# QUANTIFYING THE BENEFITS OF ANCILLARY TRANSPORTATION ASSET MANAGEMENT

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# QUANTIFYING THE BENEFITS OF ANCILLARY TRANSPORTATION ASSET MANAGEMENT

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# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF SYMBOLS AND ABBREVIATIONS

| | |
|---|---|
| AASHO | American Association of State Highway Officials |
| AASHTO | American Association of State Highway and Transportation Officials |
| ADA | Americans with Disability Act |
| ADABAS | Adaptable Database System |
| BCA | Benefit-Cost Analysis |
| BCR | Benefit-Cost Ratio |
| BMS | Bridge Management System |
| Caltrans | California Department of Transportation |
| CDOT | Colorado Department of Transportation |
| DMS | Dynamic Message Sign |
| DOT | Department of Transportation |
| ESRI | Environmental Systems Research Institute |
| FAC | Features Attributes and Conditions |
| FACS-STIP | Features Attributes and Conditions Survey – Statewide Transportation Improvement Program |
| FHWA | Federal Highway Administration |
| GASB | Governmental Accounting Standards Board |
| GIS | Geographic Information System |
| GPS | Global Positioning System |
| HERS-ST | Highway Economic Requirements System – State Version |
| IRI | International Roughness Index |
| ITS | Intelligent Transportation Systems |

| | |
|---|---|
| KPI | Key Performance Indicator |
| LCCA | Life-Cycle Cost Analysis |
| MLOS | Maintenance Level of Service |
| MoDOT | Missouri Department of Transportation |
| MOP | Maintenance and Operations Plan |
| MR&R | Maintenance, repair and rehabilitation |
| NBI | National Bridge Inventory |
| NCHRP | National Cooperative Highway Research Program |
| NPV | Net Present Value |
| NYSDOT | New York State Department of Transportation |
| ODOT | Oregon Department of Transportation |
| PMS | Pavement Management System |
| PQI | Pavement Quality Index |
| PSR | Present Serviceability Rating |
| RFI | Road Feature Inventory |
| SMS | Safety Management Systems |
| SQL | Structured Query Language |
| TAM | Transportation Asset Management |
| TSO | Transmission Service Operator |
| VDOT | Virginia Department of Transportation |
| WAM | Work and Asset Management |

# SUMMARY

As asset management continues to gain ground in the transportation industry, many agencies are looking to reach beyond pavement and bridge management to include other ancillary infrastructure in their systems. Ancillary transportation assets are those lower-cost, higher-quantity infrastructure, such as traffic signals and guardrails, that work together to improve the overall performance of the transportation (and specifically, highway) system. For the most part, these assets are directly related to improving the safety of roadways; however, they play an integral role in relation to other performance measures such as mobility. As agencies work to incorporate ancillary transportation assets into their existing systems, many may benefit from prioritizing the different asset classes for inclusion, particularly where there are limited funds for the development of formal asset management programs.

This thesis investigates the state of practice of ancillary transportation asset management in the United States and reviews the opportunities for prioritizing ten asset classes for formal asset management procedures based on quantified benefits of managing these assets. The classes considered are culverts, earth retaining structures, guardrails, mitigation features, pavement markings, sidewalks and curbs, street lights, traffic signals, traffic signs and utilities and manholes. Data is also considered as an information asset in this investigation; however, it is excluded from the benefit quantification process due to the different nature of the requirements for data management. This study was conducted using a literature review followed by a survey targeting agencies identified from the literature as those making significant progress with

ancillary transportation asset management. Based on the results obtained, the opportunities to quantify the benefits of managing these assets were investigated, in order to make a business case and to enable data-driven prioritization of the assets.

The literature review and survey revealed several important aspects of agency implementation of asset management practices. Although some actions are driven by Federal mandates, most depend on the priorities and goals of state and municipal agencies. As a result, ancillary transportation asset management practices vary by agency and no specific trends were observed. Nevertheless, agencies that manage a significant number (greater than 6) of the asset classes investigated in this research seem to be further ahead in terms of data analysis and the use of data in informed decision-making practices. These agencies and several others investigated are developed past the general inventory stage, which is usually the first step in the creation of an asset management program. Overall, many agencies are working towards improved asset management programs for their ancillary assets and greater data and system integration to reduce redundancies and increase data sharing. In comparison to the results of the literature review, findings from the survey present a more comprehensive and up-to-date synthesis of the data and data collection tools required in asset management systems.

Finally, this work evaluated the opportunities to quantify the benefits of ancillary transportation asset management based on a review of previously proposed methods and an evaluation of a proposed framework based on benefit-cost analysis. The almost secondary nature of ancillary assets within the transportation system makes it difficult to attribute certain costs and benefits (i.e., reduction of those costs) to specific assets. In order to use the framework proposed, there is a need for agencies to identify cost-benefit factors and metrics that relate to their strategic objectives and for which data can be obtained (or predicted), and dedicate resources to developing good quality data for comparative evaluation of the various asset classes.

# 1 INTRODUCTION

## 1.1 Background and Motivation

Transportation Asset Management (TAM) is a concept that continues to gain ground in agencies as a decision-making tool for capital investment and the maintenance, rehabilitation, and replacement of transportation assets, and as a core business process for broad agency decision making. Although the term asset management has been used in different contexts by different agencies, all uses tend to have the same objective of upgrading, preserving and maintaining infrastructure over the lifecycle. According to the American Association of State Highway and Transportation Officials' (AASHTO) Subcommittee on Asset Management, "Transportation Asset Management is a strategic and systematic process of operating, maintaining, upgrading and expanding physical assets effectively throughout their lifecycle. It focuses on business and engineering practices for resource allocation and utilization, with the objective of better decision making based upon quality information and well-defined objectives" (1). With growing demands for infrastructure systems, continuing deterioration of these systems, and increasingly scarce funding, there is a growing need to develop the practice of systematically managing the assets that make up these systems to keep their performance at or above acceptable levels of service for longer periods of time.

Over the past fifty years, it has become apparent, as transportation infrastructure systems age and funds become more and more limited, that a new paradigm of asset management has to be adopted to help allocate limited resources more effectively and efficiently in order to keep infrastructure assets functioning at the highest level possible. As a result, many transportation agencies have established some form of asset management capability such as Pavement Management Systems (PMS), Bridge Management Systems (BMS) and Safety Management Systems (SMS). The genesis of pavement management systems was the Association of American State Highway Officials' (AASHO) Road Tests in the late 1950s in Ottawa, Illinois where experiments were designed to establish the relationship between structural designs and expected loadings over pavement life(2). The data from these tests were applied to develop the first models linking pavement serviceability to distress data (3), one of the first elements of PMSs. The primary impetus for the development of BMSs has been the implementation of regulatory requirements to improve the stewardship of bridges as a result of the critical nature of bridge failure, as well as the costs of replacement. SMSs seek to incorporate safety assets (such as roadway lighting, traffic signals, earth retaining structures and guardrails) as key components in all transportation infrastructure-related decision-making processes. The use of SMSs in transportation agencies has been limited, perhaps as a result of the rescinding of requirement to have such systems by the 1995 National Highway System Act(4). However, a few Departments of Transportation (DOTs) are still using SMSs, most having developed them prior to 1991 when the short-lived Federal mandate to have them occurred.

Although the cost to build and operate these safety assets may not be as high as that for bridges and pavements, they are critical to the safe and effective operation of the transportation system. Additionally, the rate of failure of some of these assets might be low; however, the consequences of their malfunction could be fatal. There is thus a need for an asset management system for these and other ancillary assets that facilitates more effective budgetary prioritization. To develop such a system, however, requires making a business case for expending the dollars necessary to collect data and develop analytical capabilities for managing these assets more systematically. Furthermore, when the decision has been made to manage these assets systematically, which asset to begin with may be unclear, given the extent of available options. Quantified benefits and costs can influence which assets are prioritized for formal management, when considered with other criteria.

## 1.2 Objectives & Organization of Thesis

The purpose of this thesis is two-fold: first, to synthesize the current state of practice of managing ancillary transportation assets, including the identification of data needs and costs for developing systematic capabilities to manage these assets; and secondly to assess the opportunities for quantifying the benefits of asset management programs in order to make a business case for their use. This work focuses on ten main asset classes selected from a review of asset management literature: culverts, earth retaining structures, guardrails, mitigation features, pavement markings, sidewalks & curbs, street lighting, traffic signals, traffic signs and utilities and manholes. Most of these assets are usually classified as roadway safety hardware assets and thus may be included in an SMS. In addition, these assets are typically managed at the state level with the exception of utilities and manholes that are managed at the local level. The work also considers data, which is an information asset.

This thesis is presented in three main sections. The first section offers some significant findings of a review of literature that included the general asset management literature and other documents relating specifically to each of the eleven asset classes under consideration. The literature review findings were used as guidance in selecting agencies for a targeted survey of practice. The literature reviewed also included papers documenting the benefits of asset management and some efforts put into quantifying the benefits in fields not limited to transportation. The survey approach and results are presented in the next chapter, highlighting noteworthy agency practices with case studies of four agencies that have made significant progress in implementing asset management programs for ancillary assets. The next chapter presents a proposed framework to quantify the benefits of asset management with an assessment of the data that would be necessary to use the framework. Finally, the conclusion discusses opportunities and challenges for managing ancillary transportation assets and the implications of this study, in order to understand the requirements for successful operation of an ancillary transportation asset management program.

# 2 LITERATURE REVIEW

The literature review conducted for this research was primarily focused on reviewing the practices of transportation agencies, both domestic and international, in an attempt to document the state of the practice regarding the management of the eleven classes of assets. The literature revealed that there is at least one agency in the United States managing each of the eleven categories of assets being considered in this work. However, no single agency was identified to have an asset management program or programs in place for all eleven asset classes. In addition, most of these efforts seemed to be limited to the initial stages of developing more comprehensive asset management programs. These stages include the development of asset inventories, some condition assessment and information management. Overall, 64 agencies (34 state transportation departments, 11 local county and city agencies and 19 international agencies) were identified through a literature review as having some activity in ancillary transportation asset management. A chart showing the specific assets managed by each agency is provided in Appendix A; however, Figure 2.1 shows the percentages of the agencies identified that manage each of the asset categories. As shown, culverts are the most common assets managed by about 50% (32) of the agencies identified. This is followed by traffic signs and then pavement markings. Culverts are managed as a result of some agencies including them (and other structures) in their Bridge Inventory Systems ; however, according to Davidson and Grimes(5) culverts are not given the required attention they deserve, even with the introduction of the Federal Highway Administration (FHWA) voluntary Culverts Management System in 2001. The prevalence of signs and pavement marking management systems, on the other hand, could be attributed to FHWA legislative mandates for retro reflectivity (6) (7). With the lack of such directives pertaining to the rest of the asset classes, few agencies have included them in their management systems.

