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### 8.1 List of Acronyms and Abbreviations

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<tr>
<td>3DWBIS</td>
<td>3D Wireless Bridge Inspection System</td>
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<tr>
<td>App</td>
<td>Application</td>
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<tr>
<td>AASHTO</td>
<td>American Association of State Highway and Transportation Officials</td>
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<tr>
<td>BMS</td>
<td>Bridge Management System</td>
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<tr>
<td>CoRe</td>
<td>Commonly Recognized</td>
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<tr>
<td>DoF</td>
<td>Degree of Freedom</td>
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<td>DTMB</td>
<td>Department of Technology, Management and Budget</td>
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<td>FHWA</td>
<td>Federal Highway Administration</td>
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<td>HUD</td>
<td>Heads-Up Display</td>
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<td>MBIS</td>
<td>Michigan Bridge Inventory System</td>
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<td>NBI</td>
<td>National Bridge Inventory</td>
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<td>OS</td>
<td>Operating System</td>
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<td>PI</td>
<td>Principal Investigator</td>
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<td>SIA (SI&amp;A)</td>
<td>Structure Inventory and Appraisal</td>
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<td>UE4</td>
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<tr>
<td>XML</td>
<td>Extensible Markup Language</td>
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State of the Practice and Literature Search Review for Wireless Bridge Inspection Data Collection Technology

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Introduction

Under federal regulations, all state-managed bridges located on public roads, fully or partially contained within a state’s boundary, must be inspected with a minimum frequency of 24 months (23 CFR 650.307 and 23 CFR 650.311, 2009). To comply with the rules and regulations set forth in the Code of Federal Regulations (CFR), state transportation departments utilize a variety of bridge inspection tools, databases, and management solutions to comply with the federal regulations. Currently, there are a limited number of commercialized software solutions to help agencies with the task of collecting and recording bridge inspection data. Because of the relative lack of options, State DOTs have designed their own customized systems to meet their particular needs or utilize one of the commercial solutions. This state of the practice document examines the existing solutions and discusses some of the custom tools currently being utilized.

Existing Commercial Solutions

To assist infrastructure monitoring and maintenance, the commercial industry has developed tools and systems that are compatible with federal regulations. The most well known of these organizations is the American Association of State Highway and Transportation Officials (AASHTO). AASHTO is the official source for transportation organization, technical excellence and advocates for transportation related policies, technical services and support for state transportation needs (AASHTO, 2014). AASHTO supports the most popular product for bridge management solutions, including AASHTOWare Bridge Management™ (BrM) Software (formerly Pontis, http://aashtowarebridge.com/). This software integrates the entire bridge management process, from data entry and federal reporting to public safety and risk reduction. Some of the features of BrM include:

- Functional Geographic Information System (GIS) utilizing Google mapping technology
- Add on applications for mobile devices (such as the iPad) which allow for data collection on these mobile devices
- Accurately assess performance and risk
- Cost calculations and budget assistance
- Priority and need assessment

These features of the AASHTOWare BrM are not entirely exclusive to the BrM software. One of the more recent upgrades to the system is the previously mentioned application add on. Through an agreement with Bentley Systems, AASHTOWare BrM can be compatible with mobile data entry systems developed by Bentley and marketed as InspectTech©. InspectTech©, a division of Bentley Systems, is a commercial firm specializing in mobile inspection and asset management solutions. Their software platforms are compatible with NBI, Pontis/Element level data, and custom databases. There are two core products offered by InspectTech©: BridgeInspect™ Collector and BridgeInspect™ Manager. The Collector

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software can be utilized in the field on mobile devices such as laptops and tablets as well as in the office settings. This software allows for advanced reporting formats, editing functionality as well as quality assurance and controls. One of the highlighted features of this software is that it can incorporate digital pictures directly into the reports for easy and effective use. The Manager software is also equipped with many efficient tools such as database management, report generation tools and a functional Geographic Information System (GIS). The following groups/agencies currently use this software: the United States Fish and Wildlife Service, the Indiana Department of Transportation, Washington Metropolitan Area Transit Authority (DC Metro), New Jersey Turnpike Authority, Minnesota Department of Transportation, Iowa Department of Transportation, and Montgomery County, Maryland. (http://www.inspecttech.com)

The Minnesota Department of Transportation utilizes the InspectTech© software in their system, Structure Information Management System (SIMS, http://www.dot.state.mn.us/bridge/bridgereports/index.html). The workflow of the SIMS systems consist of collecting data in the field, entering this data into the database once back in the office, review and generation of the report. This report is reviewed, approved, and made available through a search function within the database. Figure 1 is a flowchart designed by the Minnesota Department of Transportation for SIMS.

