Infrastructure Asset Management For Strategic Planning

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Abstract

The inventory of deteriorating infrastructure is increasing, and government resources are contracting inversely. The added expenditures of "emergency" repairs caused by asset mismanagement is too expensive and untenable. In response to the funding shortfall for transportation projects throughout Wisconsin, the Wisconsin Department of Transportation (WisDOT) needs to develop a strategic level asset management analysis tool for strategic planning. Infrastructure Asset Management (IAM) is a cohesive process that integrates data storage, software systems and analytical methods for strategic planning. The purpose of this paper is to analyze how the WisDOT currently manages their infrastructure assets and demonstrate how IAM technologies could improve efficiency and cost savings. Interviews were conducted with WisDOT staff on multiple occasions to ascertain current methods of asset management and project planning. Case study research and comparisons of successful asset management by other progressive state agencies were utilized to formulate the results. It was determined that the only instrument that can effectively realize long term performance, dependability in financial assessment, and prevent an unanticipated inflow of repair work is an Infrastructure Asset Management (IAM) system.

Keywords

Infrastructure; Asset; Management; Information; Technology;

1 Introduction

The costs associated with America's deteriorating infrastructure is well documented, along with a chronic shortage of funding available for maintenance, repairs or replacement. Additionally, much of America's infrastructure is nearing the end of its design life and will need to be replaced over the next decade. The American Society of Civil Engineers estimates that $3.3 trillion dollars is needed over the next 10 years just to maintain our aging public transportation network [1]. Meanwhile, government agencies are encountering increasing difficulties because of the aging and decline of infrastructure assets, insufficient budgets, escalating repair costs, swelling demand, and new environmental requirements to comply with.

Unfortunately, it has become obvious how dilapidated the state of Wisconsin's transportation infrastructure has become. The American Society of Civil Engineers 2017 Infrastructure Report Card estimates that, 1) of the 14,230 vehicular and pedestrian bridges in the state of Wisconsin, 1,232 (8.7%) are classified as structurally deficient, and 2) of the 115,372 miles of Public Roads, 27% are in poor condition [2]. Several years before the $1.7 billion Zoo Interchange reconstruction project began in Milwaukee, one of the existing bridges had a catastrophic failure and needed an emergency, temporary replacement. More recently, there was a WisDOT project where a bridge was overlaid with new asphalt as part of a larger project, and shortly thereafter it was determined that the bridge was failing and needed a fast track replacement. With the list of aging assets growing and government budgets shrinking in comparison, the additional costs of "emergency" repairs due to asset mismanagement is unaffordable and unsustainable. Or as Curry puts it, "Putting aside the complete chaos that any major failure of our infrastructure would cause to the economy, it's just flat out unsafe" [1].

Infrastructure Asset Management (IAM) is a fundamentally cohesive process that requires the integration of an array of information, methods and IT/software systems [3]. New asset management technology can greatly reduce the need for emergency repairs and replacements, as well as "to store and manage information and to support tactical and strategic decisions regarding the operation, maintenance, rehabilitation, and replacement of their infrastructure. Implementation of efficient and cost-effective management strategies largely depends on the ability of these systems to share and exchange asset life cycle information” [4]. IAM is “helping to control costs and program maintenance by combining its various infrastructure inventories into a single platform, resulting in an integrated pavement, bridge and utility management tool. It will overlay sewer, water line, pavement and bridge conditions to facilitate programming of maintenance and capital projects by city management, as well as assist in determining optimal allocation of the city's funds” [5]. Mahmoud Halfawy also points out that many of WisDOT's software tools were not developed to exchange data with other systems. The unforeseen result is information “silos” causing issues with “data consistency, accuracy, and accessibility” [3].

