ASSESSING THE GAPS IN MANAGING TRAFFIC AND SAFETY ASSETS

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ABSTRACT
Effectively and efficiently managing a roadway network involves achieving a complex balance between infrastructure, maintenance, operations, safety, and customer service. There are a number of assets crucial to the operation and safety of roadways. While there are established asset management practices for bridges and pavement, there is currently no well-established guidance for traffic and safety assets. The traffic and safety assets explored in this paper include signs, signals, pavement markings/markers, barrier systems, and lighting. This paper focuses on the issues that cut across the management of all of these types of assets, as well as the gaps in the existing knowledge based on a thorough literature review. Furthermore, the transferability and experience in establishing pavement and bridge asset management systems is discussed. The review found that data needs and the uses and applications of the data are two primary types of gaps that exist across these five safety-related assets. The results presented in the paper are based on the results of Phase I of NCHRP 07-21, Asset Management Guidance for Traffic Control Devices, Barriers, and Lighting.
INTRODUCTION

The Moving Ahead for Progress in the 21st Century Act (MAP-21) transportation legislation defines asset management as “a strategic and systematic process of operating, maintaining, and improving physical assets, with a focus on engineering and economic analysis based upon quality information, to identify a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions that will achieve and sustain a desired state of good repair over the lifecycle of the assets at minimum practicable cost.” (1) MAP-21 requires states to develop a risk-based, performance-based asset management plan for preserving and improving the condition of the National Highway System (NHS). States must address pavements and bridges but are encouraged to include all infrastructure assets within the right-of-way corridor.

While the term “all infrastructure assets” can encompass a variety of asset types, there are a number of assets crucial to the operation and safety of the roadways. These include signs, traffic signals (including beacons, flashers, and ramp meters), pavement markings and markers, barrier systems (including guardrails, end treatments, and impact attenuators), and lighting (as shown in Figures 1, 2, and 3). These help guide, protect, and increase visibility for all roadway users (e.g. motorists, pedestrians, bicyclists) which help to improve traffic safety.

• Signs: Signs convey critical operational information to roadway users to guide their travel including the direction of travel, changes in alignment, and intersection control. This information must be conveyed in a visible and conspicuous manner for the safety of the transportation system.

• Signals: Traffic signals control the flow of traffic at intersections and ramps by separating movements in space and time. For example, traditional intersections have 32 potential conflict points. Traffic signals systematically assign the right-of-way to the various movements to minimize these conflict points.

• Pavement markings/markers: Similar to the function of signs, pavement markings provide information on the design and intended operation of the roadway to users including the presence of turn lanes, advance warning for intersections, and the presence of passing zones. Pavement markings and markers also help guide roadway users to stay in their travel lanes and alert them when they have left.

• Barrier systems: Guardrails, end treatments, and impact attenuators all help to reduce the potential consequences of leaving the roadway by shielding hazards such as fixed objects and opposing lanes of travel.

• Lighting: Lighting helps increase the visibility of the roadway and the surrounding environment for motorists on segments, intersections, curves, and ramps-helping them avoid potentially hazardous situations.

With the growing emphasis on safer and more efficient operations of roadways, the need for mechanisms to track and manage these types of assets is becoming more important. However, the lack of existing asset management guidance tailored to these asset types and the variation between state DOTs in terms of how they inventory and manage...
these assets makes it difficult to achieve the goal. Considering these factors, it is crucial to assess the gap thoroughly based on current practices and agencies’ needs, as well as legislation requirements, before developing a guidance to manage these assets. This paper starts with an overview of cross-cutting issues that are important to consider across assets. This paper also presents gaps in the knowledge regarding asset management for the selected assets. Following identified gaps, this paper also explores the possibility of transferring experience in managing pavement and bridges to managing safety-related assets. The work presented is a result of Phase I of NCHRP 07-21, Asset Management Guidance for Traffic Control Devices, Barriers, and Lighting.

