IT Infrastructure Problems for Asset Management

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Abstract

Transportation infrastructure asset management efforts normally focus on collecting data on items with low volumes and higher capital costs, such as bridges. Road signs and pavement markings, on the other hand, are high volume, low capital cost items but are critical elements of the transportation infrastructure. These high volume assets serve a critical function, safety, and thus they are receiving attention. In particular, the Federal Highway Administration (FHWA) has been working to establish minimum retroreflectivity standards for signs and pavement markings.

This paper seeks to address information technology (IT) problems that emerge when developing an overall asset management system for high volume assets and to identify their unique characteristics. These IT problems include asset identification, asset location, data availability, data fragmentation, automated data collection, software selection, and system size and resources. A discussion of the issues related to these problems is presented herein to facilitate the development of more comprehensive systems to manage the automation of infrastructure asset management systems (AMS).

Introduction

Maintaining aging transportation infrastructure concurrently with transportation budget constraints has resulted in a need for new tools to manage transportation assets. These tools include inventory, condition, and performance databases and models for predicting budget needs, maintenance, and asset performance among others. All of these databases and tools rely heavily on information technology (IT) to streamline the gathering, analysis, and interchange of transportation asset data.

The first major applications of asset management to transportation infrastructure focused on low volume, higher capital cost assets such as bridges and traffic signals.

Once management systems were developed using IT for these low volume assets, the focus began to shift towards high volume, low capital cost items which had previously not been considered. Examples of higher volume, lower capital cost assets include signs, pavement markings, guardrails, and roadway lighting. In NC, there are over one million road signs with an average cost of \$65 each and 78,000 miles of road with pavement markings whose average replacement cost is 35¢ per foot. These high volume assets are as critical to the safety of the transportation system as the low volume assets. In addition, the high volume assets as a whole represent one of the largest capital investments of state governments (Haas and Hensing 2004). An asset management system for high volume, lower capital cost assets can enable transportation agencies to direct budget resources towards the maintenance of assets that are in the poorest condition, are the most critical to motorist safety, and have the lowest lifecycle costs.

For low capital cost assets, several IT problems arise related to collecting, managing, and analyzing asset data. These include: Identification of the asset, Locating the asset, Critical data are unavailable, Existing data is fragmented, Automating data collection, Choice of software, and System size and resources.

Asset identification requires assigning a unique identifier to each low value asset and having this number accessible both in an asset management database and in the field at the asset's location. The location of the asset also needs to be included in the transportation infrastructure AMS database. The location information can be recorded and included in the database using Global Positioning System (GPS) coordinates, a linear referencing system (LRS), or through other means. In a typical roadway LRS, each roadway is given a unique route number and the distance along the route from a specific point of origin (usually a state or county boundary) is used to locate points along the route. The distance units are usually marked with signs placed along the route (mileposts) to determine the position of either linear features (such as a guardrail segment) or data collection points in the field (Flintsch et. al., 2004).

In addition to an asset's identification number and location, an asset database will include attributes such as installation date, material characteristics, and asset condition. These attributes are critical to determining which assets require maintenance and when but they are often unavailable. Asset condition information is also needed to determine compliance with minimum performance standards. Recently, the FHWA has proposed that minimum sign retroreflectivity standards are included in the *Manual on Uniform Traffic Control Devices* and is developing minimum standards for pavement markings (Schertz 2002).

The fragmentation of existing data results from transportation agencies using different data collection standards over time with the net result being that data is stored in dissimilar formats. Automated data collection for low value assets generally involves mobile units that can collect identification, location, and attribute data for hundreds or thousands of assets in a single day. Problems in automated data collection arise in

calibrating the mobile unit, integration of the instruments and hardware in the unit, and integrating the collected data into the AMS.

Data integration also depends on the choice of asset management software. A transportation infrastructure AMS can be based on software that is custom developed for the agency using it, or an existing application can be purchased from a vendor. The overall asset management strategy chosen by an agency depends on the size of the transportation infrastructure system to be managed and on the financial and personnel resources available to collect data, analyze results, and maintain the AMS. The following sections expand upon each of these problems.

Asset Identification

A key IT problem for low capital cost, high volume assets is asset identification during data collection and analysis. Identification system technology is critical for IT implementations. An asset cannot be linked to its attributes in a database without an identifier. Typically, this requires labeling each asset in the field with an identifier, which can be a daunting task when millions of low capital cost assets need labeling. Most often, assets in the field are not labeled, making it impossible to ensure that the asset is consistently identified over time. Some assets, such as pavement markings, are very difficult to label at all due to their location and characteristics.

Identification labels can take on several forms. The simplest is to write or attach the asset's identifier onto the asset. In a project conducted for the North Carolina Department of Transportation (NCDOT), the authors used a permanent marker to write an identification number on each road sign that was included in a study of sign replacement and deterioration (Rasdorf et. al. 2006). The drawback to using such a label is that the marking could fade over time. Furthermore, it is not machine readable which limits the automation of data collection.