The intention of this paper is to illustrate how escalating construction and preservation costs along with amplified traffic loads have momentously increased the need for an effective Infrastructure Asset Management (IAM) software at WisDOT. This paper will also investigate the use of the IAM to supplement or replace existing management tools for strategic planning at WisDOT by exploring data flows, return on investment, I.T support requirements, staff requirements, and data analysis outcomes.

2 Measuring Infrastructure Deterioration

Currently, WisDOT is using legacy systems such as META manager. These systems have several shortcomings. They:

- Do not all connect to Geographic Information Systems (GIS).
- Do not connect to Building Information Modeling (BIM).
- Are not stored in the cloud.
- Do not communicate with each other, creating information silos.
- May only have printed copies for output.
- Are up to thirty years old.

2.1 Current Measuring Techniques

Due to the excessive costs of replacing infrastructure there has been an increased focus on maintaining existing infrastructure to extend its useful lifespan as much as possible. This strategy is also used to maximize the usefulness of the limited funds available by spending it where it is most needed and preventing larger replacement costs in the future. Bridges can suffer structural deterioration due to aging, misuse or lack of proper maintenance. It is crucial to inspect the bridge periodically and to assess its condition and evaluate any possible damage.

Visual inspection, complemented with Non-destructive Testing and Evaluation (NDT/NDE) has long been used to determine the structural health of bridges. The Wisconsin DOT relies almost exclusively on manual inspections to determine the status of their infrastructure. These inspections are recorded either on paper copies in the field and then manually entered in to a data base or tablets that can input the inspections directly from the field. These inspections follow the National Bridge Inspection Standards (NBIS) and the requirements are explained in detail in the WisDOT Structure Inspection Manual. Table 1 below contains an overview of inspection types and recommended intervals.

Table 1. WisDOT Structure Inspection Manual Requirements

Structure Type	Inspection Type*	Max. Inspection Interval
Public Roadway Bridges	Initial/Inventory Update	After Const. & Major Rehab. or 48 months
	Routine Visual	24 months
	Damage	As needed
	Interim	As needed
	Load Posted	12 months
	In-Depth	72 months
	In-Depth with NDT	72 months
	Fracture Critical	24 months
	Fracture Critical with NDT	72 months
	Paint Assessment	As needed
	Movable	12 months
	Underwater Survey	24 months
	Underwater Diving	60 months
	Underwater Probe/Visual	24 months
Traffic Operations Support Structures	In-Depth	48 months
	NDT	As needed
Roadway Lighting Structures	Routine	48/96 months
	NDT	As needed
Earth Retention Structures	Routine	48 months
Noise Barriers	Routine	60 months
Culverts and Tunnels	Routine	24/48 months
Impact Protection Systems	Routine	60 months
Other Structures over Roadways	Routine	24 months
Pedestrian Bridge	Routine Visual	24 months
Ferries and Ferry Terminals	Routine	24 months
	Underwater	60 months
Truck Weigh Scales	Inspection and Maintenance	48 months
	Calibration	12 months

The key inspection points are as follows:

- All bridges with spans over 20 feet must be regularly inspected.
- There are several types of inspections that are classified based on their level of thoroughness. The normal inspection frequency is 2 years, but this can be extended to 4 years when an in-depth inspection has not reveled any major deficiencies.
- Both WisDOT and the NBIS have stringent qualification requirements to becoming certified to perform bride inspections. The inspector has five general responsibilities:
    1. To ensure public safety and confidence.
    2. To protect the public’s investment.
    3. Identify and assess structure needs.
    4. Provide accurate structure records.
    5. Fulfill legal responsibilities.

- The best approach at present is to obtain a baseline evaluation of all bridges and note any damage. 2-3 inspection cycles will yield excellent prognostic data on bridge deterioration. Those structures found with deterioration not yet requiring repair should be monitored closely, at shorter time intervals.
- The WisDOT Structure Inspection Manual discusses testing methods in detail, ranging from visual and audible inspections to ultrasonic and impact echo testing.
- The WisDOT Structure Inspection Manual provides all the forms required for carrying out an official bridge inspection.

