ABSTRACT
The continued focus on bridges across the nation has led to increased regulations being implemented on both highway and railroad structures. In addition to meeting regulatory requirements it is good operational and economic practice to maintain bridges in appropriate structural conditions for railroads of all sizes. Structure inspection and management programs need to be designed to meet key organizational goals and allow for data to be easily entered, retrieved, and analyzed. Information related to annual inspections, condition and deficiency photographs, maintenance plans, schematics, drawings, and other documents need to be accessible to all stakeholders to allow a seamless process and ensure that problems are quickly identified and resolved.

This paper/presentation will present an overview of key concepts for improving inspection and management of structure data. Technology is allowing railroads and their consultants, ranging from passenger transit organizations such as the Utah Transit Authority and DC Metro, to freight railroads such as the West Virginia Central Railroad, to be able to effectively capture and organize important inspection information. Some highlights from each of these entities will be presented along with the general best practices for data collection, data organization and technology. Recipients of this presentation will come away with a clear understanding of various approaches available to easily manage bridge data.

INTRODUCTION
Railroads have continually sought ways to improve their operations and safety. Improvements in technology and processes have often provided the means to achieve better operation practices. As computer software and hardware has considerably advanced in recent years this is once again presenting the opportunity as a means of significantly improving the best practices for inspecting, maintaining and managing railroad structures. Many organizations have already begun to fully integrate the latest technology into
their structure and maintenance of way management and inspection processes helping to advance overall efficiencies and organize the vast amount of historical and ongoing collection and maintenance of structure data. This paper will utilize examples from the Washington Metropolitan Area Transit Authority “DC Metro”, Utah Transit Authority, and the West Virginia Central Railroad. Each organization or their inspection consultants implemented a structure inspection and/or management system which can be accessed via the internet or from a tablet computer in the field. This allows for integration and storage of all data files pertaining to the railways and is resulting in saved time and money. A system like this reduces massive paper reports, saves significant time in entering of data and the approval process, provides quick searching capabilities across any field, provides the ability to view and analyze all data including past inspections, and provides a single source for all data pertaining to the railway including pictures, sketches, PDFs and other files. Not only has an integrated system increased efficiency and effectiveness in the inspection and management of assets, it is also proving to be the best practice method because of the unparallel advantages it gives the organization.

BACKGROUND

Freight and passenger railroads come in a variety of sizes and possess a diversity of structures in their inventories. These structure types include considerable inventories of timber, steel, and concrete representing lengths from simple one span bridges to viaducts that stretch for several hundred spans over a mile long. All of these bridges require some form of annual inspection to be conducted per FRA standards and may also need to meet additional FHWA or state requirements depending on traffic that is under/over the railroad.
Inspections are performed to check for the structural condition of the bridge and ensure that it is safe and in good operational order. Most inspections rely primarily on a visual approach to observe any defects and collect needed data. When issues are found this can prompt further investigation that often leads to detail tests from borings to a wide variety of non-destructive techniques. The detailed information collected during a condition inspection forms the basis upon which maintenance and major capital planning needs are determined and prioritized. Collecting accurate and informative data is critical to system safety and also the effective planning of millions and in some cases billions of dollars of repair and replacement needs. Erroneous or unavailable information has the potential to result in incorrect decisions that can negatively affect resource allocation and user safety. In an age of reduced budgets, increased focus on safety, and new FRA regulations it is imperative that entities establish effective bridge inspection and management programs.

Traditionally the approach to managing structures in all transportation industries has been highly reactive in nature, where a maintenance or corrective action is taken only when a problem or deficiency manifests itself. But, as more advanced management programs are being deployed owners are attempting to move toward a more proactive maintenance approach. Addressing problems early or performing preventative actions, such as maintaining coating systems and proper lubrication, can extend the bridge service life with efficient usage of resources. One of the least productive maintenance approaches toward bridges, and virtually every other asset classes, is the worst-first strategy in which problems are only attended to when they reach a certain level of severity compared to the other assets. Effective programs help agencies began to see the life-cycle of their structures and how various decisions can negatively affect this.

