# Utilizing Tomorrow's Technology to Manage "America's Tunnel Highway"

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ABSTRACT:

The size and age of the PA Turnpike presents many challenges in managing its structural assets. The Turnpike utilizes its extensive recordation system and the latest technologies such as Electronic Data Collectors for the continuous inspection, maintenance, and condition assessment of its many bridges and tunnels.

## INTRODUCTION

The Pennsylvania Turnpike System has been operating for over 50 years. The age and size of the Turnpike, which continues to expand, presents a large array of assets to manage when compared to a more typical toll facility.

**Figure 1 - Original 1950's construction**

Structures Operations is one component group of this overall system. The relatively small Structures Operations group is responsible for the continual condition assessment and maintenance of bridges, culverts, tunnels, sign structures, high mast lights, and other miscellaneous structures. In addition, Structure Operations is responsible for emergency assessment and repair of damages due to collisions with, or accidents adjacent to, the numerous structures along the over 530 miles of highway. Condition assessments, maintenance, and rehabilitations are accomplished with regionalized turnpike maintenance crews, outside contractors and engineering consultants. The skilled and knowledgeable staff must prioritize the limited funds available while considering and coordinating with the numerous ongoing and planned new construction and rehabilitation projects. This task is accomplished by using advanced management tools and progressive technology. Several database systems are used to aid in tracking condition and repairs. These databases include the Bridge Management System (BMS), the Tunnel Management System (TMS), Bridge Inspection program utilizing Electronic Data Collectors (EDC), and the Service Order Management System (SOMS). Each of these components is integrated to the overall Roadway Management System (RMS) to provide a comprehensive management tool

Structures Operations small group of engineers and technicians manage over 1700 various types of structures throughout the system. The turnpike is a quasi-public toll facility that does not receive federal or state funding. Most inspection and repair work is contracted with outside sources. Regional turnpike crews perform some minor maintenance.

ASSETS

The various structures under the operations group include bridges, culverts, tunnels, sign structures, high mast lights, and other miscellaneous structures. Continual inspection programs are maintained for these structures on periodic basis as established by federal law or standards of practice.

**Figure 2 - Joe Montana Bridge on the Mon-Fayette Expressway**

Bridges constitute the largest component of the structural assets. There are over 800 structures throughout the system that fit the federal definition of a bridge, which is a span greater than 20 feet. These bridges are inspected on the required 2-year cycle.

Despite the many bridges, the Turnpike was labeled the Tunnel Highway for its many tunnels throughout the system. Five sets of active tunnels and one inactive tunnel are maintained. The active tunnels total more than 4.5 miles of underground roadway.

As with any turnpike system, there are also numerous sign structures, retaining walls, noise abatement walls, and various other structures that must be maintained. The Turnpike has embraced technology as a means to manage the various elements of one of the largest turnpike systems.

ASSET MANAGEMENT

BRIDGE MANAGEMENT SYSTEM – The Turnpike maintains an Oracle database Bridge Management System. Referred to as the Bridge Log, this database contains geometric information, load and condition ratings, and other pertinent information. Integration of the Bridge Log with bridge inspections and maintenance work orders has eliminated multiple file sources and increased efficiency.

As shown in Figure 3, the data is separated into seven tabbed categories - structure data, location, inspections, load ratings, clearances, work orders and miscellaneous. In general, the information provided is obvious. Therefore, only key components will be discussed.

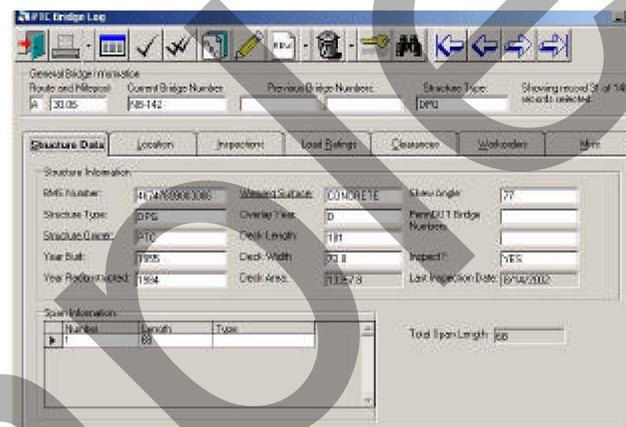


**Figure 3 - Bridge Log Structure Data Screen**

The Inspections tab is shown in Figure 4. This screen provides the most recent inspection data including a links to inspection reports and photos. The inspections data is populated directly from a separate Inspection Database, which is discussed in more detail later. This compatibility improves recording efficiency and accuracy. These links (highlighted) improve the program utility and provide efficient access to relevant data.