These inspections show how the bridge is deteriorating with time, and provide inspectors and engineers with information about how long before repairs are necessary.

2.2 Current Data Management

In theory, this system is simple, effective, and easy to track. However, Wisconsin Department of Transportation is responsible for approximately 13,400 fixed roadway bridges, 50 moveable bridge, and 100 pedestrian bridges over highways [6]. This makes it extremely difficult to efficiently prioritize maintenance needs. Often preventive maintenance actions should occur when a structure appears to be in a "state of good repair" to nonprofessionals, which compounds the challenge of demonstrating and communicating the value of the right sequence of actions over a facility's life cycle [7]. In times of significantly constrained resources, delaying preservation activities is often attractive in the short term to fund other programs even though the long-term costs and consequences of such a strategy can be significant. There is currently no "golden measure" that is likely to resolve all the difficulties in properly evaluating and communicating preservation needs. Every transportation agency is different. Each face unique challenges in measuring performance and preserving their transportation system.

The next challenge is to be able to analyze data from all the bridges in the state and rank them to determine which have the greatest need for repair or maintenance to prevent higher repair costs in the future. Over the past ten years, a significant amount of research has focused on performance measures, data requirements, analytic tools and approaches for integrating measures into a performance management process that supports performance-based decision making at both the state and regional levels. With recent advances in computer technologies, developing intelligent bridge monitoring systems is becoming a more viable option. Data sensing is become more common.

A data sensing system will typically consist of six common components:

- Sensors and data acquisition networks;
- Communication of data;
- Data processing;
- Storage of processed data;
- Diagnostic and prognostic analysis (i.e. damage detection and modeling algorithms, event identification and interpretation)
- Retrieval of information as required.

3 Literature Review

When transportation departments are considering whether to make the investment into IAM, it can appear expensive. There can be costs associated with gathering new data and modernizing existing data. Fortunately, WisDOT has done an admirable job of inspecting their assets. The costs would be in integrating and managing asset data. To positively influence data management, Brous et al. [8] proposes four fundamental facets to data governance. These facets are; Coordination mechanisms, data quality requirements, monitoring data quality, and creating shared data commons. Naturally, because IAM is a data driven discipline, its effectiveness is dependent on the data being of superior quality as well.

Governing bodies at every level acknowledge the need for asset management as reflected by regulations such as ISO-55000 and the Moving Ahead for Progress in the 21st Century Act [9]. These are devised to swing management approaches away from funding reactive repairs, and toward embracing strategies to proactively finance a more enduring infrastructure. "The most efficient way to satisfy these requirements, secure funding and ensure a process that proactively detects needed repairs and safely prolongs the life of equipment is by investing in asset management and the technologies that provide the needed visibility and predictive maintenance." [1]

Because of IAM's dynamic nature, integrating sustainability practices is straightforward [10]. When making sustainability decisions, each phase needs to consider the triple bottom line (TBL) of sustainability to create greater value [10]. The TBL framework considers the potential social, environmental, and financial impacts. The US Environmental Protection Agency (EPA) has provided direction [10] to facilitate agencies to establish targets and execute methods that feature TBL considerations. Adding sustainability to IAM can compensate for shifting environmental changes and fluctuation in transportation demands.

Finally, as agencies consider and evaluate the implementation of asset management, a cohesive management team who share a common vision for system objectives is critical to success. [9]

4 Asset Management Software

As an example, Deighton is an asset management software used by several transportation departments. It is designed specifically to prevent data fragmentation and incorporate pavement, bridges, subsurface utilities, signs, safety, and traffic data using cross-asset analysis capabilities [5]. Regulations such as ISO-55000 and the Moving Ahead for Progress in the 21st Century Act are devised to swing the approach away from using funding to go after reactive repairs, and rather implement a strategy to proactively finance a more enduring infrastructure [1]. “The most efficient way to satisfy these requirements, secure funding and ensure a process that proactively detects needed repairs and safety prolongs the life of equipment is by investing in asset management and the technologies that provide the needed visibility and predictive maintenance. Government agencies that can administer public infrastructure are finding that new asset-centric software helps them prioritize projects based on risk and criticality, and invest their capital improvements funds in ways that will have the greatest impact [1].