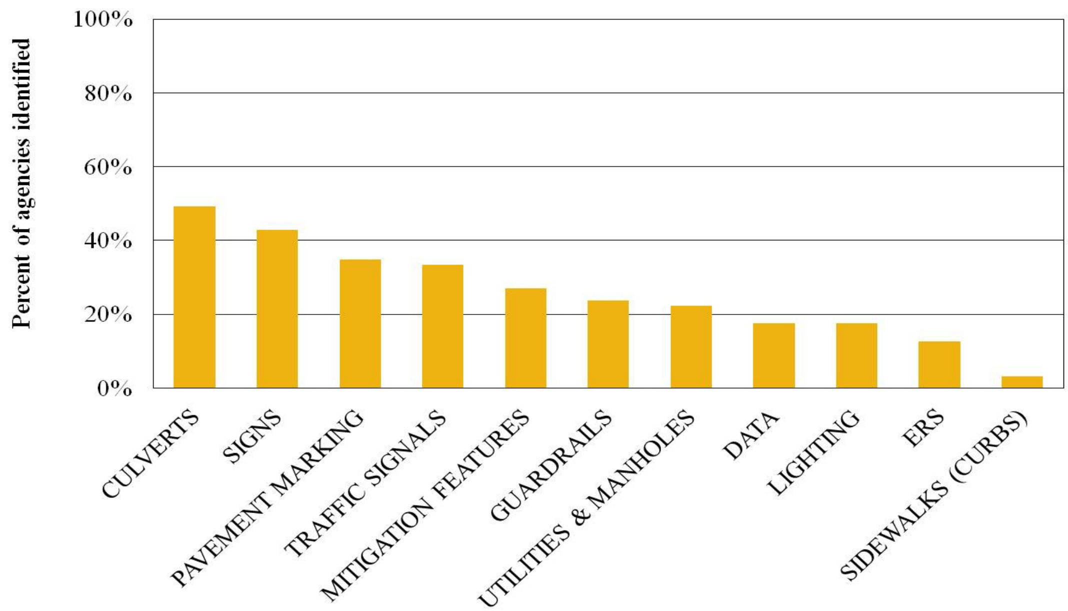


**FIGURE 2.1 Assets managed by agencies as identified from literature review.**

## 2.1 Data Needs, Data Collection Costs & Analysis Tools

Effective planning of a transportation asset management program includes an assessment of the data needs, costs and analysis tools that are needed to run a successful program. According to a study conducted by Markow on behalf of the National Cooperative Highway Research Program (NCHRP), agencies often lack the necessary data to complete their management systems(8). In addition, a lack of standardized measurement methods of service life has created challenges in data coordination and compilation for asset management. A 2008 study by Li and Madanu further supports this finding of a deficiency in asset service life evaluation methods(9). Although data collected by agencies with asset management programs vary, they generally include standard inventory data (location, type, etc.) and some attribute data relating to the condition and operational performance for the specific asset.

The analysis tools employed in asset management systems should enable effective decision making and planning. Agencies have employed various analysis tools according to their specific needs. For example, in 2008, the City of Clearwater, FL implemented the Oracle Utilities Work and Asset Management module to "gain a comprehensive view of [their] infrastructure assets to help enhance planning, streamline operations and contain costs"(10). Oracle database tools are, arguably, the most common advanced asset management analysis tools utilized by many other agencies, such as, the California DOT (Caltrans), which used the Oracle Road Feature Viewer in 2008(9). In addition, many states have developed individualized software systems to manage assets based on their needs, as seen in Alaska and Ohio DOTs efforts to manage their culverts and other drainage infrastructure(11). Regardless of the existence and use, albeit limited, of database and analysis tools which could inform data-driven decisions, agencies often employ historical data, political input and professional judgment in determining asset service-life estimates and in creating their operating budgets(8). Although these less quantitative approaches may be common, several agencies are considering or investing resources in data collection for more systematic decision making for their assets.

In order to fully develop a business case for any asset management system, it is important to know the costs of running and maintaining the system. However, there has been very little documentation of data collection costs for developing asset management programs. Hensing studied several roadway safety hardware asset management systems in 2005 and estimated that the New Mexico Road Feature Inventory (RFI) system had an initial cost of $2 million with an additional $500,000 to complete the acquisition of data that was missing from the initial process(12). Essentially, this was the only information found on data collection costs in the asset management literature. Undoubtedly, identifying the costs for developing and operating asset management programs continues to be an important research need with practical implications for agencies that want to prioritize formal asset management of ancillary assets using economic principles

### 2.2 International Practices & Standards

In 2005, the FHWA, AASHTO and NCHRP sponsored an international scan study of asset management experiences, techniques and processes in Australia, Canada, England and New Zealand. This report from this scan provides a comprehensive synthesis of asset management best practices outside the United States. England's Department for Transportation, Gloucestershire County in England, the cities of Edmonton (Canada) and Brisbane (Australia), the New Zealand Transport Agency and the Quebec Ministry of Transportation were all identified as having transportation asset management systems that incorporate at least one of the 11 classes of assets being investigated(13). Generally, much more documentation, relating to data costs, was found from the international scan report than was found from the literature on domestic transportation agencies.

For example, in Canada, the City of Edmonton manages a collection of assets that include culverts, sidewalks, street lights, traffic signals and traffic signs, among others. Data collection costs were said to be at about $400,000 as of 2005 with analysis tools that include an infrastructure report card and a pavement quality index (PQI). The report card gives details on various asset characteristics including replacement value and expected life. The PQI is an in-house measure that can be estimated using deterioration curves, based on assumed budgets(13).

### 2.3 Benefits of Asset Management

Although the practice of asset management has spread throughout public works and other infrastructure-related departments throughout the United States and the rest of the world, there are several barriers to implementing asset management programs, especially for ancillary assets, which are seemingly, the “less important” assets. One of the main barriers to the success of these programs is the cost associated with their development and implementation. In order for an agency to justify an investment in an ancillary asset management system, there needs to be evidence that the benefits outweigh the costs. There are several benefits resulting from the use of asset management programs, either in the short-term or the long-term that have been outlined in various published papers. Generally, there are more long-term benefits than short-term, which poses difficulties for advocates of these programs because positive effects are not recognized early.

The most prominent benefit from asset management programs is the ability to devise rational, data-driven, well-informed decision-making strategies when allocating resources or making investment-related decisions(14), as opposed to ill-informed decisions that cannot be justified. Justifying investment decisions is a critical aspect of agency accountability and transparency especially in relation to the public. For example, in Missouri, since the inclusion of asset data in financial reports resulting from the

Governmental Accounting Standards Board (GASB) Statement 34, Missouri Department of Transportation's (MoDOT's) functional managers at all levels have began understanding the effects of investments on the condition of their roadways and bridges(15). Furthermore, MoDOT reports that the public can "see how the budget drives the outcome on net assets and other services provided"(15) increasing credibility of the agency to its customers.

Related to data use in decision-making, a second important benefit of asset management programs is the support they provide in helping agencies understand the implications of different investment options(16). In Missouri, the implementation of asset management provided the tools to determine how available (or constrained) funding can be used to improve asset condition, or assess the funding needs to attain a certain level of asset performance. Essentially, the program created the ability to determine the impact of various funding levels on infrastructure condition over the long-term(15).

Where a management program is integrated with many different assets, consistent evaluation of the infrastructure condition as well as trade-off investments across different elements to determine the best investment at the appropriate time can be conducted(16)(14). Clearly, this integrated approach to decision making especially pertaining to resource allocation means that agency investment decisions will be more efficient and cost-effective. With this level of informed decision making that integrates all the levels of infrastructure making up a transportation system, agencies can increase their effectiveness and efficiency in relation to infrastructure maintenance, repair and rehabilitation.

In the long run, successful asset management programs should eventually lead to appropriate maintenance, repair and rehabilitation (MR&R) of infrastructure which improves asset performance while simultaneously reducing MR&R costs(16). Overall, “more timely decisions and other efficiency improvements combine to reduce the costs of acquisition, maintenance, upgrade, and replacement of assets”(14). These improvements in asset condition provide a better driving environment for users of the highway system, thus reducing user costs, vehicle operating costs and other external costs(16), which are all important benefit-cost factors.

Evidently, the benefits of ancillary transportation asset management programs and asset management programs in general, are many and varied and can be seen in both the short- and long-term. Nonetheless, implementing asset management as a standard business tool within transportation agencies still faces obstacles from an investment perspective. Generally, “upper-level managers are interested in benefits that can be translated into monetary values”(16 p. 232) which would help in convincing them of the importance of these programs. This comes as no surprise since money is a universal language easily understood by anyone from the common infrastructure user (the general public) to the highly technical engineers who develop these asset management programs. As a result, it is necessary to quantify the benefits of asset management program implementation in order to demonstrate clearly, how these benefits exceed the costs associated with program development; and where there are various asset classes competing for formal management programs, the relative benefits of one class over another, if any. In Chapter 4, the opportunities for quantifying the benefits of asset management programs are presented, with a specific focus on ancillary transportation assets.

## 2.4 Knowledge Gaps

The literature reviewed for this work revealed several gaps regarding ancillary transportation asset management in the United States. Firstly, there is a need to refine data inventory processes and data collection standards in order to make accurate assessments of the data needs for these asset management systems(9). Additionally, information on estimating and evaluating asset performance and incorporating performance data to enrich decision-making and budgeting practices requires improvements(8). As Markow noted, the process of developing ancillary transportation asset management systems is complicated because deterioration models are difficult to build. In relation to the benefits of asset management, it is apparent that there is some significant amount of documentation of the benefits in literature; however, quantification of these benefits is an area that has not been fully developed, especially for transportation infrastructure. Where some quantification of benefits has been attempted, it is fairly difficult to identify applications of the methodologies to ancillary transportation assets, which is the focus of this work. Details and evaluations of some attempted benefit quantification are presented in Chapter 4, and the possibilities of their applications to ancillary assets are evaluated.

# 3 ASSET MANAGEMENT SURVEY OF PRACTICE

A targeted survey of the U.S. agencies identified in the literature review was conducted to obtain up-to-date information on the status of these agencies' asset management systems. Representatives from 41 agencies (33 State DOTs and eight local agencies) were contacted from January to May 2011 and asked to complete a survey either through a written response or telephone interview. Eighteen (44%) of the agencies surveyed responded, almost equally between interviews and completed questionnaires. The respondents included 16 state DOTs (shown in Figure 3.1) and two local agencies (Seattle DOT & Hillsborough County Public Works Department, Tampa, FL). Two responding agencies reported that they do not currently operate an asset management program, as was suggested by the literature, and have therefore been left out of this discussion. A copy of the survey is available in Appendix B and the next few paragraphs examine the questions and present the results.

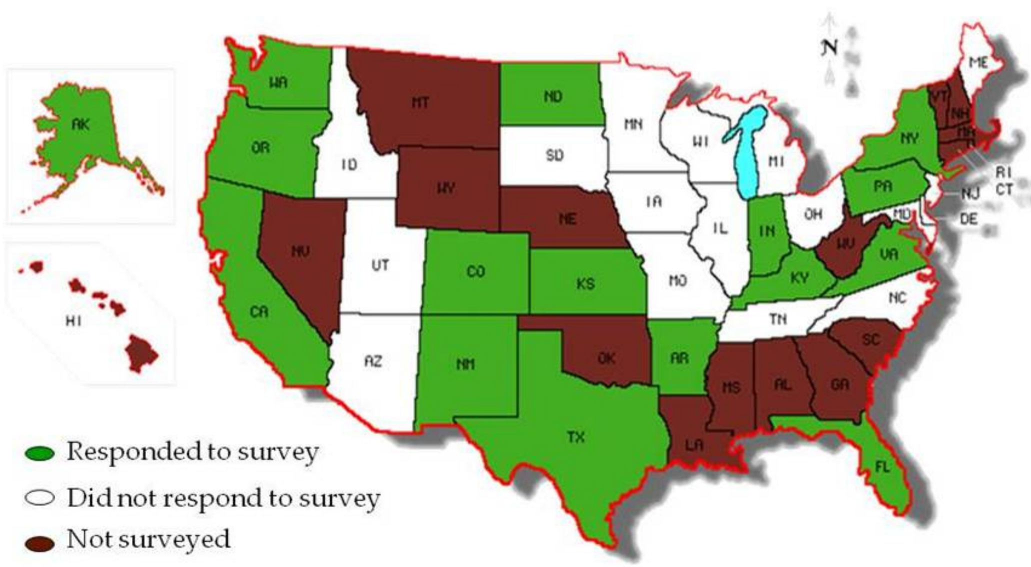


**FIGURE 3.1 States responding to asset management survey of practice.**

### 3.1 Findings on the State of Practice

Overall, no agency was found to manage all 11 asset classes, consistent with the findings from the literature. Over 60% of the agencies responding to the survey had management systems in place for six or more of the asset classes all including traffic signs and guardrails. Figure 3.2 shows the percentage of the total number of agencies responding to the survey reporting that they manage each asset class.

