funds in the inventory; indication of where money is being spent (no such fields)
7) Indication of how often bridges are inspected, how often scoped, how often rehabilitated (no such fields for aggregation)
8) Alert or preset filter indicating when/which bridge(s) should be load-tested (e.g. after threshold of corrosion met, after significant section loss, after change in superstructure rating)
9) On-demand (re-)calculation of sufficiency rating (based on back page of Structure Inventory Appraisal Guide)
10) Bridge cycle of life
11) Preset filter for certain ADTT of poor/critical bridges
12) Last photo of bridge
13) Markov change transition probability

Task 5: Field Demonstration

During this last quarter, three bridges were selected for the upcoming field demonstration period. The bridges provide a variety of conditions from poor to good and are the same type (prestressed concrete I-beam with concrete deck) to provide comparability between remote sensing results but under different condition states. Two are near the Michigan Tech Research Institute in Washtenaw County, enabling easy deployment of several remote sensing technologies and providing a base of operations. One bridge is in mid-Michigan, near the town of Clare, and was selected because it is a relatively poor condition concrete I-beam bridge. The permitting and access process is currently underway with excellent collaboration from MDOT. The bridges (see figures below) and the tentative demonstration dates are:

- MDOT structure nº 10940 – Freer Road over I-94, Washtenaw County, Aug. 1-3, 2011
- MDOT structure nº 10892 – Willow Road over US-23, Washtenaw County, Aug. 3-5, 2011
- MDOT structure nº 1713 – Mannsiding Road over US-127 north bound, Clare County, Aug. 8-10, 2011

Figure 2: MDOT structure nº 10940, Freer Rd over 1-94

Figure 3: MDOT structure nº 10892, Willow Rd over US-23

Figure 4: MDOT structure nº 1713, Mannsiding Rd over US-127 NB

- ✓ **Technical Memorandum No. 20** discusses each bridge and its field instrumentation installation and calibration plan, and outlines the planned field deployment for each remote sensing technology per Task 5.2.

Task 6: Assessment

Discussions on the assessment task of the project have continued this quarter and have focused primarily on the challenges associated with the assessment and the inputs required from project partners to allow for a realistic assessment. We have further refined our economic valuation approaches for Task 6, including conducting a comprehensive literature review and investigating bridge inspection costs using conventional methods. (We have found annual cost information for Wisconsin and Connecticut, and are working on collecting information for Michigan.)

We have also started to prepare for meetings with MDOT partners on assessment techniques, including list of contact, timeline, and meeting formats. These meetings will occur in the second half of August after the Task 5 Field Demonstration makes progress in early August.

PROBLEMS ENCOUNTERED

No technical problems were encountered during this quarter. As previously discussed with our project manager and to ensure a quality final report with adequate review time, we will submit a no-cost time extension in the next quarter.

FUTURE PLANS

Quarter 7 activities will continue to follow the general schedule outlined within the technical project proposal. Task 1 administrative activities are progressing well. From a technical perspective, the primary focus of the activities in Quarter 7 will continue on with bridge characterization (Task 2) and with field demonstration testing (Task 5).

Anticipated Activities and Deliverables for Quarter 7 include:

- Technical Memorandum No. 21: Field demonstration results of remote sensing applications for bridge condition assessment on the three selected bridges, including DSS and sensor evaluation (Task 5.2) and correlation to laboratory testing and modeling of remote sensing responses to bridge characteristics.

- Technical Memorandum No. 22: Discussion of technical and economic approach for evaluation of commercial remote sensors for bridge condition assessment (Task 6.1, 6.2).

ADVISORY/STEERING COMMITTEE MEETING

Members of the Technical Advisory Committee include:

Steve Cook – Michigan Department of Transportation
C. Douglas Couto – Transportation Research Board
Charles Ishee – Florida Department of Transportation
Michael Johnson – CALTRANS
Dan Johnston – Independent Materials Consultant
Dennis Kolar – The Road Commission for Oakland County
Duane Otter – Transportation Technology Center, Inc.
Keith Ramsey – Texas Department of Transportation
Roger Surdahl – Federal Highway Administration
Peter Sweatman – University of Michigan Transportation Research Institute
Carin Roberts-Wollmann – Virginia Tech
Amy Trahey – Great Lakes Engineering Group

TAC members will be provided with a summary of Quarter 6 activities including field demonstration testing.

ATTACHMENT Listing – Quarter 6

- Technical Memorandum No. 19 - laboratory and modeling progress made on full bridge models and remote sensor correlations found.
- Technical Memorandum No. 20 - field instrumentation installation and calibration, and outline of the planned field deployment.