4.1 Pricing

There are several (IAM) software packages available to Departments of Transportation, such as Deighton's Total Infrastructure Management System (dTIMS), Bentley AssetWise, or Decision Lens. For simplicity, this paper will use pricing information for Deighton software. The dTIMS software appears to contain an initial cost for the license and an annual fee dedicated towards maintenance and updates for the software. A comparison between various infrastructure asset management (IAM) software conducted by an individual at Saitama University in Japan found the initial cost of the license to be in the range of $60,000 to $80,000 and the annual fee to be around $4,000 per license. Considering these costs, they estimated that the typical cost to implement the dTIMS CT software at around $225,000 [8].

4.2 Price Comparison

Several department of transportation (DOT) budgets were examined to determine the costs of a single license. The City of Des Moines (Iowa) paid an initial cost of $64,125 for a single license in 2016, with the annual fee at $12,000 [9]. The South Dakota DOT conducted a year-long research project into the life-cycle sustainability for various rehabilitation structures and paid $65,000 for a single license. An annual maintenance cost did not appear in the budget for the project due to the project taking less than one year [10]. Research conducted by the University of Wisconsin-Madison into the Wisconsin DOT budget yielded a cost of $60,000 for license, and an annual maintenance and support fee of $7,000 [11]. An investigation by Caltrans into the Colorado DOT’s use of the dTIMS software estimated that the total cost to implement the software at $225,000. This supports the claim that was made earlier from Saitama University; however, this includes the cost of approximately 2000 working hours dedicated to the investigation [12]. Even assuming a high hourly wage (such as $80/hour), the labor cost comes out to $160,000, leaving $65,000 for the initial purchase of the software. Table 2 contains a summary of the various costs researched:

Table 2. Summary of dTIMS CT

Source	Single License Cost	Annual Fee
City of Des Moines	$64,125	$12,000
South Dakota DOT	$65,000	-
Wisconsin DOT	$60,000	$7,000
Saitama University	$60,000 to $80,000	$4,000

4.3 Return on Investment

Purchasing IAM software and incorporating it can pay for itself by preventing only one of the two instances of resource mismanagement at WisDOT. Earlier in the paper, a project was mentioned that included a bridge that was overlaid and then needed emergency reconstruction. This is a perfect example of why an IAM system is needed to prevent further occurrences, and it is also an optimal demonstration of the Return on Investment (ROI) potential. The initial project was three miles long, or 15,840 linear feet. The cost of the initial project was $1.5 million. The cost of the initial project divided by the length of the initial project results in a cost of $94 per linear foot of overlaid roadway. On a similar project with a road overlay that included a bridge reconstruction, the length of the bridge reconstruction "footprint" was 0.5 miles, or 2,640 linear feet. It is assumed that the initial projects bridge reconstruction "footprint" will also be close to 2,640 lineal feet, multiplied by the overlay cost of $94 per lineal foot, the lost funds spent on the overlay are $248,160. This one occurrence cost WisDOT is $23,000 more than the projected price of implementing dTIMS CT, for $225,000.

4.4 Workflow

Investigating two state DOTs can provide useful insight into the workflow for the implementation and use of the dTIMS CT software. Two are examined: Pennsylvania and Colorado.

