The Evolution and Benefits of Web Based Viewers for Pavement Data

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ABSTRACT
The data collection and processing for transportation asset management has evolved over time with technology. Collection results now contain a larger volume of data than ever before, and the time to obtain the results is getting closer and closer to real time. The industry has developed web based data viewers to better provide instant representation of the data. Pavement images are hosted in the cloud and made rapidly available to agencies. This allows for feedback within days of collection on location, data quality, and pavement condition. Accurate GIS information allows agency personnel to implement quality control (QC) on the data instantly and flag potential issues prior to the final delivery. Incorporating distress information and other innovations will allow agencies to get more out of the results while the results are still current. Once accepted, the data can be quickly shared to a range of stakeholders. This prevents long trips to view remote sites and extra project level investigations. Web based systems have evolved dramatically in the last five years and are widely used by a variety of agencies. The coming years will show many new features, such as back projection, asset identification/measurement, and collection tracking, all of which can be completed on the web, in real-time, as the vehicle drives down the road.
INTRODUCTION
For many years now, road agencies have been collecting information on the condition of infrastructure assets. This information gets collected, typically on an annual basis, and used for the specific purpose of developing a priority plan for future construction and rehabilitation of roads and other transportation assets. As more years of data become available, other groups are starting to see the value in the data that is being collected and stored.

To attain the greatest value from data collection, the data must be shared with as many people as reasonably possible. The ability to collect data has increased exponentially, and the Information Technology (IT) infrastructure of agencies has greatly improved, especially in the last few decades.

Today, agencies are willing to make the data and results public due to the acceptance of the results and the known benefits of transportation asset management. Increasing the transparency of the information and distribution within the agencies is becoming an agency priority.

One of the simplest ways that agencies have started to adopt this is through the use of web based viewers to show current and historical information on transportation assets. A range of solutions are being developed in-house and by the private sector to show off this information. These web based systems display the video recorded and create customizable maps to provide the information in a meaningful format. If more information can be made available and structured in such a way as to suit the needs of multiple departments within road agencies, the need for information will increase, as will the application of recommendations.

EVOLUTION OF ASSET MANAGEMENT INFORMATION
The information collected for asset management purposes has changed dramatically over time. While the information continues to advance, it has transitioned from analog to digital, and the formats have moved from difficult to access localized storage, to cloud based technologies. As such, it is much easier to get the information out to those that need it.

Right-of-way (ROW) Video
To understand the condition of the road network, video has often been used. By having images of the assets, a detailed history is created. Film photography was the first stage of this process, as engineers and contractors recorded the results of construction and inspections. However, this record was limited to those who had access to the developed photographs.

The inspections took a technological leap forward when moved to recording a continuous video of the road right-of-way. This meant that a complete record of the road could be taken as opposed to an individual deciding which photos to take. Most commonly, VHS tapes were stored in a department of transportation office, making them difficult for other interested parties to view. The other major issue with the media of VHS tapes was locating a specific location on a library of tapes.

The application of digital video cameras was the next major step forward for asset management systems. Digital images allowed the information to be seen by anyone with access to the computer network. The quality of digital video cameras has greatly improved with time, providing increased resolution, less light sensitivity, and improved image quality and contrast (1). See Figure 1 for a sample ROW image.

However, the use of digital imagery has led to new challenges regarding the data storage requirements for many agencies. With High Definition (HD) quality video, the long term storage
can be up to 250 megabytes (MB) per mile of road monitored. This is further increased when pavement images showing detailed surface conditions are included, which require an additional 700 MB for every mile (2).

FIGURE 1 Sample ROW image.

Geographic Information Systems
The ability to map performance data is by no means a new concept. However, digital maps are more common in presentation and report materials provided to decision makers today because of the ability to generate these maps quickly, without extensive training.

Much of the data provided by service providers consists of flat tables. This information has always been tied into linear reference systems, which for many years were the only way to align data, provide a consistent record, and track changes of performance. The linear reference system uses a series of locator fields to indicate the exact location of test results. Depending on the state and the referencing system, this typically includes a reference specific to the highway, mile post, direction, and lane.