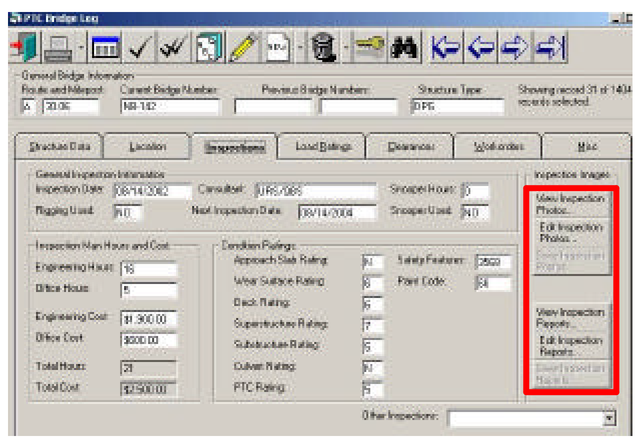


**Figure 4 - Bridge Log Inspections Screen**

The Work Order screen is another feature of the Bridge Log that provides efficient and accurate information accessibility. Shown in Figure 5, this screen provides details of work orders for each structure. This information is tied to the Bridge Inspection Database and a work order management database. These connections provide efficient transfer of data from bridge inspectors, to the structure's group, to the maintenance foreman, and back again to the structure's group upon completion of the work.

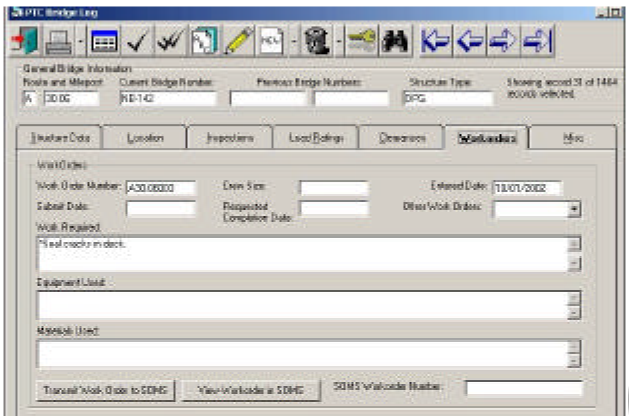


**Figure 5 - Bridge Log Work Orders Screen**

The Service (or work) Order Management System (SOMS) is another Oracle based database used to generate and track work orders throughout the turnpike system. This management tool is used by all disciplines within the Turnpike. The limits of this article do not allow for a more detailed description of SOMS. However, SOMS is an integral part of the Turnpike's overall asset management.

TUNNEL MANAGEMENT SYSTEM – In the 1990's the Turnpike developed a Tunnel Structural Database for management of the various system tunnels. This 'first generation' program was developed for storing and tracking in-depth inspections findings such as condition ratings, photos, and sketches. The system initially included a component to generate work orders and track maintenance of the various tunnel systems. As previously discussed, SOMS is now used to track all turnpike maintenance work orders.

The Structural Database allows the inspectors at the tunnels to utilize data collectors to gather the data in the fields and to download this data directly. As noted, this is a first generation program and is being considered for update to improve usability and incorporate new methods and technology.

A Tunnel maintenance database, founded on the Turnpike's Tunnel Structural Database was developed for Federal Highway Administration (FHWA) and Federal Transit Administration (FTA). This FHWA/FTA program is now available to all tunnel owners.