**PRIMARY INSPECTION AND MANAGEMENT COMPONENTS**

The primary components of integrated inspection and management system can be divided between inspection and management areas. It is important for there to be a seamless transfer of data and information
between each of these areas, so field inspectors and office based managers can function as a unified team even when located in different locations. The Federal Railroad Administration defines the basic foundation for data to be collected in its “Essential Elements of Railroad Bridge Management Programs” as including: location, feature intersected, number of tracks, number of spans, types of construction (substructure, superstructure, and deck), length, dates of construction and major rehabilitations (1).

Inspection

Inspection forms the foundation of a successful bridge program providing the literal eyes and ears in the field to collect the actual condition information. Inspection is often one of the least expensive parts of an overall structures office, but the information it generates is used to drive the decisions on major rehabilitation and replacement decisions. Inspectors come from a variety of education and experience backgrounds. Some inspectors are professional engineers who have years of inspection experience and understand not only the information they need to collect but the reason behind it. On the other side of the spectrum are newly trained technicians who are learning how to collect information needed but lack a detailed structural engineering background. An effective inspection process must deal with all potential users and provide a mechanism to assist and guide them in collecting the required information in an easy and efficient manner. The following are some of the software tools and processes that inspectors should have to help them perform their jobs in the most efficient manner.

- Utilization of interactive inspections forms
- Ability to store photographs and other attachments
- Access to all structure information
- Ability to categorize and prioritize deficiencies and needs
- Integrated manuals and reference material
- Built in formulas, worksheets, and secondary forms used

Management

Management personnel overseeing bridge or structures departments are typically highly experienced professionals with extensive experience. These users often have significant training, educations, and hands-on experience with their structures. They review and make decisions from the inspection data that is gen-
erated. They must balance multiple needs and constraints related to budgets, organizational priorities, personnel available, long range plans to develop effective plans for maintaining their systems. Structure departments must often be an advocate for its own needs within the larger organization as it competes for limited resources with other departments. It is important for the bridge managers to be able to present clear and informative data that defines the current and future needs, the options available, and the benefits/downsides of each potential action (deferred maintenance, proactive actions, etc). The following are a few tools/processes that managers should have to accomplish this:

- Instant access to all current and past bridge and structure information
- Ability to schedule and monitor status of inspections
- Standard reports that provide details on regular lists and needs monitoring
- Ad-hoc reports that can be easily constructed and allow any single data or combination of data to be returned
- Generate cost estimates and maintenance needs by type and location
- Ability to provide access to additional users within the organization
- Automatically send alerts if certain conditions occur
- Interactive tools to visualize data and results

TRADITIONAL CHALLENGES

Most highway and railroad entities face a set of common challenges in collecting and organizing data from their structure inspection processes. For instance, inspectors must manage their time accordingly to allow enough ample time to complete the inspection at the site, while having enough time back at the office to organize notes and type the report. In the challenges which burden many inspectors there exist significant capabilities for streamlining the inspection process and freeing inspectors from the clerical, office burdens imposed in trying to generate a report. In the process of providing inspectors with more time to efficiently collect data on-site, software solutions can also solve the following problems which often face inspectors of all structure types:

- Duplicate Data Entry: Inspectors are often faced with having to record the same information in different parts of the reports leading to wasted time or worse inconsistent data. A software solu-
tion can solve this by allowing one data field to be entered anywhere and then automatically filling in all of the others, eliminating the need to re-type the data and providing consistency (2).

- Lack of Historical Data: Typically, inspectors have copies of their past inspection reports. These are usually black and white and of poor quality making it hard to compare past pictures with present status. Sometimes past reports are not available or too difficult and time consuming to obtain. However, having all information stored in a software solution can remove these burdens and provide numerous benefits. For example, software removes the obstacle of locating information from past inspections by automatically uploading previous reports into the same location. The past inspection reports can also serve other purposes such as using data from the previous report to pre-populate the current report. Inspectors can quickly edit the information and be able to visually determine what has changed from the last inspection.

- Inspection Manual Lookups: Bridge inspectors carry with them inspection manuals (3) (4) that they use in helping to determine ratings for specific items and what procedures to use (5). When needed these manuals require time to look up the specific entry and are an additional burden to carry out in the field. A software program can intelligently link the hundreds of pages of these manuals into the software via drop-down select lists. It can also provide more detailed links to the full page descriptions displayed whenever a field is clicked.