The popularity of Geographic Positioning Systems (GPS) has increased over time and the increases in accuracy have also become available (3). GPS information provides the ability to know the location of testing and has taken a step to the next level. While linear reference systems are still used to relate historic data, GPS provides an independent source of information.

Many of the collection vehicles, currently being used around the world, use technology beyond what is standard in satellite navigation devices. The availability and use of Inertial Movement Units (IMU’s) has become common in data collection. These devices determine vehicle movement and direction changes, which increase accuracy and provide information with a temporary loss of GPS signal. While these devices can be expensive, they improve position accuracy when coverage is expected to be intermittent due to roadside obstructions such as
topography, buildings, bridges, tunnels, and heavy tree coverage. Many of these systems provide accuracy levels less than 1 m while travelling at highway speeds.

**ASSET INVENTORY**

Asset collection and maintaining an accurate inventory has always been a fundamental part of pavement management. However, technological advances have improved the ability to collect additional roadside assets beyond just pavement.

Photogrammetry can be used to triangulate the position of assets, such as road signs, by using the location of the collection vehicle and the location of the asset within calibrated camera images. The assets are identified in consecutive images and the GPS coordinates of the assets are measured generally with an accuracy of approximately 1 m. Photogrammetry techniques have been used for almost 15 years to improve inventories. This methodology can be used to measure the location and dimensions of assets in the right-of-way videos. This has been frequently used for assets such as signs, lighting, guide rails, shoulders, lane widths, medians, etc.

New technologies are taking advantage of Light Detection and Ranging (Lidar) advancements. Lidar uses a series of lasers to measure the location of many points within the line of sight of the vehicle. Combined, these form a point cloud which can generally describe the outline of an entire neighborhood.

**Asset Condition Information**

In the 1950’s, the AASHTO Road Test used a simple rating system of one through five to evaluate the condition and usability of roads. This system is designed to exhibit the perceived service quality for passengers driving over a road section.

This system worked well to describe when a road was due for rehabilitation, but it didn’t provide any information on why the road was deteriorating or how best to maintain its condition. Other systems were developed to provide more specific information for these issues.

The International Roughness Index (IRI) was adopted by the World Bank in 1980. This measurement provides an objective, vehicle based measurement to evaluate the functional characteristics of a road. The IRI provides a consistent method of testing that can be used to compare the same road year after year.

However, the roughness of a road does not provide much information on how to repair a road for a longer life. So distress monitoring procedures were developed to identify a range of common symptoms that relate to the root causes for some of the more common issues. A variety of distress manuals became very common, as different agencies developed their own protocol to ensure that their specific issues were adequately represented. Many of the early distresses are becoming less common as technology for construction has improved. As more distresses were identified, the causes became better understood and the issues were able to be addressed through updated construction specifications and practices. For example, bleeding and corrugation are substantially less common, now that the causes are better understood and can be controlled in advance. See Figure 2 for a sample pavement image and distress.
ASSET MANAGEMENT INFORMATION FOR ALL
The information collected as a part of the asset management program has changed a lot over the last two decades. Specifically, there is a lot more information now in a format which is much more easily distributed. Organizations are starting to recognize the benefits of having accurate and easily accessible asset management information.

This increased need for cooperation has spawned the creation of many different ways to make the data available. Historically, desktop software has been installed on individual computers, then using local area networks, databases and images were shared with the software. Needless to say, most IT departments were hesitant to implement these solutions, specifically when thousands of users were required to have access and up to date software.

There is also a need for users in remote offices to have access to asset management data. Either additional copies of the large datasets were needed in several locations, such as district offices, or wide area networks with limited speed were used. This has led to a range of performance issues and complaints.

Now that all of the data being collected is available in digital format, this information is significantly easier to distribute. Subsequently, cloud based technologies and road agency networks have improved to make them more practical.
Web Based Data Viewers
Taking web based data and distributing it to a larger audience is exactly what the internet has been designed to do. Web viewers are available on every modern computer, and have the ability to view and manipulate large amounts of data on remote systems (see Figure 3). Data can be uploaded from the host computer, and instantly rolled out to all users, without changing anything on end user computers.