INSPECTIONS

The Turnpike selects consultants from statements of interest to perform federally mandated periodic bridge inspections on a two-year cycle. These contracts include system-wide inspection of bridges and may include inspections of sign structures, walls, high-mast lights, or tunnels. The consultant is also responsible for around the clock emergency response to assess collision damage or other incidents that may affect structure integrity.

In-depth inspections of Tunnels and major structures are generally contracted separate from the routine inspections. However, interim structural inspections are conducted as part of the bridge inspection contract.

In the past, inspections have required taking field notes and photographs and returning to the office to assemble a neatly hand-written report. Information from the handwritten report was then manually transferred to the appropriate management database. This method was time consuming and required significant paper file space to store the reports and photographs.

Therefore, the turnpike has turned to electronic data collecting as a means to improve data management efficiency.

INSPECTION PROGRAM – The turnpike has developed an electronic data collection system, to increase inspection efficiency and provide electronic reports, which are suited to the industry trend toward electronic storage of data.

Developed in cooperation with experienced inspectors, the program utilizes MS Access and the Windows operating system to provide a user-friendly field tool. The program provides a series of pick lists that the user can select, which minimizes typing by the inspector. The pick lists provide consistent terminology between inspection teams and inspection cycles. The electronic reports, which are saved as MS Snapshot files independent of the database, reduce paper storage requirements and improve report consistency. Combining the electronic report with digital photos allows for fast and simple transfer of data between inspectors, reviewers, engineering and maintenance. The database format also permits easy portability of data between various management databases and systems.

The following provides representative steps in the program used by inspectors in the field to record inspection data.

Initially, an inspector logs into the program and selects the bridge identified for inspection, to bring up the screen shown in Figure 6. This screen provides specific bridge identifying information and current available inspections. By simply selecting the Duplicate Inspection button (highlighted), the latest inspection is copied.

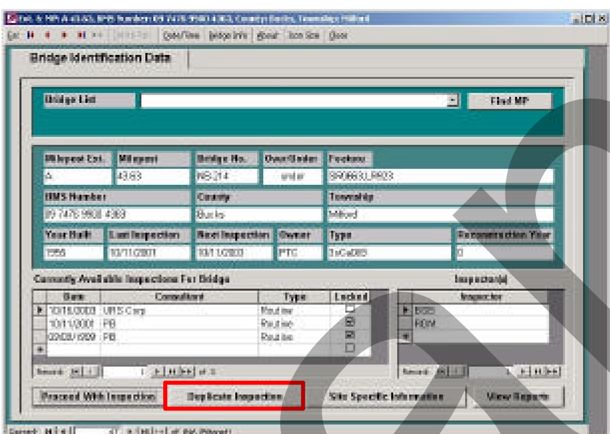

**Figure 6 - Initial program screen**

Having selected the bridge for inspection and duplicating the previous report, the program defaults to the deck description of deficiencies shown in Figure 7. Any bridge component can be chosen from the pull down menu.

The inspector then proceeds through various screens making edits to indicate the current bridge condition. Since information is copied from the previous inspection, much of the inspectors work is merely verifying the existing deficiencies and adding new information.

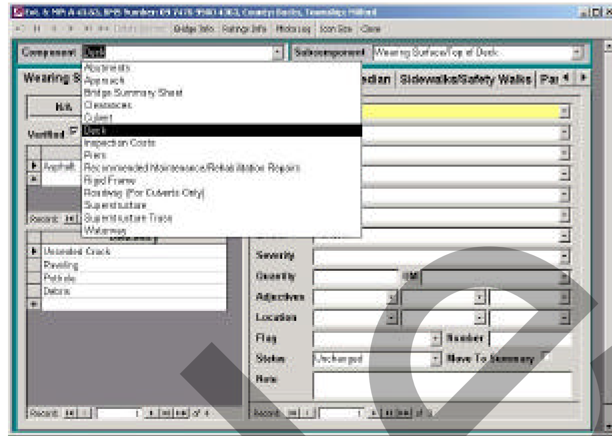

**Figure 7 - Component Pick List**

For simplification of presentation, we have proceeded through the deck component screen. The various components and subcomponents of the bridge function similarly. That is, each has various pull down menus to describe subcomponents, deficiencies and complete various information fields.