- Formatting Reports: Typical inspection reports can include a cover page, table of contents, summary narrative data, forms, pictures, sketches, and calculations. The task of compiling the report, especially for inspectors on larger structures, can be unwieldy. However, a software system can eliminate this task and by simply entering data the program is automatically able to fill in the correct forms and perform all of the painful and time-consuming tasks that often lead to hours of office time: page numbering, picture layout, table of contents, headers/footers, cover page, etc. This allows inspectors to focus on the tasks of performing the inspection and not wasting time on formatting and report presentation issues.

- Long Approval Process: For some inspectors the review and approval process involves weeks of delay because of in hand delivering or mailing copies of reports back and forth to managers. Comments are written on the printed versions until the report is approved. A benefit of using software for this process is that it provides the mechanism to digitally submit the report over any
internet connection for review and approval, offering the ability to cut approval time from months or weeks to days. Further it helps to ensure that nothing is missed by tracking each individual report and allowing detailed comments to be submitted with the reports.

- Specify Maintenance Needs and Estimates: Inspection results are often directly used by maintenance departments. Inspectors are asked to adequately document repair needs and even develop cost estimates and priorities for each individual need resulting in a time consuming and error prone process. A software solution can provide the inspector with codes for maintenance items, which automatically generate cost-estimate guidelines based on the unit and pricing. The inspectors may either use or change these auto-estimates. Further, pictures can be directly linked to each deficiency providing visual support. Total costs and priority breakdown pages can be automatically generated in the report from the data entered.

Overall, the process of generating an inspection report is time consuming and involves intensive data entry and formatting when performed without software. These tasks have proven ideal to automate allowing for time-saving and quality improvements.

**QUANTIFYING BENEFITS**

When considering the implementation of a bridge inspection and management solution managers often look for the potential benefits and advantages of the system. Many of these benefits can be quantified through time savings on particular tasks in inspection and management. Other benefits can only be described more abstractly and are derived in an overall process that prevents mistakes and helps ensure maximal structure life and optimal resource utilization. Table 1 outlines the various advantages obtained from a computerized inspection and management system.
**Table 1 – Benefits of Computerized Inspection and Management System**

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased Inspection Efficiency</td>
<td>Inspectors performing bridge inspections can save significant time in recording and writing up results of the inspection.</td>
<td>25% - 50% time savings over traditional paper based inspections <em>(2) (6)</em></td>
</tr>
<tr>
<td>Shortened Analysis Time</td>
<td>Information on bridge conditions are immediately available to managers. No wait is incurred for a report to be collated and written up. Maintenance and safety actions can be immediately taken.</td>
<td>Instant action can be taken with all current and past inspection data available. Enhances safety and reduces repair costs by correcting the source of the problem before it becomes worse.</td>
</tr>
<tr>
<td>Simplified Reporting and Management Tasks</td>
<td>With all the information present in a Management system the data can be retrieved instantly and reports generated with a couple clicks.</td>
<td>Time saved in report generation and information retrieval. New and more powerful reports can be generated.</td>
</tr>
<tr>
<td>Linkage to Work Order Systems</td>
<td>Information from inspection reports can be directly used to generate work orders. The system can be integrated with popular computer programs. No need to retype maintenance descriptions or take new pictures that show the problem.</td>
<td>Time savings and improved accuracy in describing maintenance needs.</td>
</tr>
<tr>
<td>Avoid Costly Mistakes</td>
<td>When all information is in paper format or scattered across various computer files communication can break down and important information can be lost. This can lead to costly mistakes such as painting bridges that are scheduled to be replaced soon.</td>
<td>Monetary value that depends on mistakes avoided.</td>
</tr>
<tr>
<td>Maintenance Prioritization</td>
<td>Over the long term making the correct decision as to when and where to spend money can be a challenge. Incorrect prioritization can lead to structural closures or even failures that force expensive emergency maintenance tasks.</td>
<td>Monetary value dependent on type of problem. Can also include economic time loss of the structure's users/passengers.</td>
</tr>
<tr>
<td>Improved Data Quality, Consistency, and Completeness</td>
<td>Inspection data is used to make decisions on maintenance and capital improvements to perform on structures. Having higher quality data, which is more consistent and complete, can help make these decisions better. Errors such as misreading handwriting on paper and transcription mistakes can be avoided.</td>
<td>Correct and error free data to make important capital decisions.</td>
</tr>
<tr>
<td>Liability Documentation</td>
<td>With a computerized inspection management system a thorough record of all work with pictures and actions can be easily retrieved for each item. This provides valuable information in case of liability lawsuits.</td>
<td>Save money on potential lawsuit costs.</td>
</tr>
<tr>
<td>Increased Safety</td>
<td>One of the primary purposes of inspections is to ensure that structures are in a safe order. A comprehensive inspection and management system helps to improve overall operational safety of structures.</td>
<td>Decrease loss of human life or injury.</td>
</tr>
</tbody>
</table>
IMPLEMENTATION OF AN INTEGRATED SOLUTION