The Pennsylvania DOT (PennDOT) uses dTIMS as a pavement asset management system for its interstates, US highways, and state roadways. There are two types of primary inputs into the analysis: inventory, current conditions, and financial records, along with decision criteria and performance. The inventory, current conditions and financial records come from diverse types of monitoring and control software, such as PennDOT's Engineering and Construction Management System (ECMS) or Multi-modal project management system interactive query (MPMS) [13]. Data from the two types of main inputs are then inputted into the dTIMS CT software. The analysis from the software then outputs strategies, recommendations and strategic reports. This is then given to other field and office staff. Field personal end up submitting maintenance records to the dTIMS analysis, while office staff provide feedback in what PennDOT calls the district feedback program. Figure 2 demonstrates an overview of the dTIMS workflow.

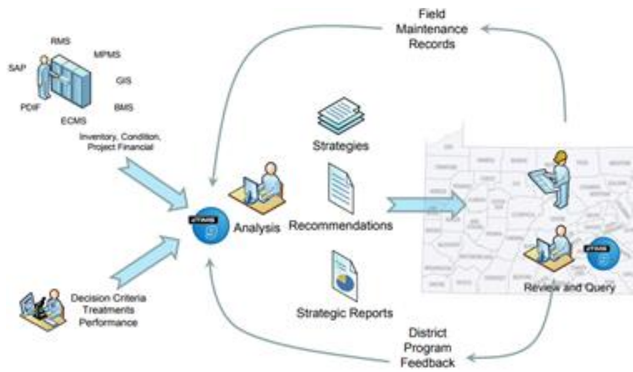

Figure 2. PennDOT Workflow for dTIMS CT (PennDOT, n.d.)

The Utah DOT (UDOT) provides a simpler outline for their implementation of dTIMS CT. They are applying it on a larger scale compared to PennDOT, using it not only for pavement, but bridges, safety, mobility and maintenance features. This appears to be part of a cross-optimization model, which will be discussed later. UDOT's two inputs are infrastructure data, and analysis parameters [14]. Presumably, like PennDOT, they have their own ways of collecting and gathering infrastructure data. These, along with the required analyze parameters, are analyzed by dTIMS. Outputs are provided in terms of long-term impacts and construction schedules [14]. The workflow process for dTIMS CT is illustrated in Figure 3.

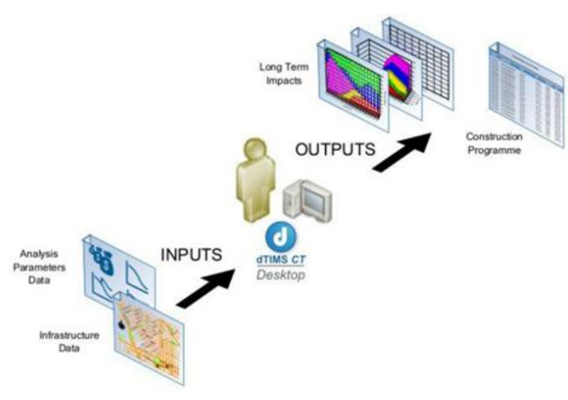

Figure 3: UDOT Workflow for dTIMS CT [14].

The Colorado DOT and others utilize a Cross Optimization Model. Cross optimization IAM systems take in multiple types of asset data, such as pavement data, structure data and safety data, runs it through the dTIMS software, which provides analyses in the distinct types of assets, suggests strategies based on the various assets analyzed, and finally culminates in a cross-asset analysis report [15]. Figure 4 shows an illustration.

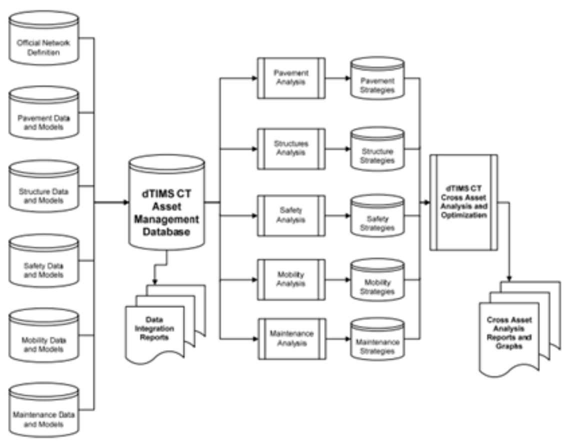

Figure 4. Typical Workflow for Cross Optimization Model Analysis [15].