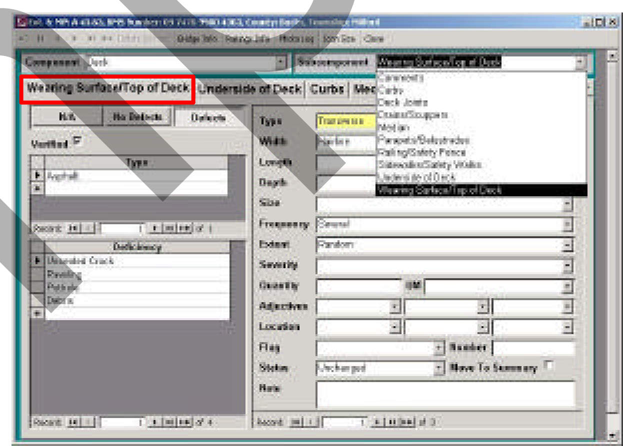

**Figure 8 - Subcomponent Pick List**

The inspector next selects a subcomponent from the pick list shown in Figure 8. The inspector also has the option of picking a subcomponent from the tabs provided near the top of the form.

In this instance, the inspector has selected Wearing Surface/Top of Deck. He then proceeds to describe the type of wearing surface, concrete, asphalt, etc., using the pick list shown in Figure 9.

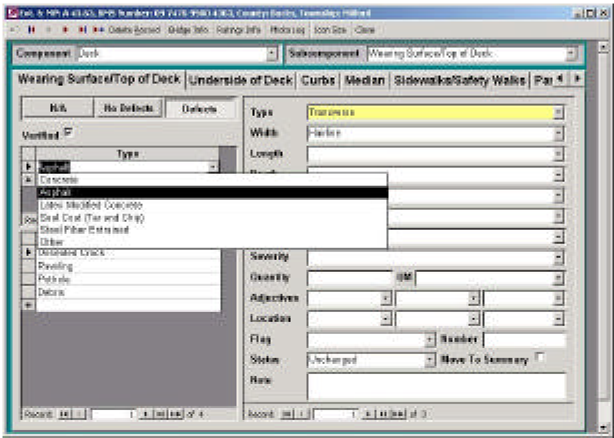

**Figure 9 – Subcomponent Type Pick List**

Multiple subcomponent types can be chosen. For instance, if Span 1 is overlaid with asphalt and Span 2 still has the original integral concrete surface, a separate type for each is identified. Descriptors that identify the location for each type can then be picked. The inspector then chooses the deficiencies from another pick menu. See Figure 10. As with the Type, multiple deficiencies for each subcomponent type can be recorded. In addition, an unlimited number of deficiencies can be described for each deficiency type.

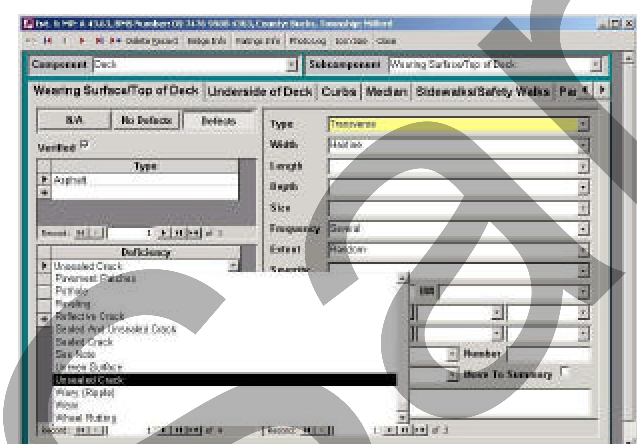

**Figure 10 - Deficiency Type Pick List**

Deficiencies are further described with a series of standard adjective descriptors that indicate size, location and extent. See Figure 11. For each deficiency, the inspector also indicates the status as either unchanged, worsened, repaired, or improved. The deficiency may also be identified to be moved to the report summary if the inspector feels the deficiency is important or is representative of the overall condition. Finally, the inspector may also choose to flag the deficiency as a repair or rehabilitation item.