CROSS-CUTTING ISSUES

Asset management requires knowledge of the individual components of the transportation network. Transportation asset management (TAM) is recognized as a strategic business approach to managing infrastructure assets, which is a data driven, risk, and performance based approach to maintaining assets in a state-of-good repair. A generic asset management system overview was developed by the FHWA (2) along with a list of key questions (FIGURE 4). Since there are issues that commonly exist across all assets, it is necessary for agencies to understand these cross-cutting issues before improving their own safety-related asset management system. The following paragraphs summarize these issues based on the generic asset management system and key questions developed by FHWA.

Planning and scoping entails defining the needs within an asset management program. Hawkins and Smadi (3) reported in a recent survey that only 60 percent of responding state agencies have an asset management group, and only 15 percent have created separate divisions within their organization to support asset management activities. They also found that asset management within an organization most commonly resides across divisions (7 of 23 agency responses), implying no formal asset management unit. In an interview of 34 AASHTO members and FHWA stakeholders, Park and Robert (4) found that management activities of safety assets for programming, budgeting, condition data collection, and inventory data collection are most commonly controlled by an agency’s operations and maintenance division. The FHWA (5) found that there is no one correct system of organization and no one set of performance measures that will guarantee an effective TAM.

Inventory and inspection issues exist across all assets since each asset requires specific in-depth knowledge and varying measures of performance. More importantly, an agency would need to identify what data are necessary to quantify or characterize the outcomes they want to measure. This cross-cutting issue may lead agencies to different data elements specific to their use. For example, some agencies may be interested in keeping inventories—identifying the number of nuts and bolts, associated with longitudinal barriers, are in the field—while other agencies may only be interested in knowing where and how many linear feet of barriers they have.
Condition and performance measurement is essential for planning purposes and requires minimum thresholds to be established. Currently some agencies have established minimum thresholds for maintaining their safety assets to minimize asset failures, while others do not. Gordon et al. (6) show that asset failure can be identified through condition, functional performance, or obsolescence. A physical failure is obvious, such as when a lamp burns out or a detector ceases to detect vehicles on an approach. A functional failure may occur if the asset is still operating, but is operating incorrectly. An example would be if a traffic signal fails to maintain its intended timing plan. Cambridge Systematics et al. (7) emphasize that effective decision making processes are only as efficient as the quality of condition/performance data being used. It is becoming more understood that many assets deteriorate at known rates, and these rates can be modeled, accounting for other factors, such as location, weathering, and usage. However, life expectancy and deterioration models cannot be used if data used to develop them are not accurate or are unreliable. Hawkins and Smadi (3) found that sign and pavement marking condition is assessed annually by only 30 and 27 percent of responding agencies, respectively. Lighting and guardrail condition is
assessed annually by 18 and 13 percent of agencies. However, it is worthwhile to conduct life-cycle cost analysis for these longer-term assets. Additionally, most data for these devices are collected manually, meaning that condition assessment is a slow, cumbersome process.

A process must be in place to evaluate needs, prioritize, and select projects within a constrained budget. Decision support systems were developed and used by agencies to fulfill these needs. Cambridge Systematics et al. (7) present a review of existing tools that evaluate investment levels and tradeoffs, identify needs and solutions, evaluate and compare options, and monitor results. Most tools focus on pavements and bridges, but several tools exist for project prioritization and investment decisions for different project types.

Many of the issues with maintenance management have been discussed between performance measurement and prioritization. To better address the issues, a work planning and tracking system is in need. As noted by the FHWA (8), asset failure can be examined as a function of treatment timing, treatment appropriateness, material acceptance, construction techniques, and maintenance history.

Hawkins and Smadi (3) found that approximately 81 percent of responding agencies with or without a transportation asset management plan (TAMP) think that a TAMP would allow them to review and update performance targets as well as identify limitations of data collection and decision making. Sixty-five percent of agencies reported that they forecast the capabilities for asset performance, but only 26 percent verify that forecasts provide realistic projections of system deficiencies.