Several agencies have implemented systems to help them realize the benefits and advantages from field to office. A typical system that is composed of three primary parts and is customized to the exact needs of the entities will be described thoroughly throughout the paper. The first component is the field collection software, which the inspectors have installed on their tablet computers. This software is taken on-site and used to document the inspection at the structure. When the inspector returns to the office the tablets can be automatically synchronized with the server. The central server is running the second part of the software: a web-based version of the inspection program that allows reports to be continued or finalized from any desktop computer via an internet browser. Additionally, this module allows the reports to be reviewed and QA/QC to be performed by managerial personnel once the inspectors are completed and before the report is finalized. The third software component is the web-based management software allowing for full searching across any field, historical trending, access to summary reporting, and full structure history with photos, sketches, and other attachments (Fig. 3).

INTEGRATED SOLUTION:

Figure 3: System Solution Diagram showing new WMATA Software System
METRO Details:

The DC Metro system is one of the world’s premier heavy rail transit systems, operating an extensive 106 mile track and a diversity of structures from 20 miles of elevated track to numerous underground tunnels. To manage and maintain the system, WMATA desired a customized solution which could handle their exact needs and diversity of structural data. A core software system was chosen to handle this task and was customized to the exact needs defined by WMATA. Obtaining a customized solution was a major advantage for the authority as the desired workflow, forms, and roles could be retained. The standard features along with the minor customizations created a system that has been adopted with great success. Some of the specific features available to inspectors and managers now include:

- **Web Access:** With personnel in multiple offices/facilities being able to access the information easily and in real-time via a centralized location was a critical need. The web modules of the system allow this to be done securely and further allow access to be limited by structure or read/write capabilities based on the user’s account.

- **Easy to Use:** Metro personnel desired a very easy to use yet full-featured system; they did not want to create a system that was so cumbersome that it complicated rather than simplified the process. With the software these needs were met and inspectors were provided with a program that literally was “pick up and go” with minimal training required (Fig. 4).

- **Flags per component:** Every component on a structure can not only be ranked on a 0-9 condition scale, but they can also be flagged according to certain conditions/needs that exist such as Safety Hazard, Engineering Evaluation, Emergency, or Aesthetic. These flags help to drive the corrective actions taken.

- **Pictures linked to components:** The software has greatly streamlined the process of taking and attaching digital pictures. Pictures can be instantly loaded into the inspection report and also attached to the specific components of the structure that they are related to (Fig. 6). This provides significant benefit when trying to track problems over time.
• Videos: The system supports the ability for inspectors to attach videos and other electronic files to the fields. This allows for the display of the effect of heavy dynamic loads on various components. This has already been used to demonstrate how in unloaded situations the structure appears normal, but when a load transverses it’s various components begin vibrating and contacting each other out of tolerance.

• Standard Report Output: The same paper reports plus photos and attachments are still available from the system at the click of a button. They are generated as PDF files and can be printed out just as before providing for a consistent reliable format with no work needed by the inspector (Fig. 6).

• Summary Reports and Tools: With all of the inspection data available in a powerful database, a wide range of new summary reports and search tools are now available to all personnel. Line managers have access to reports that show all items under their responsibility that have received flags (i.e. safety hazard) or they can sort by those receiving low condition ratings.