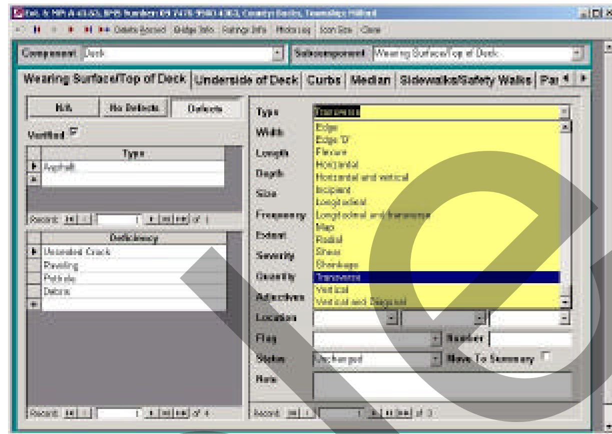

**Figure 11 – Deficiency Descriptor Pick List**

This process of selecting a component, subcomponent, deficiency, descriptors and status is repeated for each applicable component of the structure to complete the report.

Condition ratings are selected from a separate input screen. Help screens describing the purpose and method of condition rating and are available to aide the inspector in the assessment.

Once the inspection report is complete, a more readily readable copy is generated and saved as an MS snapshot file. The report summary page includes inspector-selected deficiencies that represent the overall condition. The deficiencies are written in semi-sentence form using the descriptors from the various picklists. An example follows.

> Deck-Wearing Surface/Top of Deck-Asphalt has Unsealed Crack, Transverse, Fine-to-Medium, Full Length, Several, Above, Bearing(s), And, Along, Deck Joint(s), Repair Item, Worsened

In addition to representative or major deficiencies, the report summary contains repairs since the last inspection and recommended maintenance or rehabilitation items. Examples follow.

**<u>Repairs/Improvements Since Last</u>**

East approach repaved

**<u>Recommended Maintenance Repairs</u>**

**PTC** * Repair damaged fence.
* Clean and flush deck and joints.
* Seal cracks in deck.

**Local** * Stabilize approach roadway settlement.
* Seal cracks in approach roadway.

**Recommended Rehabilitation Items**

* Paint entire superstructure.
* Upgrade/Install bridge parapets.
* Replace/repair expansion bearings.
* Seal longitudinal center deck joint.

As with the other input the recommended maintenance and repair items are selected from pick lists by the inspector. More in-depth descriptions can be typed if desired or required.

The summary page is followed by detailed output of each component, subcomponent, and associated deficiencies. Condition ratings are printed along side the applicable component being rated.

SYNCHRONIZATION – The previously described inspection procedure might be performed by more than one inspector on the same bridge or by multiple teams on various bridges simultaneously. Therefore, synchronization of the database is a necessary step in maintaining current information.

Procedures have been established to insure multiple inspectors work on separate components of the same bridge to avoid duplicate input. When the inspection is completed, the inspectors synchronize the database from their individual EDCs to create a complete report. If the inspectors have inadvertently input information for the same component, conflicts will be flagged by the synchronization process that must be revised before synchronizing with the master database in the home office. As with any computer work, backup files are also created.

Generally, each inspection team will then synchronize their individual database with the office database as often as practical – usually after about one week's worth of inspections. This routine maintains current information and allows for quality assurance review in the office while inspections continue in the field.

ELECTRONIC DATA COLLECTOR – The Electronic Data Collecter (EDC) used by the Turnpike, shown in Figure 12, is the Fujitsu 3400 Pen Tablet. The EDC is 8.5 inches by 11 inches, just over 1 inch thick, and weighs 3.2 pounds.

**Figure 12 - Electronic Data Collector**

Commands are pen activated. A padded carrying case that protects the EDC and facilitates use in the field is not shown.

The computers are powered by rechargeable lithium ion batteries or by AC/DC electric cords with converters. Additional compatible hardware includes a AC/DC battery charger, a portable zip drive or flash card, a docking station, and an infrared (wireless) keyboard. The docking station also has ports for a mouse and full size keyboard if desired. The entire set-up for a single inspector fits into a small backpack or a briefcase.