To improve roadway safety and to allocate funding appropriately, agencies would need to embark on improved asset management of safety-related assets. With an understanding of cross-cutting issues discussed above, agencies may want to refine the structure of their teams, such as having a cross-cutting asset management team or having asset management as part of everyday business for each business group within the agency.

**GAP ASSESSMENT**

It is essential to identify agencies’ needs before assessing the gaps. Generally, there are several basic questions that an agency needs to consider in order to effectively manage their safety assets. These include:

- **What is the current state of the physical transportation asset?** This includes identifying what assets are in place, where they are located, when they were installed, what their current condition is, how much useful life remains, and determining their remaining value.

- **What are the required levels of service and performance delivery?** This includes identifying the required functional level of service, the need/demand for services by stakeholders, the regulatory requirements for the assets, and the actual asset performance.

- **Which assets are critical to sustained performance of the transportation system?** This includes determining the impact of asset failure, potential methods of failure, likelihoods of failure methods, and the cost of repair/replacement.

- **What is the expected growth in the number of assets given new standards, increased traffic, and changes in traveler and community expectations?** This includes identifying new and evolving standards, estimating the expected changes in traffic volumes, identifying how new technologies will impact traveler and community expectations, and how these factors will impact the number and placement of assets.

- **What are the funding needs and best investment strategies for operations, maintenance, replacement, and improvement?** This includes prioritization and program investment decisions for each asset type, effectively managing asset cost, potential funding sources, and identifying which strategies are the most feasible.

- **What is the best long-term funding strategy?** This includes identifying how assets will continue to be managed in the long-term.
Another primary process for assessing gaps is understanding current practices through a thorough but targeted literature review. Several gaps in the existing body of knowledge across these five types of safety assets were identified through comparing current state and local agencies’ practices to their needs. Below is a discussion of some of the key gaps.

### Data Needs and Quality

Several research reports \((9, 10, 11, 12, 13, \text{ and } 14)\) outlined critical and desirable data for signs. Critical data for pavement markings have been established by a variety of researchers \((15, 16, 17, 11, 18, \text{ and } 19)\). Traffic signal inventory data are also compiled by Li and Madanu \((11)\) and FHWA \((20)\); however, neither source specified what data should be considered to be critical and what data are desirable. The lack of foundational relationships between data elements and data uses \((e.g., \text{ critical and desirable data for budgeting, inventory, and benefit-cost analysis})\) makes it difficult for agencies to determine what data is critical and what data is desirable for their needs. For example, an agency would like to collect data for benefit-cost analysis. With the constrained budget, they would like to collect the minimum required data rather than the entire dataset. Without understanding what data elements are necessary to perform the analyses, the agency may waste effort on collecting unnecessary data. Another sequence for incomplete information on data inventory is that no information is available for data quality in terms of completeness, timeliness, accuracy, accessibility, uniformity, and integration.

Data quality is also affected by how often and to what extent the data are collected. For example, some states use a sampling approach to represent asset conditions. The number of samples has a direct impact on the reliability of the data for reporting. Additionally, some safety assets, such as pavement markings, are replaced as part of construction and resurfacing projects. Updated data may not be entered into the system when markings are replaced. Thus, Quality Assurance (QA) and Quality Control (QC) processes require a context of documented standards. They are the mechanism, by which adherence to standards is measured. Utah is implementing Maintenance Management Quality Assurance (MMQA) programs with the purpose of evaluating and reporting the effectiveness of their maintenance programs for signs and pavement markings \((22)\). They encourage semiannual measures and measures after significant changes. However, most agencies do not have a statewide and consistent QA/QC program or a well-documented QA/QC process for traffic and safety assets. The City of Portland has implemented a QA/QC for sign assets on an as-needed or as-discovered basis \((9)\).