![Overview]

**Inspection Report → Review**

- Start inspection on laptop/tablet
- Submitted to Web-Server when in office
- Report continued from any computer
- Submitted for review
- Reviewed and approved online
- Able to run reporting and searching on data

![Figure 1: Flow chart and description of the Minnesota DOT SIMS data collection and entry system.](image)
Bentley Systems is also known for their ProjectWise Information Management and Collaboration products (http://www.bentley.com/en-US/Products/projectwise/projectteam-collaboration). The ProjectWise product is a series of software platforms, which are exclusively focused on architecture, engineering, construction, and operations (AECO). Part of this information management system is specifically dedicated to bridge infrastructure. The Bridge Information Modeling (BrIM) system is designed to ease the design and development of a bridge structure as well as maintenance and inspection. Figure 2 is a diagram of the ProjectWise BrIM information network (http://www.bentley.com/en-US/Solutions/Bridges/brim.htm).

![Figure 2: A diagram featuring the information network that can be utilized with the ProjectWise BrIM software.](image)

While the Michigan Department of Transportation (MDOT) utilizes ProjectWise for construction purposes and limited storage for bridge inspections, it is MDOT’s overall goal to utilize the MiBridGE application to find and retrieve all current information regarding bridge inspection data (Rich Kathrens, Bridge Safety Inspection Engineer, MDOT, January 2014 personal communication).

In addition to AASHTOWare BrM and the InspectTech® systems, another commercial product for bridge management and inspection is the AgileAssets Bridge Analyst and Bridge Inspector software. Similar to the other available software packages, the AgileAssets Bridge Analyst has a built in GIS, offering analysis of bridges to the inventory level with specific algorithms to analyze what-if scenarios and fine tuned to achieve the highest return on investment for management decisions. This software is flexible enough to be configured to meet many management agencies requirements. When the Bridge Analyst package is coupled with the Bridge Inspector software, the user has a system that will allow for compliance to federal regulations through generating National Bridge Inventory reports, National Bridge Inventory System (NBIS) and Structure Inventory and Appraisal (SIA) criteria. Figure 3 is an example of the Bridge Analyst GIS interface.
The AgileAsset software is web-based so mobile devices can have access when an internet connection is available (http://www.agileassets.com/solutions/road-bridge). In addition to these Bridge Analyst and Bridge Inspector packages, AgileAssets offers AgileAssets mobile. This mobile application is compatible with smartphones, tablets, and laptop PCs, and offers online and offline access for data collection, report generation, and work orders. In addition to the application, AgileAssets Mobile Inventory Manager is a GPS enabled Windows device that works regardless of cell phone network availability. This device allows managers to record work orders, equipment orders, and other cost factors (http://www.agileassets.com/products/mobile-apps/). To operate any of these packages, the user will need to purchase and install the AgileAssets System Foundation package that serves as the root of all the products offered by AgileAssets.

Another management and inspection tool available is the BridgeWeb management system (http://www.bridgeweb.us/). Like many of the other tools available, BridgeWeb is broken in task specific programs. BridgeWeb offers a Bridge Management System (BMS), an Inspection Management System (IMS), and a Data Collection System (DCS). The BMS system is a web-based software designed to provide management insight that prioritizes tasks by assessing bridge condition, deterioration, and cost to effectively manage bridge maintenance. Figure 4 is a flow chart of the BMS organization.
The IMS is a system designed to help oversee large-scale inspection programs. Offering inspection scheduling, quality assurance and control, reporting, and other features, this system can provide managers solutions to large scale inspection programs. The DCS is marketed as an easy to use tool that can incorporate text, photos, and tables using a stylus-based tablet. This tool is designed to provide the necessary information to inspectors, such as past inspection reports and real time quality control, and has an interface that allows inspectors to move from one element to another. This system can upload collection data to the BridgeWeb server through an internet connection.
Customized Bridge Inspection Data Collection and Management Solutions

While commercial data collection and management solutions exist, some state transportation departments utilize multiple software platforms to meet their needs. Alternatively, some cases exist where agencies are developing customized data collection and management systems to meet their needs.