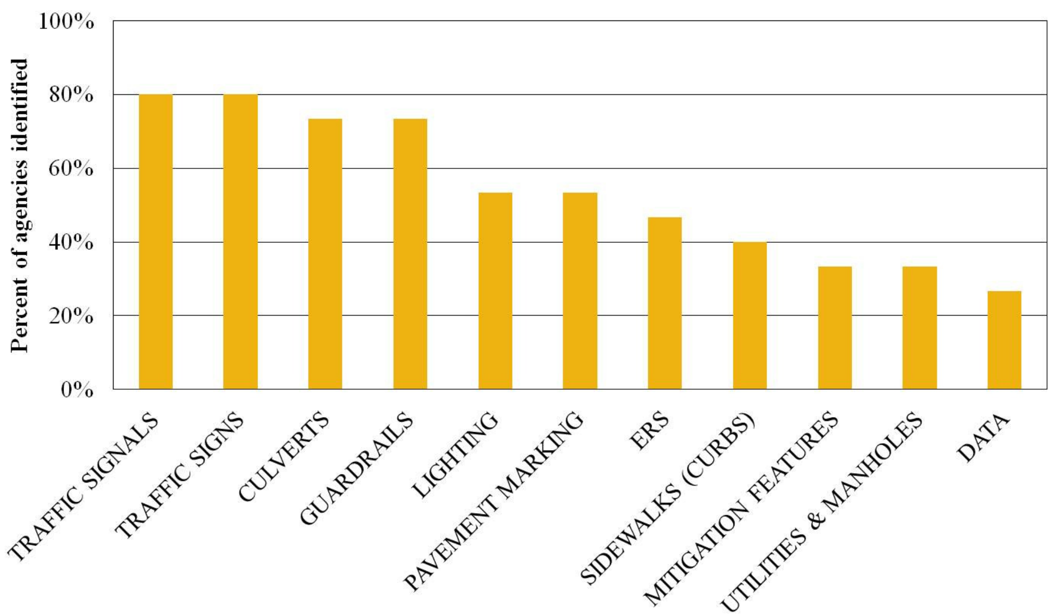


**FIGURE 3.2 Assets managed by agencies as identified from targeted survey.**

From the surveys, traffic signs and signals were found to be the most commonly managed assets, as indicated by 13 (81%) of the 16 responding agencies. Considering their importance in roadway safety, it seems logical that agencies have taken steps to systematize their management of traffic signals. Additionally, the 2007 FHWA retro reflectivity mandate gave agencies until January 2012 to implement a management system to maintain minimum levels of retro reflectivity in signs(6), which is likely an important factor in the increase in management of traffic signs. The next most commonly managed assets are guardrails and culverts, which were reported as managed by 12 (75%) and 11 (69%) of the 16 responding agencies, respectively. Survey responses showed that culverts are typically managed with bridges in the bridge management systems that already exist. On the other hand, the least managed asset according to survey responses, was data, which was reported as managed by only four (25%) of the 16 agencies responding to the survey.

Figure 3.3 shows a comparison between the results of the literature review and the survey for the percentage of agencies managing each asset class. One impetus in conducting a targeted survey based on the literature was to have a basis for validating the results, to some extent. The results seem to reinforce each other and provide some evidence of validation as the survey results in each case either equal to or exceed the literature review results, with the exception of the culverts data. This could be interpreted as the surveyed agencies having developed their ancillary and information asset management activities either to the extent determined from the literature or beyond and above what was found in the literature. In instances where what was reported in the literature did not match what was found in the survey, a follow up survey was done to clarify the actual status ancillary asset management in the agency to ensure that what was being reported conformed to the actual programs, procedures and systems within the agency. Where no alignment was found pertaining to what was reported in the literature and the survey, adjustments were made in a follow up interview or the data was not included in the analysis. Data for two agencies were not included as a result of discrepancies between what was reported in the literature and survey.

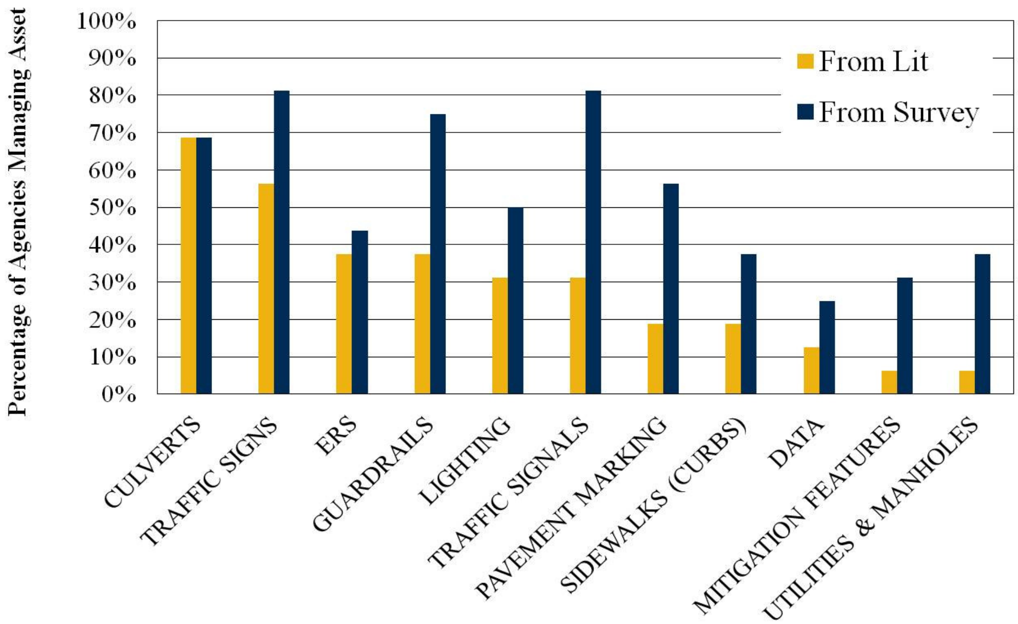


**FIGURE 3.3 Comparison between literature and survey for assets managed.**

The number of agencies from the literature review results is different from what was reported in Figure 2.1 because only the 16 agencies surveyed are used to calculate the percentages. With the exception of culverts, there were a higher proportion of agencies managing each asset reported in the survey results than from the literature. This indicates that discrepancies exist between the literature and survey results, which could either mean that literature on ancillary asset management is out-dated and agencies are managing more assets than they did in the past; that the state-of-practice has historically not been comprehensively reported; or that there has been a reduction in the agency activities previously reported. Besides the actual numbers being higher, the overall trend of most popularly managed assets also changed from literature to survey, making traffic signs and signals the most popular, as opposed to culverts. In the same way, as opposed to mitigation features and utilities and manholes being the least commonly managed assets from the literature, the survey results indicate that data is least commonly managed by the agencies surveyed.

Data integration in asset management systems is important due to the large quantities of data used in these systems. It is the process of combining or linking two or more data sets from different sources to facilitate data sharing, promote effective data gathering and analysis, and support the overall information management activities in an organization. Data integration and the integration of other asset management functions allow for effective data sharing across and within agencies, and more holistic decision-making in the face of shrinking resources and other constraints(9). Four (25%) agencies reported that they have fully integrated asset management systems for the assets they manage. Another five (31%) reported that they have some assets integrated into one database, with others still managed independently. Generally, a number of the responding agencies indicated a transition towards integrated systems to be completed within months of the survey.

In order to identify best practices in managing ancillary transportation infrastructure, it is important to consider the proportion of all the existing assets that are included in management systems. Agency representatives obtained this information by contacting their respective database managers or asset management team leaders. These numbers are generally ballpark estimates of the extent of data collection for the inventory. This information was difficult to obtain from survey contacts; very sparse and incomplete responses were given in most cases. Table 3-1 shows a summary of the results obtained.

**TABLE 3-1 Percentage of Assets in Management System for Respondents Indicating Asset Inclusion in System**

| Asset Class | # of Reporting Agencies | Min* | Max* | Median |
|---|---|---|---|---|
| **Culverts** | 8 | 10% | 100 | 72.5% |
| **Data** | 1 | 100% | 100% | 100% |
| **Earth Retaining Structures** | 7 | 15% | 100% | 90% |
| **Guardrails** | 8 | 10% | 100% | 100% |
| **Street Lighting** | 6 | 75% | 100% | 100% |
| **Mitigation Features** | 3 | 90% | 100% | 100% |
| **Pavement Markings** | 5 | 33% | 100% | 50% |
| **Sidewalks (& Curbs)** | 4 | 90% | 100% | 100% |
| **Traffic Signals** | 10 | 75% | 100% | 100% |
| **Traffic Signs** | 10 | 10% | 100% | 100% |
| **Utilities & Manholes** | 4 | 50% | 100% | 96.5% |

*Min and max percentage of all the percentages reported by different agencies

As shown, the ranges of values vary for each asset class. All median values are greater than 70% with the exception of pavement markings. For almost all of the asset classes, the most frequently occurring percentage of the asset base included in management systems is 100% indicating that most agencies reported that they have taken account of all the assets within their jurisdiction.

## 3.2 Asset Management Guiding Principles

Agency goals and policies for asset management provide guidelines for consistent evaluation of asset management systems(17). Furthermore, these goals establish a homogeneous understanding of the purpose of managing assets for decision makers and the general public. Four (25%) of the agencies responding to the asset management survey of practice indicated the existence of a program statement or some guiding principles. For some agencies, policies exist for some of the asset classes they manage. For others, while no formal statement exists; general goals are apparent and communicated throughout the agency. By and large, agency goals whether documented or not, center around optimizing operational efficiencies, maintaining assets at or above minimum levels of performance for their useful life and providing a basis for data-driven recommendations and decisions considering condition, performance, life-cycle costs, benefits and risk.

### 3.3 Data Needs & Data Collection Costs

In agreement with the findings from the literature, data collection practices vary from agency to agency; however, in general, agencies collect data on the asset type, location, installation details, components and condition, for use in their systems. Most agencies have employed some form of geographic information system (GIS) or global positioning system (GPS) technology in referencing assets by location. Inventory data collected includes this location information and other general details such as asset type, geometric information and, in some cases, digital photographs. On the other hand, performance data varies by asset and are driven by the measures used to assess performance or predict service life. The frequency of inventory and inspections also varies by asset and by agency as shown in Table 3-2. The table shows ranges of data collection frequency schedules as reported by survey respondents. For a number of assets and agencies, inspections had only been performed once since the implementation of the management system.

**TABLE 3-2 Ranges of Data Collection Frequency as Reported in Survey Responses**

| Asset Class | Data Collection Frequency |
|---|---|
| **Culverts** | 1 – 5 years |
| **Data** | Weekly – Annually |
| **Earth Retaining Structures** | 2 – 5 years |
| **Guardrails** | 1 – 2 years |
| **Street Lighting** | 1 – 5 years |
| **Mitigation Features** | 1 – 5 years |
| **Pavement Markings** | 1 – 5 years |
| **Sidewalks (& Curbs)** | Continuous, 5 years |
| **Traffic Signals** | 1 – 5 years |
| **Traffic Signs** | 1 – 2 years |
| **Utilities & Manholes** | Irregular, 5 years |

The tools used in data needs and cost assessment are another important determinant of an effective asset management system. Twenty-eight (28) different data collection methods were reported by agencies with some repetition. Visual inspection is by far the most common inventory and condition assessment technique used by the reporting agencies. This is followed closely by the use of contracted services collecting data in whichever way the contractor chooses, especially in the case of the utilities and manholes asset class. Other data collection techniques are listed in Table 3-3. As shown, there were variations in a number of the methods used; for example, two agencies specified that their data collection involved field collection with verification through GIS and GPS tools as opposed to a simple visual inspection. In another case, some agencies used mapping grade GPS while others used resource grade GPS, which are variations of GPS technology.