### Data Collection Methods and Costs

An extensive asset management system requires widespread data collection activities and can be cost-prohibitive for agencies to collect data in the field. It may be easier for a larger agency to absorb costs on data collection, but more difficult for smaller agencies. There are four types of data collection methods that are commonly used in data collection, including: manual, automated, semi-automated, and remote data collection. Manual data collection employs two or more data collectors and a distance-measuring device. The data collector documents the data either with pen and paper or, in more recent cases, with hand-held computers equipped with Global Positioning Systems (GPS) mapping capabilities. Most small agencies may rely on manual data collection since they cannot afford to purchase or develop an advanced data collection system. Automated data collection involves the use of a multi-purpose vehicle that is equipped with a distance-measuring device, digital video cameras, a gyroscope, laser sensors, computer hardware, and potentially GPS antennas in order to capture, store, and process the collected data. Semi-automated data collection has similar equipment as the automated method but with a lesser degree of automation. Remote collection involves high resolution images acquired through satellites or other types of images and scans obtained by remote sensing technologies \((e.g., \text{ lasers, aerial photos})\). In conjunction with ground information, the user would be able to refer the location of the
transportation assets and to assess asset condition or capture various asset attributes and characteristics.

**Uses and Applications**

While it is important to identify budgeting and per capita costs for planning purposes, typically there is very little information available for maintenance, safety, traffic, and budgeting costs. Portland, Oregon reports that the average sign crew cost—labor and equipment only—is about $1,769 per crew per day (23). Gordon and Braud (24) provided a guideline to estimate the staffing and resource needs to effectively maintain traffic signal systems and achieve Objective Oriented Operation (OOO). It was estimated that a staffing level of 75 to 100 signals per engineer and a staffing level of 30 to 40 signals per technician will be appropriate to operate a minimum of 150 signals. With this type of information, an agency would be able to estimate the maintenance cost based on the condition and the number of devices in their region. Also, benefit-cost analyses are useful when considering whether to hiring a new employee or implementing a long-term software program, which must consider related costs. Typically, manpower and materials are the two most costly items for an agency. If an agency can track per capita data to maintain assets over time (e.g., whether or not the material is getting expensive over time, whether or not the technicians service more intersection because of new systems), they may be able to choose between hiring more manpower or using other technology to increase the efficiency of the current employees.

**Tort Liability Impacts**

In terms of tort liability, a comprehensive inventory can prove to be a useful litigation tool. This provides an agency the ability to prove the existence of a specific asset at a specific location and provide the inspection and maintenance associated with the asset. However, the literature did not provide information on tort liability impacts.

**Return on Investment Benefits**

Return on investment for an inventory can be achieved through changes to business practices, increased efficiency, cost recovery, managing tort liability, inventory control, in-time replacement, and cost avoidance. Tracking location and replacement records can allow an agency to budget and keep inventory available for an expected replacement level annually. Having inventory and location data can allow agencies to be prepared as they are damaged, allowing for increased safety and less exposure to tort liability. To officially quantify the return on investment benefits, a benefit-cost analysis of asset maintenance and management is desired, which has not been developed or used for most of the assets. One exception noted there is benefit-cost analysis for traffic operational improvement. For example, the City of Seattle (25) used the FHWA ITS Deployment Analysis System software to estimate the likely benefits and costs resulting from the full deployment and integration of ITS and operations strategies in the city. Nevertheless, it is still unknown when it is related to the traffic signal asset management. Additionally, documented return on investment for safety benefits of improving these assets is lacking. This is unsurprising since many benefits for an asset management program cannot be easily quantified. Having a program in place can allow maintenance crews to more effectively utilize their time or plan work more efficiently. This can reduce the overall cost of maintaining assets or allow crews to spend less time in the field gathering information (e.g., if a crew knows what materials are in the field, then they can bring replacements with them during routine maintenance). Increased operational efficiency can be difficult to quantify, but can have a dramatic effect on the bottom line of an agency.