The Utah Department of Transportation (UDOT) is developing a design, management and inspection system that utilizes technology from multiple sources. The program, known as the Utah Transportation Integrated Business System (UTIBS) is a collaboration of multiple sources of expert technology and innovation. Some of the collaborators in this project are Bentley Systems, Agile Assets, Oracle Corporation (database management), and Esri (GIS provider). This system appears to be similar to ProjectWise, but with a custom user-end solutions. The goal of this project is have all data accessible in a single portal with no data duplication, to easily and accurate update and complete projects, and a seamless work environment for all systems. Figure 5 is a diagram of the desired work flow for the UTIBS program (UTIBS presentation, accessed January 2014, http://www.udot.utah.gov/main/utonowner/gfn=4915503534970595).

Figure 5: Workflow diagram envisioned by UDOT for the UTIBS program.

The Oregon Department of Transportation (ODOT) currently utilizes AASHTOWare BrM software to help manage their bridge inspections. While this is a satisfactory...
management solution, ODOT is also looking to create an efficient inspection device
technology. With the goal of utilizing touch screen tablet technology, ODOT has
experienced with using iPad and Think-Pad Helix (Windows based) devices to collect
bridge inspection data. This system is still in the development phase and ODOT is facing
some obstacles. The iPad is having trouble getting through IT security measures in place
through the ODOT network. Also, the Think-Pad was developed and sold with Windows 8
and the ODOT network is operating on Windows 7. When the Think-Pad was backloaded to
Windows 7 many of the features, such as 4G mobile connection and touch screen technology,
would not operate correctly and would cause the operating system to crash (Erick Cain,
Bridge Inventory Coordinator, ODOT, December 2013 personal communication). We are
maintaining communication with the ODOT team to keep track of progress with their system.

Advitam ScanPrint Infrastructure Management System (IMS)

Advitam (www.advitam-group.com), an infrastructure monitoring and management
group, is currently using handheld tablets for bridge inspection data management. Advitam’s
ScanPrint Infrastructure Management System (IMS) software allows users to optimize
management, monitoring, and maintenance of infrastructure features. By incorporating
ScanPrint IMS on handheld tablets, infrastructure inspectors are able to simultaneously
assess the conditions of features and make updates to records while conducting assessments
in the field. Any updates are transmitted in real-time, giving insight into incident, alerts, or
scheduled future work. Any defects can be drawn directly into the software via the handheld
tablet and incorporated into an interactive geographic information system (GIS), which
provides a complete inventory of the infrastructures properties and information. An
additional component of the software is a computerized maintenance management system
(CMMS), containing scheduling and managing interventions of the assessed feature.

ScanPrint IMS is based on an interactive cycle, which is made up of six different
components allowing managers, consultants, and users the ability to adjust the program and
cycle to their distinctive needs. The six components are as follows: “Know, Track,
Evaluate, Decide, Act and Share” (http://advitam-
group.com/Home/ComputerizedInspections). The first component “Know” permits users to
access data concerning the feature of interest, including historic and current information.
The data also incorporates any previous changes that have been made to the record. “Track”
will allow inspectors to perform inspections in the field and note any structural defects that
need to be further assessed. Next, “Evaluate” allows an inspector to assign structural ratings
using the data collected during the previous component. The ratings can include only
individual distresses or the entire structure. “Decide” uses the ratings from the “Evaluate”
module and generates a report that describes the best way to maintain the structure, which
includes budgetary scenarios and calendar to provide a temporal analysis on proposed
actions. “Act” provides a variety of management tools for further planned activities. Lastly,
“Share” allows the inspection group to provide reports, charts, and other data to the required
users.

The ScanPrint IMS program has been used in detailed analysis by transportation
departments within the United States. The Michigan Department of Transportation (MDOT) was the first American based organization to use Advitam’s software for infrastructure assessment (Finley, 2005). The Zilwaukee Bridge, located on Interstate-75 in Saginaw, Michigan, is regularly inspected every two years to meet NBI standards, and every four years to assess deterioration and long-term health [http://images.autodesk.com/adsk/files/4043445_Michigan_Zilwaukee_Bridge.pdf].