The Wisconsin DOT is plagued by information silos as seen in Table 5. Because there isn't the opportunity for communication between systems, cross-optimization cannot occur. Which results in departments taking a reactionary, tactical approach instead of a proactive, strategic one towards asset management.

Table 5. Typical WisDOT Workflow demonstrating the creation of information silos.

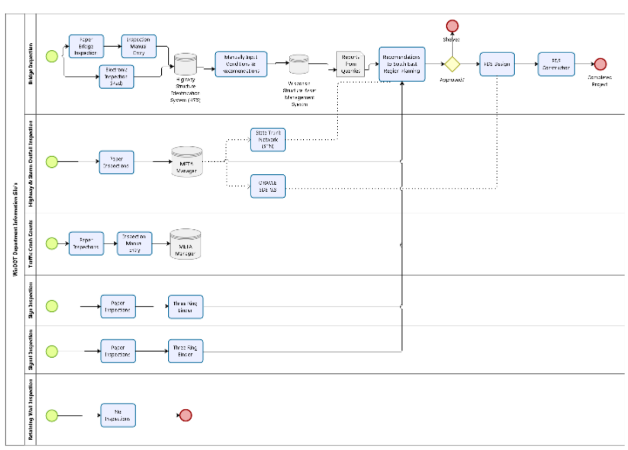

Figure 5 contains a proposed WisDOT dTIMS CT workflow. It attempts to streamline the workflow from Table 5, as well as a cross-asset optimization model hybrid as seen in Figure 4.

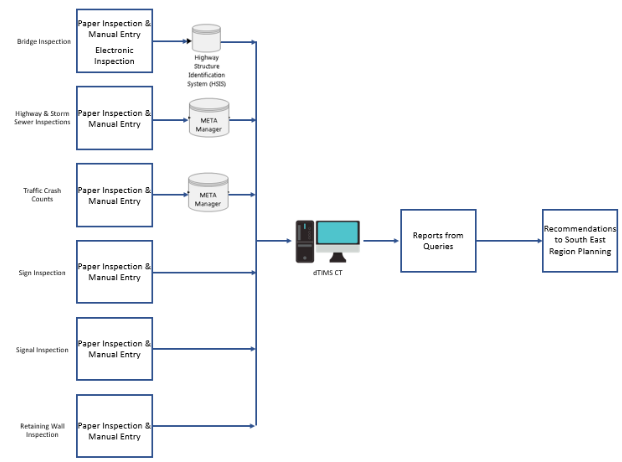

Figure 5. Proposed WisDOT dTIMS Workflow to achieve streamlined integrated outcomes

5 Conclusion

Exact long-term planning of maintenance and management is critical to safeguarding the 115,145 miles of Wisconsin's public roads [16] and ensuring their performance is in appropriate condition for today and in the future. Often, road controlling authorities are using decision-making tools that work on a snapshot of the condition of roads. To achieve for any given time, an appropriate analysis approach needs to be selected for the best possible results. For short term planning, field decisions and project prioritization may be appropriate to deal with various maintenance situations, while longer terms require more specialized and accurate planning. Deterministic models can often provide a reliable measure of the condition of the assets for medium-term planning, and anything longer requires more full-picture type techniques, such as stochastic models. There is a fine balance between attending to the urgent short-term maintenance needs of a road network, and at the same time plan well-ahead into the future to avoid an unexpected influx of maintenance work. It is not only important to know what the next treatment should be for a site, but it is also beneficial to identify the follow-on treatments based on today's decisions and planning. Currently the only tool that can successfully achieve these objectives is an Infrastructure Asset Management (IAM) system.

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