This environment is ideal for large agencies, which have users scattered over a large geographical area. Capabilities include viewing images, creating custom charts and analysis, thematic maps, and the ability to download portions of the network for other uses such as reports and distribution to third parties.

FIGURE 3 Sample web based viewer.

In addition to having access to the collected data for the most recent collection cycle, it makes it possible to see data from historic cycles as well. Since all of the data is stored in one central location, the value of maintaining the complete archive is higher. This allows technical staff to review the images and historical condition of individual sections to show when specific deficiencies manifested and can provide information on the root cause of distresses. Other internet based information can be combined and linked to the data collection surveys. Web map sources like Google and Bing Maps can be used and plotted behind the maps (see Figure 4) (6; 7). This allows for other features, such as bridges, intersections, and railroad crossings to be quickly visualized to understand localized differences in performance.
Privacy Concerns
One of the concerns with web based applications is that there is a lot of public data, including photographs, that are available. Many other sources of data spend significant time and effort to blur out faces and license plates to ensure the privacy of the general public (8). However, this is often an additional expense that many agencies do not see value in for asset management purposes.

Care must then be used by agencies wishing to open up all of the data available to the general public. Generally, this has been addressed by either ensuring the data is only available within an agency network, or using security credentials to access the data and keep the data in front of only authorized individuals and groups.

While privacy concerns should not prevent any agency from using web based systems, it should be understood that the information still needs to be controlled.

Mobile Solutions
Mobile applications are common now that the bulk of mobile phone users have smart phones and data plans. As such, vendors are looking to make the information more portable. Many people are looking to ensure that the cloud based data sources are going to be available on mobile devices (9).

The challenges with mobile devices are that different phones and tablets have different operating systems and security settings that restrict development. In many cases, different versions of software are required for different devices. For a universal solution, a web page with reduced functionality is the only option. These options may increase costs for development and improvements. Improvements and consolidation of web development tools are expected to improve the capabilities in the future.

THE NEXT EVOLUTION
As has been illustrated, the technology has changed a lot over the last few decades. It is expected to continue to improve and make the information more useful to all road stakeholders. While technology is not always easy to predict, there are some areas that are expected to be enhanced which will improve the ability of web based solutions.
Network speed has shown remarkable advances in the last few years and is expected to continue to improve. This will ensure that the data can be accessed in a timely manner to all end users. Increased network speeds provide the opportunity to add data such as Lidar results, higher resolution images, and higher levels of data detail.

Increased network traffic and server speed improvements also mean that users can process more data to meet their specific requests. This means that it is possible to do some of the analysis, asset identification, and editing of pavement distress over the web. This opens opportunities for crowd sourcing initiatives and end user quality checks.

Mobile network speeds also open the door for viewing data in real time during collection. Current technology makes it faster to move large amounts of data from collection via courier service than over the internet. The ability to upload data during collection has several key advantages, including the ability to monitor data collection in real time, identify collection problems while the vehicle is still close by, and start processing data days sooner than previously possible. Results can then be refined while available in real-time.

SUMMARY AND CONCLUSIONS
Transportation asset management has made significant improvements over time. Many of them lead directly to the ability to make data available over cloud based delivery tools like web applications. These tools allow agencies to share the data with remote users and other departments within an organization and ensure that the data is delivered to those who need it most. Having data readily available prevents unnecessary and expensive visits to the field to investigate sites. With the availability of historical information, it is easier to see trends and investigate the root causes of various problems encountered in the field.

The data itself also becomes easier to manage. IT departments can maintain a single repository of the data and software, rather than deploying it to different offices and installing desktop software for thousands of users. Updates can be completed simply and the information is then available to all users simultaneously, greatly reducing support time and expenses.

There are many potential future advances for this technology as well. This will allow for data to become available to end users in almost real time which improves the amount of use it will get. Faster networks mean that quality and processing times will continue to improve and allow more information to be processed. Real-time quality control will also ensure that communication between field crews and office staff is significantly improved.

The trend towards cloud based delivery solutions is expected to increase over the next decade. With a range of hosting solutions available, the limitations will be the imagination of the industry, rather than the technology available for implementation.
REFERENCES