Previous to incorporating ScanPrint IMS, each assessment would result in thousands of pieces of paper documents and bookshelves of binders, which would have to be sorted through in order to find a specific document (Finley, 2005). However, once MDOT implemented ScanPrint IMS on handheld tablets, the time it took to share data and gather information concerning the Zilwaukee Bridge dramatically decreased (Figure 6, http://www.finleyengineeringgroup.com/cfc/cms/T/baseComponents/fileManagerProxy.cfc?method=GetFile&fileId=8DFE40D2B-F1F6-B13E-8A6745DAEFDF71F4). Upon the completion of the 2001 project, Advitam updated all of MDOT’s previous inspections and graphics for the Zilwaukee dating back to 1993 into the ScanPrint IMS. Additionally, the Zilwaukee Bridge was digitally split into 700 sections with corresponding reports and inspections attached to each within the software. As MDOT continues to inspect the bridge every two years, inspectors will be able to draw any changes in deterioration and fill in forms and reports for any of the 700 elementary sections.

Figure 6. An example of a handheld tablet device that allows inspectors to make on-site updates to bridge inspection records when using Advitam ScanPrint.

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Examples of Mobile Inspection Technology in Other Industries

Mobile and tablet technology can also be used for analyses pertaining to environmental health, building, and housing code inspections. One such company that uses this technology is Inspect2GO (www.inspect2go.com). Inspect2GO is primarily used for health inspections within food, school, water and sewage establishments. The software can perform analyses on a variety of platforms including mobile phones, iPad, and Android tablet and does not require an internet connection (Figure 7). Inspect2GO inspection solutions is comprised of three components: Inspect, Store, and Manage. The inspect component consists of checklists, photos, notes, etc. that are required for on-site inspections. These forms and data can be formatted to fit each location’s needs, and completed on-site and stored for later retrieval within Inspect2GO’s cloud database. In addition, the data can also be emailed and formatted into PDF formats. Lastly, the data can be retrieved from Inspect2GO’s cloud, managed and analyzed in charts, graphs, documents, and reports. As the database becomes more complex, search queries of customer inspection reports and violations can be completed. All inspections, permits, and violation reports are available to the public.

Figure 7. Inspect2GO’s inspection software on a mobile tablet.

Sungard Public Sector’s ONESolution software also uses mobile technology for inspections, (www.sungardps.com/solutions/mobile). ONESolution technology is intended to provide tools and forms to public safety and local governments during building inspections and crime related circumstances. Similar to Inspect2GO, ONESolution does not require internet access to conduct an inspection, and results are stored and retrieved upon the restoration of connectivity. Upon completion of a building inspection, fees and penalties can be distributed and assessed while on location. Additionally, ONESolution technology is also used in emergency situations in the Records Management System (RMS) (Figure 8). Public safety agencies can collect, store, and analyze data gathered during an investigation or within a correction system.
Figure 8. ONESolution RMS communicate crime statistics and data during public safety investigations.

IMEC Technologies Inspection System (http://www.imectechnologies.com/) is a web-based inspection system used for the auditing and inspection of equipment within work environments for insurance or monitoring purposes. Each item assessed is given a unique barcode or tag and upon being scanned by a smartphone or handheld device, the inspection system assigns the item a unique identification and location using GPS. Photos and comments can also be assigned to each item. By assigning a GPS location, each item can be accurately monitored as it is moved. This especially proves useful during the transportation of hazardous materials and regulatory requirements. Additionally, this software can be used for safety compliance management, similar to Inspect2GO and ONESolution. However, IMEC Technologies prohibits the use of a scaling system based on an individual inspector’s judgment. Instead, the software determines the safety score based on the response given during audit questions and calculated by the system and administrators. Figure 9 is an image of the IMEC Inspector software supporting mobile device platforms.
Figure 9: BMIC Inspector software dashboard showing mobile device usage.
Mobile Technology Hardware Advances

Over the past few years, the capabilities of mobile computing and wireless data connection technology have grown considerably. With more options of size, storage capacity, and operating systems, mobile computing is becoming a practical solution for data collection and recording. Currently, there are three dominant operating systems on the market: Apple iOS, Google Android, and Windows. Because of the nature of the Windows and Android operating systems, multiple companies can develop a suite of hardware designs to fill in niche markets such as rugged tablets and computers. For example, if a desired product is something more lightweight, a Panasonic Toughpad is water and dust resistant to work in many different environments while utilizing the Google Android operating system and is available with 4G LTE connectivity data options (http://www.panasonic.com/business/toughpad/us/secure-tablet-specs.asp). Figure 10 is an example of the Panasonic Toughpad; a typical system cost $1500.