**TABLE 3-3  Data Collection Techniques for Ancillary Transportation Assets**

| | |
|---|---|
| Aerial Photographs | Microsoft Access Forms |
| Capture at Installation | Mobile GPS Equipment |
| Contractor Services | Optical Observation Technology |
| ESRI ArcCatalog Metadata | Other GIS Metadata |
| Features Attributes & Conditions (FAC) | Photo/Video logging |
| Field Collection & Verification | Pontis Data Collection |
| Field Laptops | Resource-Grade GPS |
| GeoResults Mobile by Marshall | Retroreflectometer |
| Google Streetview | Trimble Data Loggers |
| Handheld Scanner | Troux Software |
| Information obtained from Utility Providers | Unspecified Metadata |
| Infrastructure Plan Sheets | Unspecified Mobile Device |
| Manli System | Visidata |
| Mapping-Grade GPS | Visual Inspection |

In terms of data collection costs, findings revealed that many agencies either do not estimate data collection costs or were not willing to give out that information in their survey responses.  Without cost data, it is impossible to quantify the overall and marginal benefits of implementing an asset management system or determine accurate financial needs for implementation.  Nonetheless, the brief cost data obtained are summarized in Table 3-4.

**TABLE 3-4  Costs of Data Collection**

| Asset Class | Average Cost Provided |
|---|---|
| **Culverts** | $140 - $200 per unit |
| **Guardrails** | $40 per mile |
| **Street Lighting** | $100 - $280 per unit |
| **Traffic Signs** | $350 per structure ($500 per DMS* structure) |
| **Utilities & Manholes** | Determined by contractor |
| **Pavement Markings** | $4 per lane mile |

DMS – dynamic message sign

In all cases, no distinction was made between inventory and condition assessment data collection; however, for culverts, one agency reported spending about $140 per asset, while another reported about $200. For guardrails, data collection was estimated at $40 per mile of roadway. Similarly, for street lighting, two agencies reported spending $100 and $280 per structure (or unit) for a condition assessment. One agency reported data collection costs for traffic signs to be at about $350 per structure or $500 for dynamic message signs. Finally, another agency estimated pavement marking data collection at $4 per lane mile. Where contracted services are used for data collection, the contractor determines the cost, as in the case of utilities and manholes. Ultimately, data collection costs will be driven by the technique used to collect the data, the type and amount of data collected, and the frequency of data collection.

### 3.4 Data Analysis and Use

Data analysis tools are important for an asset management system because their capabilities determine the extent to which the data collected can be used effectively. For the states surveyed, 36 different database systems and analysis tools were reported, which included variations of the same concept. For example, various agencies use different modules of Oracle database systems (Oracle Maintenance Management System vs. Oracle Work & Asset Management). Several agencies indicated the use of GIS, sometimes specified (ESRI ArcGIS) and other times referred to more generally. Other common analysis tools were Microsoft Office programs such as Excel and Access. Table 3-5 shows the different database and analysis tools being employed by the agencies surveyed.

**TABLE 3-5 Database and Analysis Tools Employed in Ancillary Transportation Asset Management**

| | |
|---|---|
| Adaptable Database System (ADABAS) by Software AG | Maintenance Rating Program |
| AgileAssets | Microsoft Mobile |
| Exor Management Software | Microsoft Access |
| Bridge Management System | Microsoft Excel |
| Cartegraph | Unspecified Oracle Product |
| Custom-Built (in-house) System | Oracle Data Warehouse |
| Deighton | Oracle Maintenance Management System |
| Demand model to determine maintenance need | Oracle Work & Asset Management (WAM) |
| ESRI ArcGIS | Paper Forms/Records |
| FileMaker Pro | Plant Maintenance Module by SAP AG |
| GeoResults Mobile GIS by Marshall | Pontis |
| Unspecified GIS Geodatabase | Project Scoring System |
| Hansen v.8 from Infor | Roadway Characteristics Inventory |
| IBM DB2 Enterprise Server | Sign Deterioration Curves |
| IMF Mainframe System | SQL Server/Database |
| Legacy DB II on Mainframe | Toad for Oracle |
| Level of Service Analysis | Utility Franchise & Permits: Power Builder |
| Maintenance Level of Service (MLOS) Module by SAP AG | Utilities Module by SAP AG |

Data use in the decision-making process depends significantly on the data collected and the capabilities of the analysis tools used. Consequently, agencies apply asset management data in a variety of ways. However, the most common application is in the development of either general agency budgets or specific asset replacement budgets. In some cases, in-house tools have the ability to project future asset performance at different funding levels and can predict when an asset is likely to be replaced. When management systems are effectively integrated, geographic information can be used to guide how to be efficient in replacing multiple assets (or asset classes) at the same location, at the same time. Many other agencies use their asset management data in project prioritization and in the selection of rehabilitation candidates. Where age is being used as the performance measure for asset replacement, agencies use this data to inform decisions on asset maintenance and replacement and to estimate costs specific to a defined treatment year. Generally, asset management data is also used in answering specific questions about the transportation system or specific assets, without applying a formal approach.

As agencies consider expanding their existing asset management programs, the question of the best way to phase in different asset classes has become important, given funding limitations. Increasingly, agencies may have to make a business case to justify expenditures of funds to bring different asset classes into existing asset management programs. Agencies that can place priorities on investing in the assets that bring the highest benefits to their customers per unit dollar spent, and reduce customer and agency risks most significantly, would be making superior decisions in comparison with those that go about expanding their systems without systematic thinking about which assets must be prioritized for asset management in the face of limited funds. The survey findings indicate that agencies have not made efforts to quantify the benefits achieved (if any) from the implementation of a management program for any of the eleven categories of assets. Data on the benefits of managing other transportation assets such as agency vehicles was available for one agency responding to the survey. In many regions, individual agency analyses have shown the benefits of priority programming over a worst-first or need-based approach to asset rehabilitation, as reported in the survey.

Overall, these findings indicate that a framework that quantifies the relative benefits and costs (including risks) of systematic management programs for ancillary roadway and other transportation assets could help agencies prioritize their limited funds to areas that promise the highest returns and risk reductions. Where agencies have limited funds, such efforts can guide the use of limited resources for more effective outcomes, making explicit the existing tradeoffs and opportunity costs associated with investing in asset management capabilities for certain asset classes versus others. This way, a more systematic approach could be taken toward expanding existing asset management capabilities, with more effective outcomes with respect to an agency's strategic objectives.

## 3.5 Case Studies

From the results of the initial survey and interview process, certain agencies stood out as agencies that were not only responsive to requests for information on their asset management programs, but were making notable gains towards improving their management of ancillary assets. These agencies were contacted for a second round of interviews with more detailed questions specific to the goals of their respective asset management programs, any measured benefits relating to performance measures identified and the method used to prioritize asset classes for inclusion in their systems. As expected, answers were not obtained for all three questions from all the agencies; however, the summaries below provide an idea of asset management of ancillary transportation infrastructure as conducted in these agencies. Each case study begins with a description of the vision/mission and values of the agencies in order to provide some context for understanding their progress and performance in asset management.

### 3.5.1 Colorado Department of Transportation (CDOT)

According to their website, the vision of the Colorado Department of Transportation (CDOT) is "to enhance the quality of life and the environment of the citizens of Colorado by creating an integrated transportation system that focuses on safely moving people and goods by offering convenient linkages among modal choices." (18) Their values include safety, people, integrity, customer service, excellence and respect. The department is responsible for a 9,146 mile highway system which includes 3,447 bridges. Although this system accounts for only about 10 percent of the total mileage on the state system, it covers about 40 percent of all travel in the state.

CDOT manages its major assets with independent software solutions and staff. Pavements are managed with Deighton dTIMS CT software (dTIMS CT), bridges are managed with Pontis and maintenance fleet equipment, Intelligent Transportation Systems (ITS) and Maintenance Levels of Service (MLOS) are managed in two different modules developed by SAP AG, a German software corporation. A representative from CDOT responded to the initial survey, indicating that asset management practices are in place for ten out of the eleven classes of assets under consideration, leaving out sidewalks and curbs. CDOT's management of their assets are partially integrated with signs, signals, guardrails and pavement markings in Group 1 (pavement is managed in dTIMS, CTI, others in SAP MLOS module) and earth retaining structures, and culverts in Group 2 (with bridges in Pontis). Data is managed in multiple systems. The dTIMS CT software has the capabilities to manage multiple assets and perform projections and CDOT is looking to use it to cross-manage all five categories of assets that are currently managed in different systems. For now, the ancillary assets are managed in the MLOS system that involves an annual physical rating with nine maintenance program areas that are evaluated on a scale of A+ though F-, similar to an academic grading system. (19) The ratings assigned are then applied to a modeling system that provides cost matrices to identify budget requirements to achieve changes to the target maintenance level of service. In addition, this system is able to project asset performance for future years at different funding levels. Through a separate system, the maintenance fleet equipment is able to predict when the asset is likely to be replaced or has reached its full useful life.

In terms of goals and objectives of the system, CDOT has four investment categories which provide the framework for resource allocation within the department. They are safety, system quality, mobility and program delivery. Use of the MLOS system fits under the system quality objective, according to the 2012 fiscal year budget narrative and the goal is to achieve a B level of service grade. (19)

Although the total number of each asset was not available during the interview, CDOT reports that each management system contains 50 – 100% of the total inventory of each asset. The only exception was with water quality mitigation features, in which case inventory was in development at the time of the interview. Data collection tools for these assets vary from contractor data acquisition (guardrails) to human observation or optical observation technology. In the case of traffic signs and signals data collection varies by region but is often done by personal (visual) observation. Similarly, the inventory and attribute data collected varies by asset but generally includes basic inventory data (such as location, features of the asset) and attribute data related to the performance measures used to analyze the asset. The only available estimate of data collection was $128,000 spent on guardrails, pavement markings, traffic signs and traffic signals. Inspection frequencies ranges from one to four years, or on a rolling basis, or as regulations require inspection, such as for bridge inspections.

CDOT has made a few attempts at quantifying the benefits of ancillary asset management. For one thing, the operational savings for replacing fleet equipment assets at a certain age as opposed to another have been recognized, as have time savings from managing ITS elements. Specific benefit-cost analysis related to the asset data management has not been attempted for decision-makers at CDOT.

### 3.5.2 Oregon Department of Transportation (ODOT)

The vision of the Oregon Department of Transportation (ODOT) is to "provide a safe, efficient transportation system that supports economic opportunity and livable communities for Oregonians" (20). Their values include safety, customer focus, efficiency in the use of resources, accountability, problem solving, diversity and sustainability. ODOT uses annual performance measures which indicate progress towards their goals of safety, mobility, preservation, sustainability and stewardship and report their progress on their website, annually.

In 2006, ODOT embarked on a pilot study to determine the state's readiness for an asset management program that included nine of the eleven asset classes of interest for this work. The study was an analysis of four highway segments as a sample to learn what was known and the "level of effort required to gather [and integrate] existing or new information"(21) in order to make recommendations for broader asset management implementation. In March 2008, an Asset Management Program Plan was created, mapping out initiatives, policies and goals to direct ODOT's steps towards successful asset management(22).

ODOT currently manages nine out of the eleven asset classes under consideration, leaving out data and utilities and manholes. At the time of the initial interview, the current mainframe-based highway network information system was being replaced with a new system (Exor) that would allow better integration and a place for additional data for different asset classes. This new system is also more robust and allows tracking of the network for modeling and a more comprehensive understanding, among other options. It was estimated that the asset databases include about 100% of previously existing and new inventories, with the exception of earth retaining structures (20%), pavement markings (50%) and culverts (10%). Data collection for these systems is achieved with mobile GPS equipment and digital video logs. The data collected is commonly available to ODOT staff through the Features Attributes and Conditions Survey – Statewide Transportation Improvement Program (FACS-STIP Tool) which integrates any possible data in preparation for actual data use in project scoping and decision making.