**Prioritization Methods and Safety Analyses for Decision Support**

It can be difficult for safety-related assets to gain attention since they are typically low budget items, and are traditionally replaced through a worst-first methodology or due to public complaints. Markow (26) conducted a survey among state and local agencies to identify the prioritization methods for traffic assets. For signs, the results showed that the number of assets and target performance of assets are used to a degree in budgeting, but they are not the primary drivers of budget processes among survey.
respondents. Methods based on adjustments to the previous budget, political priorities, and citizen
demands were each selected as more common factors for budgeting. For traffic signals and lighting,
Markow found that the majority of agencies reported that they corrected problems immediately for
maintenance and preservation. With respect to pavement markings, immediate correction and
prioritization based on available resources were the next most commonly cited approaches, following
preventive schedule. There are variations for prioritization among different agencies; however, a
comprehensive and consistent method that involve safety analysis for decision support is still missing.

Agencies have recognized the value in determining life cycles and developing replacement
schedules based on asset age and condition; however, budget and manpower constraints make this a
practical impossibility. Agencies would benefit from identifying a more preventive approach and moving
away from a worst-first methodology.

Integrating New Capabilities

For signs and pavement markings/markers, the number of measurement devices and measurement
techniques for inventory and condition assessment continue to grow. Keeping informed with new
technologies and keeping databases current are existing gaps in knowledge. Also, there are shortcomings
to using retroreflectometers in determining sheeting and marking life. For traffic signals, lighting, and
barrier systems, the components and testing methods are constantly evolving. It can be difficult for larger
agencies to implement new devices and procedures, and depending on the structure of the agency, new
capabilities may be used inconsistently throughout an agency.

Smaller agencies may also have limited staff for management of all assets, not being devoted to
a single asset. Expertise on any single asset may be limited and it may be practically impossible to keep
up with emerging technology and management methods. Smaller agencies may rely on larger agencies for
technical assistance or to borrow technology that can help with asset condition or performance
measurement. It is of utmost importance to have a process in place to keep up with emerging technology
for both smaller and larger agencies.

Accomplishment Reporting

Work planning and tracking is an essential component of a well-established TAM. To accomplish
it, timely reporting of maintenance and asset condition is necessary. However, guidance on how to file a
report and what should be included in the report are not typically documented.

For agencies that have work-tracking software, accomplishment reporting may be a function of
two factors: 1) the ability to report on work in the field, and 2) the comfort level for technicians to use
computer-based technologies. It may be burdensome for technicians, who are working on multiple assets
throughout a day to keep track of what specific work was completed on each asset throughout the course
of the day. Their time is occupied with performing their duties, and most agencies do not have field ready
technologies to allow for real-time work-logging. Additionally, maintenance technicians may not be
trained to use mobile applications to report on their work, and may choose to record their activities on
paper and have someone else transcribe the information at the end of the day. These issues may lead to
underreporting of activities accomplished, or due to time constraints, may lead to not reporting work
completed, even if a mobile application is available. Agencies must be prepared for these issues, have a
training program in place, and emphasize the importance of accomplishment reporting to the technicians
completing the field work.

Moreover, it is important for an agency to know what is in the field ahead of time. A technician
may save a considerable amount of time by already knowing what is in the field (especially for signals)
and not have to make a trip out to the site to identify what components are in place, make a trip back to
the shop to get replacements, and then head back to the site. Additionally for signals, a crew may take
components to the field to only find out that they are not compatible with the cabinet at that site. A
seasoned technician may know the type and location of each cabinet and component, however, the
information does not carry over when that technician retires.
Gaps Exclusive for Traffic Signals

More gaps exist for traffic signals due to the complexity of the system. For example, physical failure may not have to occur to have a functional failure. A physical failure refers to the damage of physical components, such as loosened bolts and lamp burnouts. A functional failure could be traffic signal performance-related issues, such as outdated equipment in a traffic signal, which may be operating as intended. More commonly, a functional failure may include an inappropriate signal timing or loss of signal coordination. Thus, a functional failure may cause traffic delay or congestion but may not lead to safety hazards. Also, traffic signal systems may include electrical components outside the expertise of personnel, which makes it difficult for agencies to establish performance measurement and targets.