To speed data collection, an asset's identifier can also be encoded into a barcode label placed so that field technicians can more quickly read it using an electronic data collection device with a barcode reader. But without also having a numeric identifier on the asset, those without a barcode reader would be unable to identify it. Technologies such as radio frequency identification (RFID) tags could also be used to obtain asset identifiers without the need to approach each asset. Signals from RFID tags could be read from a data collection vehicle traveling at or near highway speeds. This would facilitate an inventory but would not support condition assessment.

Asset Location

A lack of asset location information can arise both in existing data as well as during the data collection process. Existing data may have been collected without location information, or the location information is in a non-standard format that is difficult to incorporate into a database that can be read by a geographic information system (GIS). This problem is acute for low capital cost, high volume assets because they are often not located at an intersection or other easily recognizable place on a map.

Unfortunately, during data collection positional information is often collected without using a consistent reference system. Some jurisdictions have created GIS databases of their road signs by locating assets using GPS. For road signs, lighting, and other assets located at a single point, GPS is preferred to a Linear Referencing System (LRS) because GPS coordinates locate a single point in space and are easily imported into a GIS, but even an LRS will work if used properly and consistently. Integrating GPS data with data collected and stored using a LRS can sometimes be difficult and usually requires significant processing (Flintsch et. al., 2004).

In the authors' project for NCDOT, GPS coordinates for each sign, as well as the road on which the sign was located, were used to represent the asset's location. When the research team returned a year later to re-measure signs, the GPS coordinates, although imprecise, did help the team feel confident that they had identified the same sign (Rasdorf et. al. 2006). Errors in GPS coordinates due to satellite geometry and environmental interference can make it difficult to distinguish between two adjacent assets and to determine which side of the road an asset is located on in a GIS application.

In the case of pavement markings, NC has utilized an LRS to record pavement marking locations, but the LRS has not been used consistently. (Sitzabee 2006) Even when used consistently, an LRS can develop errors due to the approximation of the three-dimensional Earth by two-dimensional representations such as maps and GIS (Cai et. al. 2006). This is due to elevation changes causing field-measured distances to be greater than their scaled distance on a map.

Data Availability

Asset data can be unavailable for several reasons. Data may never have been collected, may have been collected but lost, may be inaccessible, or may be partially missing. Some historical data may exist but may not be readily available. An agency might know that they once collected the data, but its physical location is unknown. Data can also be inaccessible because the hardware and software that was used to create the data are on some media no longer exists or because an agency or company is hesitant to share proprietary data.

Often, data have been collected but there are missing or partially filled fields in the database. Missing fields for a particular asset make it difficult to fully analyze all assets in the AMS. They can result in the need for additional data collection to obtain the missing information. If the asset is no longer in service, the data can be permanently lost, reducing the effectiveness of the AMS. In NC for example, there are no pavement marking retroreflectivity data available beyond five years ago and much of the data for the last five years has gaps and missing attributes (Sitzabee 2006).

If no existing or legacy data are available, an agency needs to design a field data collection program. The program may require equipment (such as vehicles), instruments, hardware and software, labor, and funding. Unavailable data are a very common problem for low capital cost, high volume assets. Additionally, the lack of

available data causes researchers and practitioners to use surrogate replacement measures such as utilizing retroreflectivity data from studies conducted in other states.

Data Fragmentation

If asset data does exist, it is often fragmented due to agencies using various data collection standards over time and the data being stored in dissimilar formats. During a data collection program, the attributes collected over time can change, creating a database with columns missing depending on when the data was collected. An inconsistent column set can make it impossible to compare changes in asset attributes over time, thus reducing the utility of an AMS. Attempts to create a multi-asset database can be hindered by different units of the same agency using different column sets and units.

Data is also fragmented because over time, agencies tend to use different formats to store asset data. Data from earlier years could be in paper format or in a legacy digital data storage format. It takes considerable time and money to transfer paper and legacy records into a database that can run efficiently on current hardware and software platforms. In developing their new AMS, the Tennessee DOT had to incorporate digital data going back to the 1970s as well as archived paper forms (Haas and Hensing 2005). Even asset data collected in more recent years can be fragmented due to varying digital formats and storage media. This is an ongoing problem.

Data Collection Automation

Although assets may be labeled in the field to facilitate identification, there are additional challenges involved in automated data collection. Automated data collection seeks to not only identify an asset, but also record data about the asset's attributes and condition. Automation is the only way to quickly measure all low capital cost, high volume assets owned by an agency. Automation tends to be very expensive, because mobile units containing integrated instruments, video recorders, and computer hardware need to be either purchased or leased. For example, it cost \$210,000 for the FHWA to construct its Sign Management and Retroreflectivity Tracking System (SMARTS) van that automated sign inventory and condition data collection (Smith and Fletcher 2001).