Additionally, there are reports that allow the monitoring of the status of inspections by structure. This helps in scheduling and tracking scheduling work that remains done. Inspections are tracked through each phase of the process from creation/start, to field work, to review, to final approval. Finally, the software has a built in query/report tool that allows users to create their own dynamic reports based on any ad hoc information that is needed. This powerful functionality allows for criteria pertaining to different components to be combined using Boolean logic (and/or) and detailed lists obtained on any structures or components that match that criteria. Now the answer to any question on current system status is literally a few clicks away.

**UTA Details:**

In 2009, the Utah Transit Authority began searching for a state of the art, integrated software solution that could help them inspect and manage their extensive and rapidly growing network of light and heavy rails. UTA has also adopted a system similar to that of DC Metro’s. The system allows for all of the FRA requirements to be met and for information on all structures to be located in a single easy to access location. The software allows for UTA to enter in its own inspection forms and all other documents related to the
structure. The system also provides an interactive mapping interface which provides GIS coordinates for every UTA structure as well as displays them with multiple views and zooming options (Fig 5).

**West Virginia Central Railroad Details:**

Consultants are often employed to perform inspections on railroad infrastructure. The West Virginia Central Railroad and South Branch Valley Railroad utilized this approach to inspect their 70 bridges. The consultant charged with performing this inspection was familiar with integrated inspection and management programs utilized in the highway industry. In order to streamline their inspection process and also to deliver a higher quality report they chose to implement an inspection software solution. The software was used on all structures from single span to structures with over 20 spans. For these inspections the software was configured to perform span by span inspections with an overall summary narrative. Digital pictures were also taken and attached directly to the bridge structure and specific areas. Additionally, each inspection report was generated with a cover page. This cover page could be generated automatically since all of the information it contained, including the elevation photograph were already present in the body of the report. Thus, no additional time was needed in preparing this section of the report.

**CONCLUSION**

Structure managers face an increasing challenge of managing aging infrastructure on limited budgets, leading to difficult choices and tradeoffs. Adequate and accessible condition and assessment data on structures is vital for making these critical decisions on the maintenance and safety of bridges and other maintenance of way assets. Technology is increasingly allowing railroads and transit agencies of all sizes to implement integrated inspection and management software to assist with obtaining accurate and timely data. This is helping to improve efficiency throughout the process and making data much more readily available whenever and wherever it is needed. Software is further enabling systematic maintenance efforts to move from reactive to proactive approaches, leading to an optimal usage of limited resources.
REFERENCES


**Figure 6. Example Output Page from WMATA inspection report.**

Table: Abutment (Entrance Side)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>NO.</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Drips and weep-holes</td>
<td>4</td>
<td>Mudcrack staining out of 2&quot;. Drips on southeast side wing wall and breast wall. Collecting up to 2 baskets full. Material draining from approach slab.</td>
</tr>
<tr>
<td>2. Joints (expansion, construction, cold)</td>
<td>4</td>
<td>Backer rod installed between end of span and backwall, therefore blocking visual inspection to any expansion joint. However, joint is leaking water and soil onto bearings, causing corrosion and affecting movement. See picture #5.</td>
</tr>
<tr>
<td>3. Bearings Assembly (List type and size)</td>
<td>4</td>
<td>a) Pod bearings fit at entrance side.</td>
</tr>
<tr>
<td>4. Physical condition</td>
<td>4</td>
<td>k) Grinding and concentrated box of section (2%) on exterior surface. Up to 50% of device is corroded. Picture #6.</td>
</tr>
<tr>
<td>5. Working condition</td>
<td>4</td>
<td>2) Working condition is affected by heavy corrosion. Ongoing construction on deck. Unable to determine working conditions.</td>
</tr>
<tr>
<td>6. Tension Plate</td>
<td>5</td>
<td>k) Stable, with some steel exposed due to grout pad deterioration throughout.</td>
</tr>
<tr>
<td>7. Exposed ribbed reinforcing steel</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>8. Concrete Patches</td>
<td>4</td>
<td>m) Spalled concrete on grout pads. Bearings</td>
</tr>
<tr>
<td>9. Grout (masonry pads)</td>
<td>4</td>
<td>1n) As indicated above, grout pads (2&quot; x 1.5&quot; x 6&quot;) are spalling full face and deep up to 1.5&quot; on bearings. See pictures #8.</td>
</tr>
</tbody>
</table>

**THINK SAFETY FIRST**