In addition, several studies have been conducted on the life expectancy of traffic signals. Markow (26) estimated service lives for signal system components based on professional judgment and agency experience. However, the method for the development of life-cycle cost estimates associated with all the assets deployed at a traffic signal, including detection, controller, communications devices, and preemption equipment, along with roadside support structures, signal heads and cabinets is not documented. One reason is that agencies do not track the cost every time when they repair or maintain the devices.

APPLICATION OF BEST PRACTICES IN PAVEMENT AND BRIDGE MANAGEMENT TO SAFETY ASSETS

To address the gaps across the safety-related assets management, it is worthwhile to borrow some successful experience from well-established assets management systems, such as pavement and bridge. The project team reviewed pertinent literature and conducted interviews with the Colorado Department of Transportation (CDOT), Michigan DOT (MDOT), and Virginia DOT (VDOT) to understand the current best practices and to help shape the guidance for traffic and safety assets. The following paragraphs summarize areas where current practices with respect to pavement and bridge management may be applicable to management of safety assets.

Automated data collection techniques are used to collect pavement data, such as Automated Road Analyzer (ARAN) vehicles used to collect data on ride quality, rutting, faulting, and other measures. Use of automated data collection has increased significantly in recent years, and is becoming the predominant means for collecting large scale network-level pavement data. Many agencies also collect video log data as part of the pavement data collection process. CDOT is currently experimenting with the use of video log data for assets beyond pavement (27). There are currently 12 asset types for which the data are being collected, and the video is available on the CDOT website. Video data are being used for project pre-scoping meetings and initial site investigations. VDOT also collects videolog data as part of its pavement data collection program and has extracted information about traffic and safety assets from those videos in the past (28). The use of automated and semi-automated techniques for data collection is highly relevant to development of traffic and safety asset inventories. Though there are limited examples in which agencies have supplemented their pavement data collection programs with data collection for other assets, this is an area with great potential for low-cost development of asset inventories. For instance, Utah DOT is currently exploring the use of LiDAR technology to collect asset data beyond pavement condition (29).

For bridges, agencies are required to perform bridge inspections based on National Bridge Inspection (NBI) standards on a bi-annual basis. Most also perform more detailed element-level inspections for their bridges, where data are captured for characterizing the condition of major structural elements, in addition to the bridge as a whole. The use of element-level inspection is well-established and highly applicable for some of the safety assets, such as high mast lights, sign supports, and signal poles. Application of QA/QC techniques to collection of asset data has been an area of significant interest in recent years, particularly with regard to pavement data collection. NCHRP Synthesis 401 details current QA/QC practices for pavement data collection (30). The report notes that key components of a quality management plan include calibration and verification of equipment and/or analysis criteria, testing
Agencies that wish to improve management of traffic and safety assets will benefit from practices that can
be implemented quickly; however, from a practical standpoint may not be able to utilize analytical
approaches that require multiple cycles of data collection. Moreover, pavement and bridge management
approaches are data intensive and requiring extensive data collection activities on an annual
or biannual basis. This may be difficult to justify similarly extensive data collection efforts for traffic and
safety assets, particularly short-lived assets. Secondly, pavement and bridge management approaches and
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fundamental challenges that agencies should be aware of. To begin, traditional pavement and bridge
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tools have evolved over a long period of time and often rely on the existence of significant historical data.

The consideration of risk to transportation asset management has received increased attention in
recent years, and its importance was underscored by the inclusion of a risk-based asset management plan
requirement in MAP-21. MDOT has incorporated a risk factor into their bridge management strategy,
with particular attention paid to scour (34). NCHRP Report 590 includes a detailed description of how
New York State DOT calculates risk for bridge management (35). They have identified six types of
failure modes (hydraulic, overload, steel structural details, collision, concrete structural details, and
earthquake), which they systematically use to rate each bridge’s vulnerability. Consideration of risk has
emerged as an important aspect of pavement and bridge management. This area is rapidly evolving, with
a number of agencies working to establish how asset management and risk management relate and how
this can be integrated into resource allocation and day-to-day management practices.