A study of this van's performance, as compared to a handheld retroreflectometer, found its retroreflectivity readings to be unacceptable due to the high variation in readings, a low percentage of signs captured by the van on a single pass, and no correlation between the van retroreflectivity readings and the more accurate handheld retroreflectometer (Smith and Fletcher 2001). Other automated data collection systems have had more success. The mobile pavement marking retroreflectivity measurement vehicle developed by PrecisionScan, LLC has accurately measured pavement markings over the last five years for the NCDOT (Sitzabee 2006).

Another problem in data collection automation is that the instruments on these vehicles may be poorly calibrated or the instruments may be damaged. For example, mobile pavement marking retroreflectivity measurement units are subject to errors

from variations in the roadway and the vehicle's suspension (Sitzabee 2006). Calibrating the unit after it is set up and before each daily data collection pass using a handheld retroreflector can reduce these errors.

The instruments used in automated data collection often have the ability to collect asset condition data at a very fine level of detail, but also at a very high cost. Efficiency in automated data collection can be increased by collecting data on multiple types of assets in a single pass (Haas and Hensing 2005). Often, asset condition information, especially in the case of linear assets such as pavement markings and guardrails, is averaged over fixed segment lengths to increase efficiency. This averaging can introduce errors because asset conditions in the field that occur over segments that are of different lengths may not be well represented in an asset database. Data collection automation also requires complex integration among the various hardware and software components included in the mobile unit and the database and asset management software used to analyze and store the data in the overall IT system.

Asset Management Software Selection

Once there are usable data in an asset database, agencies need to make an IT decision between developing a custom asset management application and purchasing an existing standard application. A custom application can be designed to integrate with other asset management applications but can be expensive to develop. Custom applications also take longer to put in place, since the software must be first written and tested before it is implemented. Departments of transportation in Tennessee and Virginia have developed custom software by first outlining the desired capabilities and interoperabilities of the software and then developing modules for each asset one by one (Hensing and Rowshan 2005).

An existing application from a vendor can be less expensive and be implemented in a shorter time, but also can be difficult to customize to individual agency needs. Initially, off the shelf software may have limited utility to the agency because it has not been customized to serve the agency's particular analysis needs.

System Size and Resources

For low capital cost, high volume assets, the type of AMS selected is dependent on the overall size of the highway system to be managed and the available financial and personnel resources. Agencies that own 10,000 or more miles and have plentiful resources have tended to design custom solutions and develop custom software for their AMS. The custom software is needed because these agencies often want to integrate all assets into a single AMS.

The method of data collection tends to depend on the agency's goals. For example, New Mexico, with 12,000 miles of state-owned roads, used automated data collection (in the form of an image database) and custom software to film all of their roadways because the goal of the AMS there was to allow engineers in the office to visually examine any portion of NM roads (Hensing and Rowshan 2005).

Agencies with a large amount of state-owned miles but with fewer resources tend to focus on random condition assessment instead of an appropriate sample area. In Virginia, there was concern about the condition of a number of their low capital cost, high volume assets. Since there are 57,000 miles of state-owned roads in Virginia, measuring the condition of each sign, guardrail, or pavement marking would be an insurmountable task. Instead, Virginia used a statistically-based random sampling approach, where manual asset condition data collection was conducted on randomly selected sections of road (VDOT 2006). The condition information was then entered into custom software that extrapolated statewide asset conditions for various attributes.

Agencies with a large amount of state-owned miles and limited resources also may choose to use vendor provided software over custom-developed software. In NC, a pilot AMS collects data manually through visual inspections of randomly sampled road sections. These data are entered into the Visual Maintenance Management System software purchased from TRDI, Inc. that interfaces with a GIS to provide spatial condition information (Hensing 2003). The focus of this AMS is on scheduling maintenance, not on developing an asset inventory database.

Smaller agencies, owning less than 10,000 roadway miles, tend to focus on inventories of individual assets over an integrated AMS. The more resources an agency has, the more likely the AMS is to contain multiple asset types and some integration. Typically, smaller agencies create inventories for their higher capital cost assets first. Maryland and Oregon have created non-integrated AMSs for traffic signals and traffic sign structures (Hensing and Rowshan 2005). Traffic signals and traffic sign structures have a higher capital cost and a lower volume than signs, pavement markings, or guardrails. Oregon is in the process of developing a traffic sign inventory along the lines of their traffic signals database. Smaller agencies tend to use vendor-provided asset management software or simple database applications such as Microsoft Access.

Summary

Several IT challenges exist when developing asset management systems for low capital cost, high volume assets. These challenges include asset identification, asset location, data availability, data fragmentation, automated data collection, software selection, and system size and resources. Because these assets cost less and there are so many of them, agencies are initially inclined to exclude them from their asset management efforts, instead focusing on higher value assets. However, when the economic value of the high volume assets is totaled agency-wide, these assets represent a significant part of the investment in highway infrastructure. More importantly, low capital cost, high volume assets are critical to highway safety and motorist navigation. This criticality has been emphasized on the national level by mandates for improved performance and management of assets such as traffic signs and pavement markings. It is hoped that by discussing the issues related to these IT

problems, the development of more comprehensive systems to address low capital cost, high volume asset management will be enabled, enhancing motorist safety.

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