![Toughpad Image](image)

*Figure 10: The Panasonic Toughpad featured above is water and dust resistant and utilizes the Google Android Operating System.*

Alternative to an operating system designed for mobile application, if a user needed a system to run more sophisticated software such as a Geographic Information System, there are rugged Windows tablets designed by Algiz. The Algiz 10x features a 10 inch screen designed with high visibility screens to be used in any environment and rugged enough to handle light water and dust exposure and impacts. This tablet runs Windows 7 Ultimate and is capable of wireless internet connections through WLAN networks (http://www.ruggedalgiz.com/algiz-10x/). Figure 11 is an image of the Algiz 10x rugged tablet; a typical system costs $2,785.

![Algiz 10x Image](image)

*Figure 11: The Algiz 10x rugged tablet is designed for rugged environments and runs Windows 7 Ultimate.*
In addition to the Algiz rugged Windows tablets, Xplore Technologies offers a rugged Windows tablet with 4G LTE (http://www.xploretech.com/products/ix104c5_DMSR-LTE/). This tablet runs Genuine Microsoft Windows 7 and Windows 8 (both offered in 32 and 64 bit options). This tablet is designed to resist rain, sand, dust, heat/cold, and forceful impacts. Figure 12 shows the Xplore Technologies iX104C5 DMSR LTE Rugged Tablet.

While Apple does not currently offer rugged versions of their iPad tablet, there are many weatherproof cases on the market that can be paired with the iPad if the iOS operating system is desired. A typical mid-level iPad Air costs $829, while a rugged OtterBox case costs $99 (http://www.otterbox.com/Defender-Series-Case-for-iPad-Air/29-ipad-air-protect_case.html?start=2&sz=10) (see Figure 13). If Apple tablets, and potentially smartphones, can be tough enough to survive practical use in field environments, then iPads and iPhones could be less expensive platforms for field data collection. This platform is under evaluation because of the widespread adoption of iPads and iPhones by transportation agencies on an at least personal basis, so many of these could be available in the field for inspection purposes. Similar Android tablets and phones, such as the Samsung Galaxy Note
10.1, which include a useful stylus, can also be obtained for less than $800 (see Figure 14, http://www.samsung.com/global/microsite/2014galaxynote10_1/).

Figure 13: iPad Air with rugged Otterbox case

Figure 14: Samsung Galaxy Note 10.1 Android-based tablet with stylus that can be useful for field data entry.
Also under consideration are Windows tablets. Windows 4G LTE devices such as Nokia 2520 run windows RT 8.1 (http://www.nokia.com/us-en/phones/tablet/lumia2520/?cid=ngmprod-fw-sre-na-alwayson generatetablet-na-google-us-en_us-10odtmx57c909) (Figure 15). Windows RT is a tablet-specific version of Windows that does not run legacy applications such as Excel or Word 2010, but runs more efficiently on tablet formats than a full version of Windows. If the bridge data collection inspection tool is primarily web browser based, as planned, then a 4G Windows RT tablet could be a solution. A typical Nokia 2520 Windows RT 8.1 table with 4G costs $500, so the price point is attractive. This format is also under evaluation by the project team. Tablets are offered with screen sizes ranging between 7" – 8" and 10" – 11" but the project team is focused on utilizing the larger screens giving inspectors more room to navigate the software. There are also <$1,000 Windows tablets running the full version of Windows 8.1 such as the Microsoft Surface 2 Pro, but none are yet available with integrated 3G/4G data service. This is a rapidly developing area of tablet capabilities so the project team is monitoring availability of newer systems. A tablet running full Windows 8.1 (with 4G) would be able to run traditional Windows applications such as Word and Excel while also running a browser-based data collection tool, so this could be a promising solution as the market develops.

Figure 15: Windows RT 8.1 Nokia Lumia 2520 tablet, available with 4G for $500.
Concluding Comments

This report describes the state of the practice for bridge inspection data collection solutions. Existing commercial software tools such as AASHTOWare BrM with its InspectTech® addons are reviewed, along with AgileAssets Bridge Inspector software and Advitam ScanPrint. BridgeWeb is also described. Examples of solutions used at the Minnesota Department of Transportation, the Utah Department of Transportation, and Oregon DOT are also reviewed. Solutions from the health inspection, building and crime inspections, and insurance are described. Finally, examples of more expensive fully rugged tablets and less expensive Apple, Android, and Windows tablets are described so that a representative range of hardware data collection platforms appropriate for use by bridge inspectors in the field can be understood. While many software solutions are available, state departments of transportation are also choosing to develop customized solutions to meet their particular needs while still being compatible with new element-level inspection requirements. The project team is focused on making sure that any such solution would meet the needs of the Michigan Department of Transportation.
References