Only the data collector was needed during the field inspection and the other items were kept in the inspection van. Spare charged batteries were always kept available and used as needed. Handwriting recognition is available for the data collectors, but as not been implemented.

The EDC's are relatively easy to transport in the field and the pen and pick lists make most input quick and easy for the inspector. As with any new equipment there is a learning curve until the inspectors become familiar with the software and adjust their methods to suit use of the hardware. However, after a few inspections, the user quickly becomes familiar with the program format and pick lists information available.

The ability to duplicate the previous inspection is a significant advantage provided to the inspector. Much of the inspector's work is merely updating the status or adding information. Therefore, field input is limited and made simple by the pick lists. Also, final reports are generated as the inspection is conducted. Only minimal work is required after the inspection to provide a complete comprehensive report.

However there are a few drawbacks regarding the field use that must be resolved. Screen glare can make reading the screen difficult. And taking notes beyond pick lists is cumbersome. Finally, climbing or other physical activities associated with inspections while protecting the EDC can be of concern at times. These problems will be addressed in future upgrades of hardware and software.

PHOTOGRAPHS – In addition to generating database reports, inspections include digital photographs. The Turnpike supplies cameras to the inspectors to insure uniform format and resolution of photos. The resolution of photos is optimized to provide a readable photo while minimizing the size of the photo file.

Representative photos are provided as a separate document from the database generated report. The inspectors insert photos into a MS Word document and provide captions for each. This format allows for easy storage and access.

The electronic format allows for immediate review in the field to insure photo quality. In addition this format eliminates film development time and physical storage requirements. Finally, integration with other electronic data systems is facilitated. As discussed previously, the Bridge Log has a direct link to inspection photos, which improves efficiency within the office.

DATA TRANSFER – In the field, transfer of data between handheld computers is accomplished by using a zip drive or flash card. In the office, the handheld computers can be connected directly to the consultant's office network, which allows simple and quick transfer of data between computers.

Electronic format allows easy transfer of information via the Internet or Compact Disc. This allows almost immediate access to information from virtually anywhere. Since the Turnpike regional offices and maintenance facilities are linked, availability of up to date information is readily available. This ready access improves the efficiency and effectiveness of engineering, assessment management, maintenance activities and planning

NEXT GENERATION – As with any new application whether or not technology related, the effectiveness of the application may take a few generations to resolve problems or improve the usefulness. The Turnpike's asset management through technological application, though beyond infancy, has room to improve before fully mature. Also, as technology improves, state-of-the-art hardware and software will be introduced as is practical and necessary. Therefore, improvement and upgrade of the means and methods will be continually assessed and enhanced.

Some of the improvements to be addressed in the near future are:

- Improve efficiency of database. - Use current database techniques and software to make recording and transfer of data efficient. An update of software is planned in the immediate future.

- Minimize inspection database size. – Format and quantity of files can make transfer of data cumbersome at times.

- Upgrade EDC hardware. – Minimizing screen glare and improving durability are goals.

- Develop additional inspection databases. – Develop similar programs for other structure inspections, such as tunnels, signs and walls, using a compatible platform.

- Download of information directly to PennDOT BMS – Though information is directly downloaded to the Turnpike's Bridge Log, information is also provided to PennDOT but is input manually.

- Improve compatibility. – Consideration of software upgrades to improve inspection database compatibility with Turnpike in-house systems.

- Further Integrate records. – The next phase in data storage and access is to provide electronic copies of design drawings and calculations and shop drawings as a link to the Bridge Log similar to what is currently available with inspection reports.

## CONCLUSIONS

The Pennsylvania Turnpike Commission's decision to utilize the available computer technology has greatly improved their Asset Management. The integration of the electronic data collectors for the inspections, the electronic download capability of data into the Commission's Bridge management System and the seamless connectivity between the Bridge Management System and the Maintenance's Work Order System has allowed the Commission to stay on the cutting edge of technology. With the implementation of these programs, the Commission has realized a savings of cost and time associated with the managing of their assets.

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