According to the discussion, it is essential and possible for agencies to apply some of the asset
management approaches of bridge and pavement to traffic and safety assets. Meanwhile, there are several
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As the case studies illustrate, for the purposes of communicating condition targets and results, the
common practice is to focus on a small number of key measures, such as the percentage of pavements or
bridges in poor condition—even if agencies collect a range of different condition measures. VDOT
establishes district-level targets for pavements and bridges, and is proactive in monitoring those targets
(31). All these examples illustrate that it is important to establish a small number of easily-communicated
measures for use in setting targets and communicating overall performance. Moreover, the basic approach
for establishing performance measures and setting targets are highly transferable to traffic and safety
assets.

Performance measures and targets are used to communicate current conditions, help set budgets,
and support cross asset resource allocation decisions. For instance, Cambridge Systematics describes the
asset management approach in seven state-level agencies, and in each case discusses the use of
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MDOT has adopted a work recommendation and tracking process whereby they conduct a
follow-up inspection on all bridges that are placed on the program list (34). This inspection goes into
more detail than the initial inspection, and generates a scoping document which details required work and
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Of known control or verification sites, and software routines for checking the data collected. VDOT has
an extensive QA/QC process for pavement data (37). They use 14 control sites for collection and analysis
of data. Using data from these sites, the standard deviation is calculated. If it is higher or lower than an
established acceptable standard, further investigation is conducted. In addition, an independent contractor
is hired to check a random sampling of five percent of the data against historic data for consistency.
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management approaches are data intensive and requiring extensive data collection activities on an annual
or biannual basis. This may be difficult to justify similarly extensive data collection efforts for traffic and
safety assets, particularly short-lived assets. Secondly, pavement and bridge management approaches and
tools have evolved over a long period of time and often rely on the existence of significant historical data.

Agencies that wish to improve management of traffic and safety assets will benefit from practices that can
be implemented quickly; however, from a practical standpoint may not be able to utilize analytical
approaches that require multiple cycles of data collection. Moreover, pavement and bridge management
systems and modeling approaches are based on the assumption that these assets can be managed
independently of other assets. While this assumption is generally invalid in the case of traffic and safety assets. For these assets, data collection and maintenance activities often address multiple asset types. Finally, many traffic and safety assets are replaced as a result of pavement projects or broader roadway improvement projects. Thus, development of approaches for managing traffic and safety assets needs to consider the linkages between different asset types explicitly.

DISCUSSION

This review found that several gaps exist across safety assets, of which, very limited information has been documented. Data element is a starting point for a completed inventory, however, agencies will differ on definitions of critical versus desirable data, collection methods, and the associated costs. As a result, data quality measurements in terms of completeness, timeliness, accuracy, accessibility, uniformity, and integration are missing. Thus, comprehensive guidance is needed to help agencies decide what data elements are critical for their needs along with a QA/QC program for the six data quality measurements. For agencies to confidently initiate the program, more research needs to be conducted regarding the data collection methods and costs to help them budget and be funded. Also, as mentioned in this paper, agencies can utilize the valuable experience in managing bridges and pavement, such as automated data collection method and QA/QC techniques.

For uses and application of safety assets, little information is available on tort liability impacts and the return on investment, as well as how to use the data for decision support such as periodization and safety analysis. Case studies of agencies managing these safety assets may lead to filling-in identified gaps that are important to agencies embarking on an asset management program. To support decision making, more research is needed to develop a comprehensive decision tool with benefit-cost tools and safety analysis based on the intensive data. Since techniques for inventory and condition assessment continue to grow as well as the materials for safety assets are constantly evolving, more research needs to be conducted on how to integrate these new capabilities.

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