From the survey/interview results, ODOT's efforts seem to be focused more on building the capacity of their asset management program and less on quantifying the benefits at this stage. Nonetheless, it was reported that asset inventories can be performed about five times faster than before and with greater reliability in the data collected. Data is now easily accessible in five minutes or less from one primary source as compared to previous allowances of eight weeks due to multiple individual requests. On the topic of asset class prioritization, asset values, level of risk, safety and mobility were used to determine priorities for the 2006 pilot. As of the summer of 2011, ODOT was in the process of developing a more extensive prioritization framework which considers the criticality of asset classes for mobility, operations, safety, stewardship and other measures. Risk factors are also included in this framework. Overall, ODOT has made clear and visible steps towards making asset management of all their linear and non-linear assets a priority and a part of agency culture.

### 3.5.3 Virginia Department of Transportation (VDOT)

The Virginia Department of Transportation (VDOT) is "responsible for building, maintaining and operating the state's roads, bridges and tunnels" (23). The mission of this agency is to maintain a transportation system that is safe, enable effective transportation, enhances the economy and improves the quality of life of the citizens of Virginia, with values that include responsiveness to customer needs, commitment to safety, mutual trust and respect, respect of the public investment, sound judgment and accountability, professional development and forward thinking.

In 2007, the Commonwealth Acts of Assembly established a framework which required VDOT to report "the condition of and needs for maintaining and operating the existing transportation infrastructure based on an asset management methodology" (24). This report, to be published every odd year, was to extend beyond pavements and bridges to technology assets, pipes and draining, congestion management and other structures.

Asset management is defined in the *Code of Virginia* and is based on goals which include: (a) managing assets based on a life-cycle cost analysis approach; (b) developing and implementing performance measures as a basis for identifying and prioritizing needs; (c) developing predictive models that link inventory, utilization and environmental conditions to asset condition and system performance, to generate performance based needs assessments; and (d) employing processes to plan, budget, implement, monitor and measure performance. (24)

According to the survey responses, VDOT conducts systematic asset management efforts for six of the eleven asset classes: traffic signs, street lighting, guardrails, traffic signals, culverts and sidewalks & curbs. These are all managed in a system that is used to track work done on these assets; however, it is not considered a fully-featured asset management system. Nonetheless, the overall goal is to preserve and extend the useful life of the assets. At the time of the survey, VDOT was using spreadsheets and an oracle database which did not have performance modeling, planning, budgeting or inventory management capabilities; however, there were plans to procure a new commercial software application with these capabilities to turn the system into a full-fledged asset management system. Inventory of their assets is mostly collected by contract, but in some cases, by state forces. It includes basic data such as the location and physical description of the assets. Inspections of the assets have been performed once overall in all cases, with the exception of culverts which are collected every two years in the National Bridge Inventory (NBI). Although not a fully functioning asset management system, the data collected have been used in some capacity to influence the budgeting process at VDOT, but the benefits of this use have not been documented or formally quantified.

Although quantified benefits have not been formally measured, VDOT determines the benefits of their program by realizing that better information gives more accurate forecasts with better data quality. The data they would use includes the time to enter data or create work requests, time to find data for analysis and the general effectiveness of data. In prioritizing the asset classes, data was collected on eight assets that the most amount of money is spent on. In order to improve these processes, VDOT acknowledges that goals need to be defined with benchmarked performance measures or measures of effectiveness, which are influenced from the higher level of the purpose of the asset. Previously, the performance measure used was the percent of inventory in a condition requiring repair; however, it is important to know the relationship between output and outcome in order to more effectively assess asset condition for decision making.

For VDOT, several steps are being taken to ensure the Department reaches a level of success where decisions are informed by the systematic collection of asset condition and performance data.

### 3.5.4 New York State Department of Transportation (NYSDOT)

The mission of the New York State Department of Transportation (NYSDOT) is to provide a “safe, efficient, balanced and environmentally sound transportation system”(25) for the roadway users. Their values include integrity, customer service, partnership, teamwork, people and excellence. The department’s inventory includes about 38,000 lane miles of pavement markings, 23 million feet of guardrails, 3000 miles of sidewalks and 45,000 curbs (ADA ramps), 7500 small culverts and 75,000 large culverts, 6000 traffic signals and 750,000 traffic signs.

At the time of the survey, the New York State Department of Transportation (NYSDOT) conducted systematic asset management efforts for seven out of the eleven asset classes: earth retaining structures, traffic signs, guardrails, traffic signals, culverts, mitigation features and sidewalks and curbs (ADA ramps). For the beginning stages of their asset management system, NYSDOT has had statewide inventory data for traffic signals, culverts and sidewalks & curbs; however, the inventories for the other assets are not statewide. In terms of mitigation features, the agency manages settling ponds, wetlands and outfalls. Each of these systems is loosely connected, but there is no consistent integration. Although no formal policy or program statement exists, some FHWA mandates and regulations, for example for retro reflectivity of signs and pavement markings, drive the asset management effort. In the case of mitigation features, New York state environmental conservation regulations mandate their management.

In terms of software, NYSDOT uses a combination of Microsoft Access databases, GIS geodatabases, Cartegraph and Oracle. These databases contain 90 to 100 percent of all traffic signals, sidewalks and curbs and small culverts, about 40 percent of all large culverts, but only about 15% of earth retaining structures, guardrails and traffic signs. The data are collected with field collection techniques using laptops, paper forms, photologging as well as Roadware Visidata. Asset inspections vary from annually to every 4 years, with continuous inspections of sidewalks and curbs.

In terms of data use, individual analyses are performed for some regional maintenance or capital programming, but the main use is in the maintenance and operations plan (MOP). The MOP is a tool that is able to estimate the capital improvements needed to achieve a state of good repair for the assets, based on investment needs.

Although the benefits of NYSDOT's asset management have not been quantified, individual analyses have shown benefits to this form of programming for maintenance over a worst-first approach. Even though the asset management program is not fully developed for these assets at NYSDOT, a request for proposals for an enterprise asset management system has been developed, with the goal of eventually obtaining a fully integrated asset management program for the Department.

These four case studies show various levels of progress with managing ancillary transportation assets. They also indicate the possibility of a range of different costs and benefits for any particular asset management program as this program evolves in maturity. However, there is still value in developing the capabilities to assess benefits and costs of asset management systems as they evolve on the maturity scale, in particular to determine whether the evolution of these systems is in the right direction.

# 4 QUANTIFYING THE BENEFITS OF ASSET MANAGEMENT

The effort of quantifying the benefits of asset management, particularly when focused on ancillary assets, is primarily one of identifying the agency's strategic objectives and performance measures, and assessing how formal management procedures for ancillary assets contribute to achieving these strategic objectives. A report by Amekudzi et al. showed the most common performance measures in state DOTs to be preservation, safety and mobility (26), indicating that implicitly or explicitly most agencies' strategic objectives include system preservation, safety and mobility. Various agencies may have additional strategic objectives and if they have adopted asset management as an agency-wide business process, apply asset management in achieving these objectives. Any evaluation of the benefits of asset management would thus be linked to the agency's strategic goals – some of which can be quantified more readily than others.

It is important to note here that the benefits of any asset management program are expected to be a function of the maturity of the program, and that programs tend to evolve in maturity over time. Table 3-6 shows the maturity scale for asset management programs presented in the AASHTO Transportation Asset Management Guide Volume 2(27). This scale indicates that the results of analyses conducted to determine the benefits and costs of particular asset management programs should be interpreted carefully, because the inability to make a business case for a program at some point on the maturity scale does not serve as a basis to write off that program because this does not imply that it will be impossible to make a business case for that program when it is at a higher level of maturity. In particular, two important measures for the value being added by asset management systems ought to be the evolution of the benefits relative to the costs of the system and whether these benefit and cost measures are moving in the right direction. Using these measures in a time-sensitive manner may provide more valuable information for an asset management program in the long run as it continues to be intentionally developed to higher levels of maturity.

**Table 4-1 TAM Maturity Scale (27)**

| TAM Maturity Scale Level | Generalized Description |
|---|---|
| **Initial** | No effective support from strategy, processes, or tools. There can be lack of motivation to improve. |
| **Awakening** | Recognition of a need, and basic data collection. There is often reliance on heroic effort of individuals. |
| **Structured** | Shared understanding, motivation, and coordination. Development of processes and tools. |
| **Proficient** | Expectations and accountability drawn from asset management strategy, processes, and tools. |
| **Best Practice** | Asset management strategies, processes, and tools are routinely evaluated and improved. |

Arguably, agencies at different levels of maturity are likely to demonstrate different levels of benefit from their programs. This issue presents complications for ex-ante and ex-post evaluation of asset management systems. Agencies that are considering implementation of asset management programs for particular ancillary assets may be interested in finding out the relative costs and benefits that other agencies have experienced in implementing asset management programs for similar assets. The caveat here is that analyses conducted for these other agencies would yield results based on their relative levels of maturity and the extent to which asset management decision support information is actually used in decision making. Thus, ex-ante evaluations which may be dependent on the use of data from other agencies (because the conducting agency has not yet developed a formal asset program) ought to be considered carefully in the context of the factors that influence the results of such evaluations. In addition, there should be an understanding that the evaluating agency may determine similar or different benefit-cost results after implementation, depending on what they adopt and how they actually apply decision-support information in decision making.

Another factor to consider, in determining the benefit of ancillary transportation asset management is the combination of assets that have formal asset management programs implemented. Since these assets work together to improve the performance of the highway system overall, different combinations of assets could produce different results. This problem would be exacerbated in an attempt to evaluate a particular asset class, for example, traffic signals. Asset Management programs where a wider range of ancillary assets are being formally managed may turn out different benefits and costs for a particular asset class such as signals, because of the synergistic effects of ancillary assets on overall system performance. In particular here, the task of attributing particular benefits to a particular asset class may become a challenging one. Quantifying the benefits of particular assets may also prove to be difficult, in which case performance outputs or outcomes can be considered as a function of different asset management maturity levels, and evaluated to determine if benefits have accrued with growth in the maturity of the asset management program.

Any benefit-cost evaluation of formal asset management programs must take these important factors and issues into consideration to properly interpret the results of the evaluation. In essence, given the maturation of asset management programs, one may view benefits evaluation as maturity-level dependent and any quantified benefit (in the form of a benefit-cost ratio, or otherwise) of an asset management program as a dynamic number which is likely to change over time, leading to the question of whether there is an optimum maturity level for an asset management program where the net benefits are maximized. Furthermore, depending on the types of benefits emphasized (in relation to the strategic objectives of the agency), the resulting benefits and costs may change. In addition to asking the question, which asset classes will likely provide the highest benefits when formally managed, agencies may benefit also from asking the question what types of management functions must we include in a particular asset category to enhance or maximize the benefits of such a program, and then take proactive steps to institute such elements to improve the effectiveness of such program. With these complicating factors in mind, agencies can still collect appropriate data to monitor the benefits-costs evolution of their asset management as they implement and continue to improve their systems, advancing the maturity level of these systems.

## 4.1 Benefit and Cost Factors

Benefit and cost factors are those elements that can be quantified in order to measure improvements in asset performance and condition as a result of the operation of an asset management system. These outline the type of data that should be collected when a method of quantifying the benefits has been designed or selected. Cost factors are easier to determine or measure, than benefit factors, because there is some direct cost associated with asset management program development and implementation. Benefits are usually measured in terms of cost reduction, thus, relying on the same cost factors. These factors are typically grouped in three categories: agency costs, user costs and external costs.

Agency costs are those "directly represented by the budget or out-of-pocket costs paid by the owner"(28 p. 292). Agency costs include the costs of developing and operating the asset management program - data collection costs, software development and maintenance, staffing or department restructuring, and any other costs associated with maintaining the program. User costs are those costs incurred directly by the users of the infrastructure asset. This includes occupancy time (travel time costs), vehicle operating costs, crash costs and even the time delay as a result of maintenance and rehabilitation(16)(28). External costs are those costs that do not affect infrastructure users directly, but may eventually become significant. Typically, external costs are associated with environmental and social impacts and include emissions, noise and visual pollution, and other neighborhood disruptions(28). All together, these factors are important for the quantification of the benefits of asset management.

## 4.2 Benefit Quantification Case Studies

From the literature reviewed, it was found that several researchers have made previous attempts at quantifying the benefits of asset management programs. Unfortunately, no documented processes for ancillary assets were found; however, methods have been developed for pavement management systems and even in the utility industry. The following case studies evaluate these methods of benefit quantification and examine their applicability to ancillary transportation assets.

### 4.2.1 Generic Methodology for Evaluating Net Benefit

From 2005 to 2008, Mizusawa and McNeil developed a generic methodology for evaluating the net benefit of asset management system implementation(16). They quantified the benefits of pavement management systems with a special focus on the

PMS used by the Vermont Agency of Transportation, VTrans, and the Highway Economic Requirements System – State Version (HERS-ST) created by the FHWA. The generic methodology involved two types of evaluation design – ex post facto and ex ante – and three analysis methods – descriptive analysis, regression analysis and benefit-cost analysis (BCA).

Ex post facto evaluation is retrospective, comparing conditions before and after implementation of an asset management system or conditions with and without. This form of evaluation is useful in situations where an asset management system has already been implemented. Where the asset management system has not been implemented, ex ante evaluation is employed. This prospective evaluation design compares with and without scenarios based on predicted data. Figure 4.1 below shows these concepts graphically.

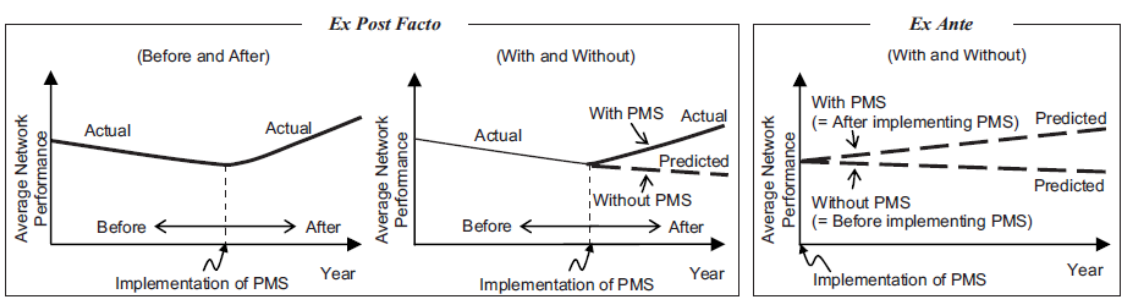


**FIGURE 4.1 Concepts of ex post facto and ex ante evaluations (16)**

Besides, whether or not the asset management system has been implemented, the selection of evaluation design also depends on the availability of time series data of asset performance/condition.

When the evaluation design has been selected, the benefits of the asset management system can be quantified by three analysis methods. The first of these is descriptive analysis, a method that captures improvements in asset performance and conditions using common performance measures such as international roughness index (IRI) or present serviceability rating (PSR). The descriptive analysis method is very simplified, either comparing actual asset performance or predicted performance. This analysis method cannot consider changes in various performance measures simultaneously, but can identify performance measures to be used in the regression analysis and BCA.

The regression analysis is a method that models several independent variables to determine the degree of their influence on a dependent variable, represented by the coefficients of those variables in the final regression equation. With this method, an appropriate dependent variable must be selected, typically related to the performance objectives of the program. This method is much more complicated than the descriptive analysis method and requires time series data for the asset condition and other measures that can influence condition.

The third part of this generic methodology is a BCA which attempts to show the cost factors described previously, in monetary values. The BCA methodology compares alternatives which in this case are to adopt or not to adopt a management system. Using the cost factors, the net present value (NPV) or benefit-cost ratio (BCR) methods can be used to show the differences in costs and benefits, making sure to use the same analysis periods for both alternatives. The analysis period would depend on the expected life of the investment and a period of time in which the benefits can be reliably predicted. This final analysis method, unlike the previous two, does not require time series data and presents benefits in monetary values, which is possibly the most relatable for decision makers.

In applying this generic methodology to ancillary transportation assets, the biggest challenge would be the availability of data and the ability to simulate predicted performance with or without the asset management program. As was observed from the literature review and in the survey results, cost data for ancillary assets have been difficult to come by. In addition, determining clear performance measures to base analysis on may be challenging for some of the assets. Finally, the data required for this methodology is highly aggregated, which works for pavement management systems because pavements are directly related to the performance measures, and therefore, changes in performance can easily be attributed to the management system. In the case of ancillary assets, however, attributing transportation system outcomes and other benefits to a particular asset is a difficult task because there are no clear and direct relationships between all the assets and all the benefit factors.

### 4.2.2 A Utilities Perspective

Outside the transportation industry, the concept of asset management continues to grow. In a white paper by the UMS Group (29), Schipper and Huisma build a framework to measure the effectiveness of asset management by transmission service operators (TSOs). Discussions between groups in the utility and energy industry led to the conclusion that specific benchmarks are necessary to assure the agencies that they are justified in implementing asset management procedures.

In this paper, the authors begin by presenting a hypothesis which states that "developing an Asset Management orientation will always bring you to a higher level of business output and success"(29 p. 1). The premise of the argument presented is based on the graph shown in Figure 4.2 which defines three distinct zones of performance.

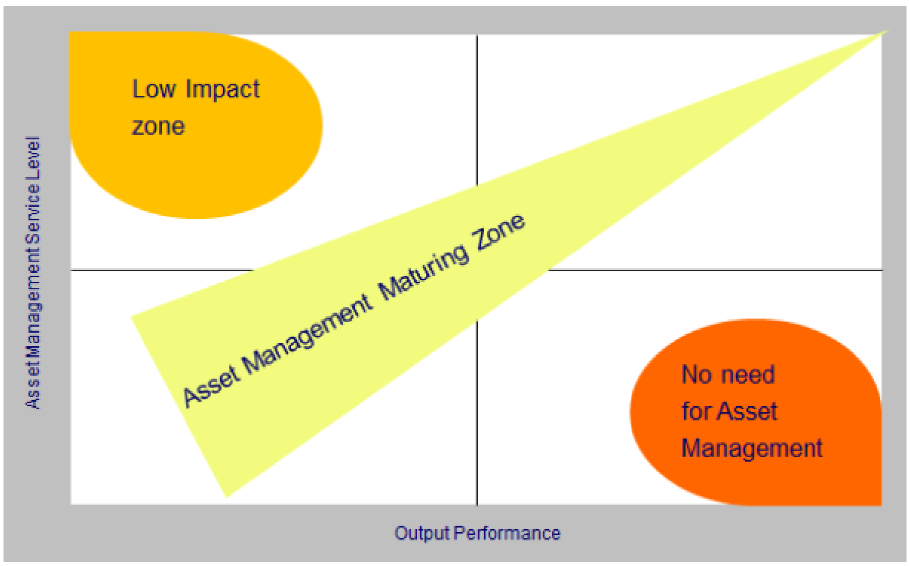


**FIGURE 4.2  Asset Management Measurement Framework(29)**

Agencies found in the "Low Impact Zone" have high asset management service levels, but with low levels of business outcome performance, while agencies in the "No Need for Asset Management" zone have high output performance without clearly expressed asset management values. When data points (representing agencies) are plotted in this framework, the hypothesis holds in the "Asset Management Maturation Zone;" however if any points fall in the "No Need for Asset Management" zone, the hypothesis is not valid.

According to the paper, the definition of the business outcome performance should be related to the stakeholders of the agency, however, standardized parameters are difficult to obtain since market conditions and stakeholder needs may be different for each agency. Nonetheless, the authors define a number of key performance indicators (KPIs) that should be applicable to all utility companies taking into consideration quality, safety, return on assets and transparency in terms of planned operating and capital expenditures. The KPIs selected are summarized into an output performance index which ranges from 0 to 2. In defining the asset management service level, the framework encompasses four areas key to asset management best practices: operating (and accountability) model, processes, competences and culture, and information management and enabling technology. These areas of competency are scored from 1 (lack of awareness) to 5 (excellence in asset management).

Based on these definitions, agencies were provided with a data pack identifying specific data to be collected which was used to plot points in the framework. As shown in Figure 4.3, the results illustrate some accuracy in the hypothesis. Most of the agencies plotted fall within the Asset Management Maturation Zone with a few outliers falling near the Low Impact Zone. Additionally, the researchers found several correlations between the KPI that suggest a positive value for asset management. To measure actual quantities of the benefits, this paper suggests comparing the difference between average, best practice and participant KPIs to obtain actual values.

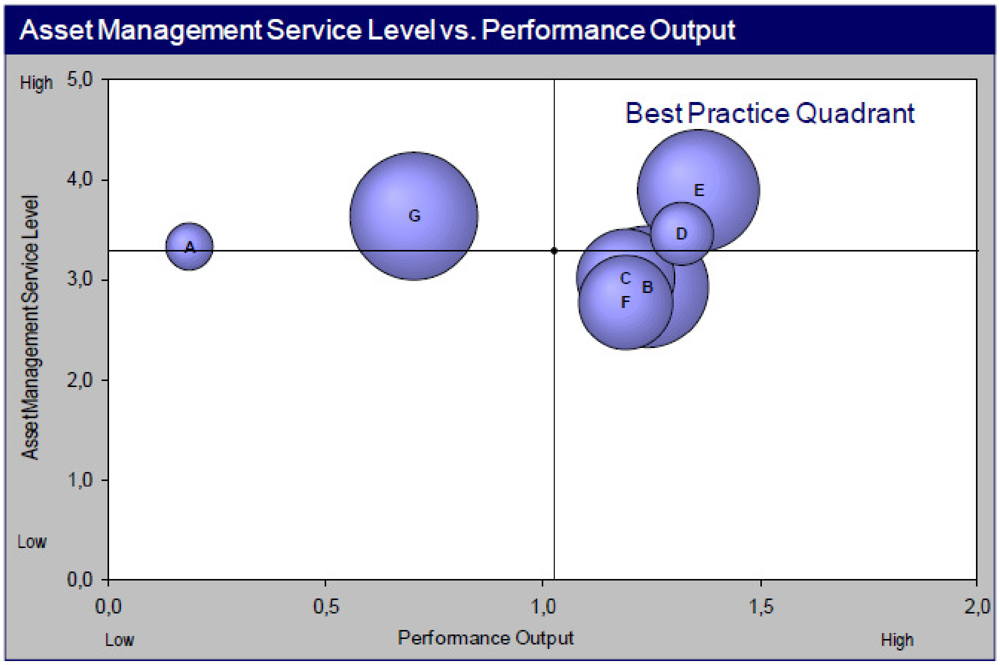


**FIGURE 4.3 Agencies plotted on Asset Management framework (29)**

This framework may be more easily applied to ancillary transportation assets, as compared to the generic methodology because the issue of attributing outcomes to specific assets is alleviated. This is because output performance metrics can be selected based on performance measures for each asset as opposed to an aggregated metric (for example, retro reflectivity for signs as opposed to reductions in crash costs). On the other hand, unlike the generic methodology, this framework only works retrospectively for asset management programs already implemented. Since ancillary transportation asset management is still a growing field, collecting the necessary data may pose a challenge. However, this finding makes it all the more important for agencies to attempt to collect data systematically in order to begin to demonstrate gains from maturing asset management programs. Finally, this framework as defined in Figure 4.2 makes the assumption that there is a fairly linear relationship between asset management service level and output performance. Any flaws or discrepancies in this assumption would change the shape of the Asset Management Maturing Zone, possibly re-defining this framework and the results obtained. One question of interest to some practitioners is whether there is an optimum level for programmatic asset management beyond which any expenditures fail to produce marginal benefits. If this is the case, the Asset Management Maturing Zone may be linear in the beginning but would flatten out at some point indicating no improvement in output with program maturation.

### 4.3 Benefit-Cost Analysis (BCA) Framework

Besides making a business case for asset management programs, quantifying the benefits of ancillary asset management is also useful in prioritizing these assets for inclusion in existing asset management programs. According to the survey conducted as part of this research, most agencies select assets for inclusion in a formal asset management program based on ease of data collection or the value of the asset, as defined by the amount of money spent on building and maintaining those assets on an annual basis. In order to improve this asset prioritization process and to ensure that agencies are integrate ancillary assets cost-effectively, the net benefit of managing each ancillary asset could be quantified and included as a factor in a prioritization framework.

Life-cycle cost analysis (LCCA) is an economic analysis tool frequently used in the transportation industry to compare highway investments to identify the least cost alternative. LCCA ensures that an alternative is not selected only based on the initial costs, but also considers the future costs and the lifetime of the investment (30). According to the FHWA Economic Analysis Primer, LCCA is used most appropriately when selecting from alternatives that yield the same amount of benefits. With the range of transportation assets being considered, each asset serves a distinguished purpose and thus management may have different benefits. In this situation, the primer recommends using BCA.

A standard BCA procedure, using the net present value method, involves six distinct steps: (a) specify the alternatives; (b) set the analysis period; (c) decide the benefit and cost factors; (d) determine the measures quantitatively based on the benefit and cost factors; (e) attach monetary values to the measures and discount to obtain present values; and (f) Compute the net present value of each alternative (30)(31). The alternatives for this framework are implementing asset management programs for each of the ten asset classes under consideration (leaving the data asset as a separate category); hence, there are ten alternatives. The benefit and cost factors are those described in the Section 4.1, with impact categories (measures) shown in Figure 4.4.

| | |
|---|---|
| **Data Collection Costs** | **Failure & Replacement Costs** |
| *Equipment* | *Asset Value* |
| *Labor* | *Injuries/Fatalities (number)* |
| *Other Costs* | *Traffic Delays (hours)* |
| **Program Implementation Costs** | *Labor Costs* |
| *Software* | *Other Costs* |
| *Organizational Changes* | **Administrative Time Savings** |
| *Other Costs* | *Administrative Tasks* |
| **System Operation Costs** | *Work Order Placement* |
| *Additional Labor* | **Maintenance Expenditure Savings** |
| *System/Program Maintenance* | *Pre-TAM Maintenance Expenditure* |
| | *Post-TAM Maintenance Expenditure* |

**FIGURE 4.4 Cost (left) and benefit (right) measures for proposed framework**

These measures were sent to selected agencies, requesting data to be used in estimating the benefits and costs of formal asset management implementation; however, none of the agencies were able to provide sufficient data to test the framework. Of the data that was returned, the benefit measures were the most deficient. Essentially, the most significant problem with attempting to quantify the benefits of ancillary asset management is attributing the benefits (or reductions in costs) to a particular asset class. The asset value may be used as the only benefit; however, this would be an incomplete assessment, leaving out the other factors that could be improved due to systematic asset management. Furthermore, the strategic objectives of an agency should determine which factors are used in the benefit-cost function, if the agency is interested in achieving these objectives through asset management.

### 4.4 Recommendations and Opportunities for Improvement

The over-arching goal of this research was to develop a simple and easily understood methodology for transportation agencies to be able to apply quickly and efficiently to estimate the relative benefits and costs of implementing formal asset management procedures for different classes of ancillary assets. Undoubtedly, the framework proposed here is one of many different options that could be attempted for the purpose of quantifying the benefits of ancillary transportation asset management. In order for this framework to be applied either retrospectively (after the management system is in place) or prospectively (in order to help prioritize assets for management), it is essential to be able to identify measures that can be attributed to specific assets. However, the transportation system is made up of components that work together, complementing each other to provide a service. Specific data needs or the specific data that needs to be collected cannot be recommended, because this should depend on the agency's strategic objectives and performance measures. The measures shown in Figure 4.4 should simply be a starting point for the use of this framework. Once the necessary data is obtained and the measures are monetized and put in present values, the present value of net benefits of each management system can be calculated by simple subtraction.

As previously stated, interpreting the results of such an analysis should be done in the context of the maturity level of an asset management program. This study has revealed the importance of considering benefits and costs of asset management programs over an extended period of program maturation, rather than at a snapshot in time, in order to make sound decisions on the value of such programs. This finding emphasizes the importance of systematic data collection to track the evolution of benefits and costs of asset management programs. Whereas a determination of a benefit-cost ratio less than one for a program at a lower level of maturity should not create concern, a reducing benefit-cost ratio as funds continue to be expended to increase the level of maturity of any program should raise a red flag, and cause the agency to ask critical questions about the nature of additional asset management functions that would raise the value of their evolving program.

# 5 CONCLUSIONS

## 5.1 Summary

This thesis has investigated the practice of ancillary transportation asset management in the United States. The literature review and survey revealed several important aspects of agency implementation of asset management practices over the past few years. Although some actions are driven by Federal mandates, most depend on the priorities and goals of state and municipal agencies. As a result, ancillary transportation asset management practices vary by agency, with some exceptions. No specific trends were observed in relation to the agencies or regions in the United States that seem to be making the most progress in the management of ancillary transportation assets. Findings also showed no specific trend in terms of jurisdictional size or the sizes of the inventories of assets that different agencies maintain. However, the agencies that manage a significant number (greater than 6) of the asset classes presented in this paper also seem to be further ahead in terms of data analysis and the use of data in informed decision-making practices. These agencies and several others investigated seem to be developed past the general inventory stage, which is usually the first step in the creation of an asset management program. Overall, many agencies are working towards improved asset management programs for their ancillary assets and greater data and system integration to reduce redundancies and increase data sharing. The practices presented in this thesis are by no means exhaustive; however the results are indicative of growth in the field of transportation asset management towards informed, efficient capital investment and effective MR&R decisions based on limited resources.

In comparison to the results of the literature review, findings from the survey present a more comprehensive and up-to-date synthesis of the data and data collection tools required in asset management systems. The only exception is in the case of cost data, which is not readily available. In the long run, one of the ways an asset management system can be judged to be successful is in the cost savings associated with higher levels of performance for the same expenditures. The availability of the life cycle costs and benefit (including risk reduction) data of asset management systems themselves are important inputs for assessing the relative effectiveness of such systems. Because most ancillary transportation asset management systems are relatively new, data collection costs may be more easily estimated than the life cycle costs of these systems at their present stage of development, indicating that the results of such analyses should be interpreted as a function of the maturity level of the programs, and that the evolution of the benefits and costs of a particular asset management program would be a better indicator of its value than a snapshot benefit-cost number. The evaluated benefits of asset management systems are also a function of the extent to which decision support information is actually implemented (i.e., used in decision making).

Finally, and most importantly, this work has evaluated the feasibility of quantifying the benefits of ancillary transportation asset management based on a review of previously proposed methods of quantification and a quantification framework based on a simple benefit-cost analysis procedure. As shown, the almost secondary nature of ancillary assets within the transportation system makes it difficult to attribute certain costs and reduction of those costs to the particular asset. In order to use this framework, agencies need to select cost-benefit factors and metrics that relate to their strategic objectives and for which data can be obtained (or predicted).

## 5.2 Contributions

This work has identified the existence and increasing use of various data analysis tools and methods for making data-driven decisions. Such data is generally used in overall budget setting including project prioritization. The study has also outlined the factors influencing the outcomes of quantifying the benefits of asset management programs, in particular the level of maturity of the programs and the combination of assets included in the programs. As agencies face decisions on where to best invest their limited resources, candidate asset classes for more systematic management can be prioritized in reference to their relative benefits and costs in helping agencies meet their strategic objectives, understanding the caveats in estimating program benefits or in using data from ex-post analyses of other agencies' asset management systems. The ability to determine these priorities is linked to willingness on the part of agencies to estimate data collection costs, and invest some time in determining how asset management systems have benefited and continue to benefit them and their customers, as these systems continue to evolve in maturity. The study also reveals that a single benefit-cost number at any point in time in the maturity evolution of an asset cannot be used properly to make a business case for formal asset management nor prioritize effectively candidate assets for an asset management program. Instead, the evolution of the benefits and costs of an asset management program, as the program matures, is a better indicator of the value of the program to the agency and system users. This emphasizes the importance of continuous, systematic data collection on the benefits and costs of asset management systems.

# APPENDIX A: ASSETS MANAGED BY AGENCIES FROM LITERATURE REVIEW

| Agency | CULVERTS | SIGNS | PAVEMENT MARKING | TRAFFIC SIGNALS | MITIGATION FEATURES | GUARDRAILS | UTILITIES & MANHOLES | DATA | LIGHTING | ERS | SIDEWALKS (CURBS) | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DEPARTMENTS OF TRANSPORTATION** | | | | | | | | | | | | |
| Alaska DOT | 1 | | | | 1 | | | | | | | 2 |
| Arizona DOT | | | 1 | | | | | | | | | 1 |
| Arkansas DOT | 1 | 1 | | | | | | | | | | 2 |
| California DOT | 1 | | | 1 | 1 | | | | 1 | | | 4 |
| Colorado DOT | 1 | 1 | 1 | 1 | | | | | 1 | 1 | | 6 |
| Delware DOT | 1 | | | | | | | 1 | | | | 2 |
| Florida DOT | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | | | 8 |
| Idaho DOT | 1 | | | | | 1 | | | | | | 2 |
| Illinois DOT | | 1 | 1 | | | 1 | | | | | | 3 |
| Indiana DOT | 1 | 1 | | 1 | 1 | 1 | | | 1 | | | 6 |
| Iowa DOT | 1 | 1 | 1 | | | 1 | | | 1 | | | 5 |
| Kansas State DOT | | 1 | 1 | | 1 | 1 | | | | 1 | | 5 |
| Kentucky DOT | | | | | | 1 | | | | | | 1 |
| Maine DOT | | | | | 1 | | | 1 | | | | 2 |
| Maryland Highways Agency | 1 | | 1 | 1 | 1 | | | | | 1 | | 5 |
| Michigan DOT | 1 | 1 | | 1 | | 1 | | 1 | | | | 5 |
| Minnesota DOT | 1 | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | | 8 |
| Missouri DOT | | 1 | 1 | | | | | | | 1 | | 3 |
| New Jersey DOT | 1 | | | | 1 | | | | | | | 2 |
| New Mexico | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | | | | 7 |
| New York State DOT | 1 | | | | 1 | | | | | | | 2 |
| North Carolina DOT | 1 | 1 | 1 | 1 | 1 | | | | | | | 5 |
| North Dakota DOT | | 1 | 1 | 1 | | 1 | | | 1 | | | 5 |
| Ohio DOT | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | | | 8 |
| Oregon DOT | 1 | 1 | | 1 | 1 | | | | 1 | | | 5 |
| Pennsylvania DOT | 1 | 1 | | | | | | 1 | | 1 | | 4 |
| South Carolina DOT | | 1 | | | | | | | | | | 1 |
| South Dakota DOT | | 1 | | | | | | | | | | 1 |
| Tennessee DOT | | 1 | 1 | | | 1 | | 1 | | | | 4 |
| Texas DOT | 1 | | 1 | | | | | | | | | 2 |
| Utah DOT | 1 | 1 | 1 | | 1 | | | | | | | 4 |
| Virginia DOT | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | | | | 7 |
| Washington State | 1 | | | | 1 | | | | | | | 2 |
| Wisconsin DOT | | 1 | 1 | 1 | | | | | | 1 | | 4 |
| **LOCAL/COUNTY AGENCIES** | | | | | | | | | | | | |
| Alameda County, CA | 1 | | | | | | | | | | | 1 |
| Anne Arundel County, MD | | | | | | 1 | | | | | | 1 |
| City of Saco, Maine | | | | | | | 1 | | | | | 1 |

| Agency | CULVERTS | SIGNS | PAVEMENT MARKING | TRAFFIC SIGNALS | MITIGATION FEATURES | GUARDRAILS | UTILITIES & MANHOLES | DATA | LIGHTING | ERS | SIDEWALKS (CURBS) | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clearwater, Fl | | | | | | | 1 | | | | | 1 |
| Dakota County Road Department, NE | 1 | 1 | 1 | | | | | | | | | 3 |
| Fairfax County Waste Water Collection Division | | | | | | | 1 | | | | | 1 |
| Greenwood County Metro Authority, SC | | | | | | | 1 | | | | | 1 |
| Harford County Public Works Department, MD | 1 | | | | | | | | | | | 1 |
| Hillsborough County, FL | | | | | | | 1 | | | | | 1 |
| Oklahoma City Water & Waste Utilities Division, OK | | | | | | | 1 | | | | | 1 |
| INTERNATIONAL AGENCIES | | | | | | | | | | | | |
| Alberta Infrastructure and Transportation, Canada | | | | | | | 1 | | | | | 1 |
| Australia | | | | | | | 1 | | | | | 1 |
| Brisbane, Australia | 1 | | | 1 | | | | | | | | 2 |
| British Columbia Ministry of Transportation Canada | | | | | | | | | | 1 | | 1 |
| Calgary, Alberta Canada | | | | | | | 1 | | | | | 1 |
| Edmonton, Alberta, Canada | 1 | 1 | | 1 | | | | | | | 1 | 4 |
| Finland | | | | | | | 1 | | | | | 1 |
| Gloucestershire County, England | | 1 | 1 | 1 | | 1 | | 1 | 1 | | 1 | 7 |
| Greece | | | | | | | 1 | | | | | 1 |
| Hamilton, Ontario Canada | | | | | | | 1 | | | | | 1 |
| London, England | | | | 1 | | | | | | | | 1 |
| New South Wales Roads & Traffic Authority (RTA), Australia | | | | 1 | | | | | | | | 1 |
| New Zealand Transport Agency | 1 | 1 | | | | | | | 1 | | | 3 |
| Oslo, Norway | | | | | | | 1 | | | | | 1 |
| Quebec Ministry of Transportation | | | 1 | 1 | | | | | | | | 2 |
| Queensland Main Roads, Australia | 1 | | | | | | | | | | | 1 |
| Saskatchewan Highways & Transportation | | 1 | 1 | | | | | | | | | 2 |
| Victoria VicRoads, Australia | 1 | | | 1 | | | | | | | | 2 |
| Wellington, New Zealand | | | | | | | 1 | | | | | 1 |
| Total | 31 | 27 | 22 | 21 | 17 | 15 | 14 | 11 | 11 | 8 | 2 | |

# APPENDIX B:  ASSET MANAGEMENT SURVEY OF PRACTICE

Georgia Tech College of Engineering
School of Civil & Environmental Engineering

**GEORGIA INSTITUTE OF TECHNOLOGY UNIVERSITY TRANSPORTATION CENTER**

**COMPREHENSIVE TRANSPORTATION ASSET MANAGEMENT SURVEY OF PRACTICE**

**JANUARY 2011**

Georgia Institute of Technology is conducting a research project titled *Comprehensive Transportation Asset Management: Risk-Based Inventory Expansion & Data Needs*, sponsored by the Georgia Department of Transportation. The purpose is to develop a risk-based framework for integrating high-quantity, lower-cost transportation assets into existing transportation asset management (TAM) systems. This project focuses on eleven main asset groups: traffic signs, traffic signals, roadway lighting, guardrails, culverts, pavement markings, sidewalks & curbs, utilities & manholes, earth retaining structures, mitigation features and data. Your agency has been identified as one that is currently managing one or more of these assets. Please complete the questions below on your management process for TAM. The survey should take about 15-20 minutes to complete. The research results will be made available to participants and made widely available through Transportation Research Board and other practitioner-oriented publications. Thank you for participating in this survey.

Agency: ______________________________________________

Survey Contact: ______________________________________________

Position/Title: ______________________________________________

Department/Division: ______________________________________________

Address: ______________________________________________

______________________________________________

City: ______________________ State: __________ Zip: __________

Tel: ______________ Fax: ______________ Email: ______________

**School of Civil and Environmental Engineering**
Atlanta, Georgia 30332-0355 U.S.A.
Phone 404/894-2201
FAX 404/894-2278
http://www.ce.gatech.edu

1. **(a) For which of the following assets does your agency conduct a systematic asset management effort?**

| | | |
|---|---|---|
| ☐ Earth retaining structures | ☐ Guardrails | ☐ Pavement Markings |
| ☐ Traffic Signs | ☐ Traffic Signals | ☐ Sidewalks & Curbs |
| ☐ Street Lighting | ☐ Culverts | ☐ Utilities & Manholes |
| ☐ Mitigation Features | ☐ Data | |

   **(b) Are the assets managed independently or within an integrated asset management system?**

   ☐ Independently ☐ Integrated

   Comments:……………………………………………………………………………………………………..………
   ...……………..……………………………………………………………………………………………………
   ………………...……………………………………………………………………………………………….…

2. **Is there a written policy or program statement that describes the objectives of this effort?**

   ☐ Yes ☐ No

   **If yes, please send to the contact email provided at the end of the survey. If not, in your own words, what are the main objectives of managing the above assets?**

   ……………………………………………………………………………………………………………………
   …..……………………………………………………………………………………………………...…………
   ……….……………………………………………………………………………………………...…………
   ……………..………………………………………………………………………………………………...…

3. **For the asset(s) included in your asset management effort, what is the approximate quantity of each asset (e.g. number of assets per linear foot/per mile of roadway)?**

| | | | |
|---|---|---|---|
| Earth Retaining structures | ……………… | Lighting | ……………… |
| Guardrails | ……………… | Culverts | ……………… |
| Pavement Markings | ……………… | Utilities and Manholes | ……………… |
| Traffic signs | ……………… | Data | ……………… |
| Traffic signals | ……………… | Mitigation Features | ……………… |
| Sidewalks and Curbs | ……………… | | |

4. **What type of database system does your agency use to manage the assets?**

   Earth Retaining Structures………………………………………………………………………………....
   Guardrails……………………………………………...……………………………………………………
   Pavement Markings……………………………………….…………………………………………….
   Traffic Signs……………………………………………..………………………………………………
   Traffic Signals…………………………………………………...………………………………………….
   Sidewalks and Curbs……………………………………………………………...…………………..….
   Lighting ……………………………………………………………..………………………………………..
   Culverts…………………………………………………………………...……………………………………...

Utilities and Manholes……………………………………………………………………………………….…
Data………………………………………………………………………………………………………………
Mitigation Features…………………………………………………………………...…………………………

5. **What is the estimate of the amount of your asset base that is included in your asset management system? Please indicate the percentage population of the system by asset.**

| | | | |
|---|---|---|---|
| Earth Retaining structures | ……………… | Lighting | ……………… |
| Guardrails | ……………… | Culverts | ……………… |
| Pavement Markings | ……………… | Utilities and Manholes | ……………… |
| Traffic signs | ……………… | Data | ……………… |
| Traffic signals | ……………… | Mitigation Features | ……………… |
| Sidewalks and Curbs | ……………… | | |

6. **What specific data collection tools are used for each of these assets?**

Earth Retaining Structures…………………………………………………………………………………...
Guardrails…………………………………………...……………………………………………………………
Pavement Markings…………………………………….………………………………………………….
Traffic Signs…………………………………………...…………………………………………………
Traffic Signals……………………………………………….....…………………………………………….
Sidewalks and Curbs…………………………………………………………………...………………….….
Lighting ………………………………………………………….....…………………………………………..
Culverts…………………………………………………………………...……………………………………...
Utilities and Manholes……………………………………………………………………………………….…
Data………………………………………………………………………………………………………………
Mitigation Features…………………………………………………………………...…………………………

7. **What other data analysis tools are used for each of these assets?**

Earth Retaining Structures…………………………………………………………………………………...
Guardrails…………………………………………...……………………………………………………………
Pavement Markings…………………………………….………………………………………………….
Traffic Signs…………………………………………...…………………………………………………
Traffic Signals……………………………………………….....…………………………………………….
Sidewalks and Curbs…………………………………………………………………...………………….….
Lighting ………………………………………………………….....…………………………………………..
Culverts…………………………………………………………………...……………………………………...
Utilities and Manholes……………………………………………………………………………………….…
Data………………………………………………………………………………………………………………
Mitigation Features…………………………………………………………………...…………………………

8. **For each asset in your asset management system, what *inventory* data are collected?**

   Earth Retaining Structures…………………………………………………………………………………...
   Guardrails……………………………………………...………………………………………………………
   Pavement Markings…………………………………………………………………………………………….
   Traffic Signs…………………………………………….…………………………………………………
   Traffic Signals…………………………………………………...………………………………………….
   Sidewalks and Curbs…………………………………………………………………...………………..….
   Lighting …………………………………………………………….………………………………………..
   Culverts……………………………………………………………………...……………………………...
   Utilities and Manholes…………………………………………………………………………………….…
   Data…………………………………………………………………….…………………………….……
   Mitigation Features……………………………………………………………...…………………………

9. **For each asset in your asset management system, what *performance* (i.e., attribute) data are collected?**

   Earth Retaining Structures…………………………………………………………………………………...
   Guardrails……………………………………………...………………………………………………………
   Pavement Markings…………………………………………………………………………………………….
   Traffic Signs…………………………………………….…………………………………………………
   Traffic Signals…………………………………………………...………………………………………….
   Sidewalks and Curbs…………………………………………………………………...………………..….
   Lighting …………………………………………………………….………………………………………..
   Culverts……………………………………………………………………...……………………………...
   Utilities and Manholes…………………………………………………………………………………….…
   Data…………………………………………………………………….…………………………….……
   Mitigation Features……………………………………………………………...…………………………

10. **Does your agency estimate the cost of collecting data on these assets? If so, on what basis (i.e. per mile, per linear feet or per number of assets)? What is the approximate cost of data collection for each of the assets managed?**

    Earth Retaining Structures…………………………………………………………………………………...
    Guardrails……………………………………………...………………………………………………………
    Pavement Markings…………………………………………………………………………………………….
    Traffic Signs…………………………………………….…………………………………………………
    Traffic Signals……………………………………………………………………………………………….
    Sidewalks and Curbs…………………………………………………………………...………………..….
    Lighting …………………………………………………………….………………………………………..
    Culverts……………………………………………………………………...……………………………...

Utilities and Manholes……………………………………………………………………………………….…
Data…………………………………………………………………………….…………………………..……
Mitigation Features…………………………………………………………………...…………………………

11. **How frequently are inspections or inventories performed?**

| | | | |
|---|---|---|---|
| Earth Retaining structures | ……………… | Lighting | ……………… |
| Guardrails | ……………… | Culverts | ……………… |
| Pavement Markings | ……………… | Utilities and Manholes | ……………… |
| Traffic signs | ……………… | Data | ……………… |
| Traffic signals | ……………… | Mitigation Features | ……………… |
| Sidewalks and Curbs | ……………… | | |

12. **How are the inventory and performance data used in decision making (e.g., budget setting, project prioritization and selection, etc.)?**

Earth Retaining Structures…………………………………………………………………………………....
Guardrails…………………………………………...……………………………………………………
Pavement Markings………………………………………….…………………………………………….
Traffic Signs…………………………………………………..……………………………………………
Traffic Signals……………………………………………………...…………………………………………
Sidewalks and Curbs……………………………………………………………...……………………..…..
Lighting ………………………………………………………………...……………………………………..
Culverts…………………………………………………………………..……………………………………...
Utilities and Manholes……………………………………………………….………………………………..…
Data…………………………………………………………………………….…………………………..……
Mitigation Features…………………………………………………………………...…………………………

13. **Has your agency quantified the benefits resulting from the asset management system or the general maintenance or rehabilitation of any of these assets? For example, has your agency estimated cost savings of prolonging the useful life of such assets?**

☐ Yes ☐ No

**If yes, please send examples of these data to the contact email provided at the end of the survey.**

14. **Are there any other aspects of your asset management systems that you consider unique or that you would like us to know about? Please indicate here.**

…………………………………………………………………………………………………………………
…..…………………………………………………………………………………………………...…………
……….………………………………………………………………………………………………..………
……………..……………………………………………………………………………………………...…

**Thank you for your participation.**

**Direct all questions and additional information to:**

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