TRANSIT ASSET MANAGEMENT PRACTICES

A National and International Review

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1.0 Introduction

1.1 Background and Research Objectives

The Federal Transit Administration (FTA) has the primary responsibility of carrying out the Federal mandate of promoting and improving the nation's public transportation system. As part of its role, FTA provides over $10 billion in annual financial assistance to transit agencies and states for building and maintaining local public transportation systems.

One challenge FTA and transit agencies face is in maintaining transit infrastructure and equipment in a state of good repair (SGR). There is growing concern that a significant proportion of the nation's public transportation assets are in need of capital reinvestment to maintain a SGR. This situation is not limited to public transportation assets, but extends to many other transportation assets as well, including highways, bridges, safety features, and transportation facilities. To address this issue, a number of transit agencies and other asset owners have invested in asset management systems to more effectively manage their physical assets. Ideally these systems use quality inventory and condition data and well-defined objectives to provide a systematic process for improving resource allocation decision-making.

In an effort to increase focus on the need for achieving an SGR, and to generate ideas on how to use asset management concepts to do this, FTA hosted a two-day discussion with senior engineers and policy-makers from 14 public transportation providers and state transportation departments (DOT) in August 2008. In July 2009, FTA hosted an SGR roundtable of about 40 representatives from the transit industry to continue the dialogue on this subject.

The objective of this report is to build on efforts to date to create a resource of information about existing practices in Transit Asset Management. The report details the published literature in this area, and includes additional information on existing practices in 11 organizations prepared through a set of case studies. The agencies included in the case studies were selected with the objective of obtaining a mix of agencies well-distributed both in size and geography, with an emphasis on cases not already documented in the literature. For the international examples, emphasis was placed on agencies with experience that would be of greatest relevance in the U.S., and that are English-speaking. This report describes what data transit agencies use to support decision-making, what systems and approaches facilitate their SGR analysis, and the major challenges and benefits for transit agencies of implementing asset management/SGR analysis improvements.

1.2 DEFINING STATE OF GOOD REPAIR

In the July 2009 SGR Roundtable sponsored by FTA, participants from agencies including Chicago Transit Authority (CTA), Greater Cleveland Regional Transit Authority (GCRTA), Massachusetts Bay Transportation Authority (MBTA), New Jersey Transit (NJT), Metropolitan Transportation Authority (MTA), New York City Transit (NYCT), and Southeastern Pennsylvania Transportation Authority (SEPTA) each provided their agency's definition of the term "state of good repair" (*1*). No two agencies defined the term in the same manner, but all definitions emphasized one or more of the following concepts:

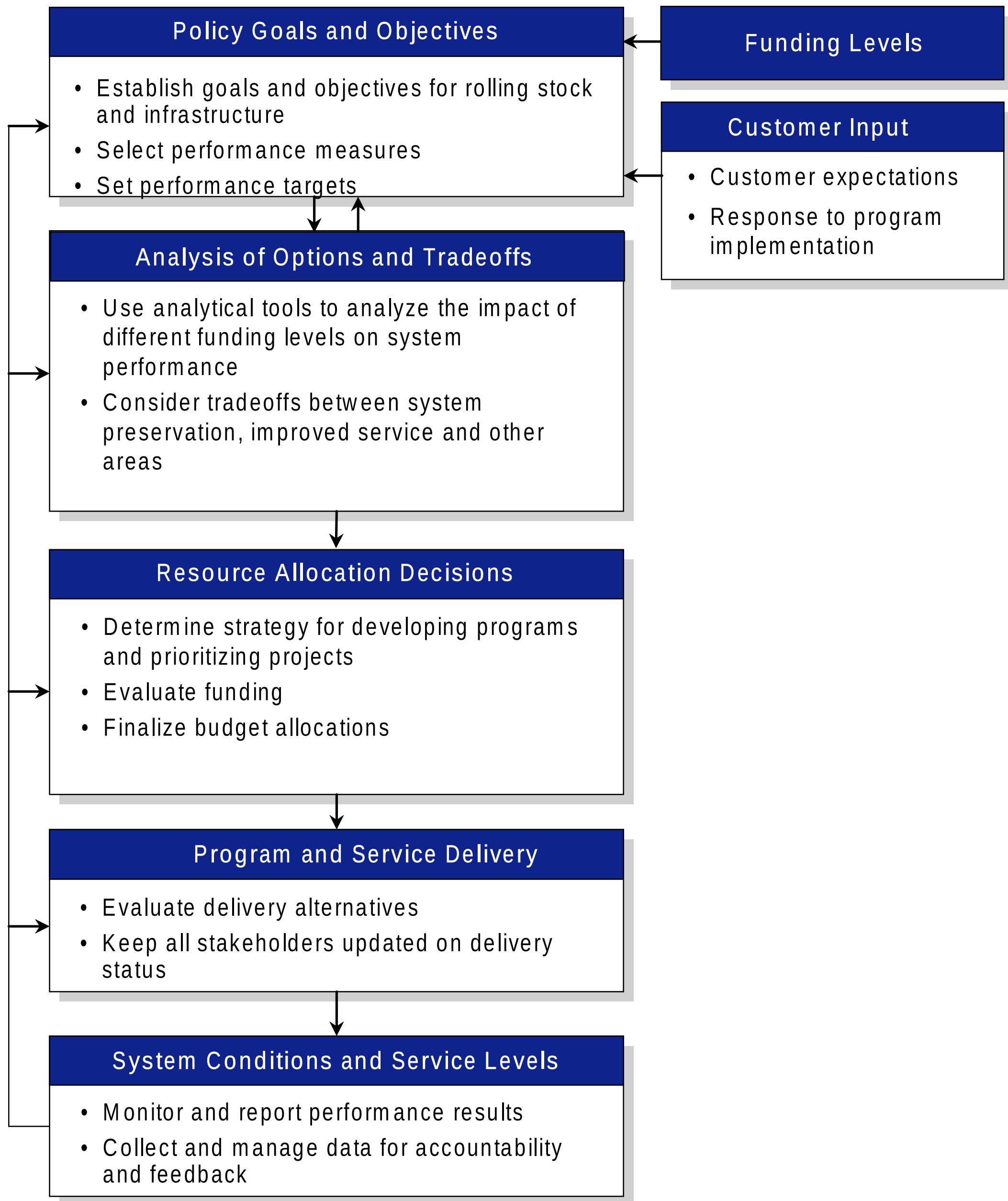
- Maintaining an agency's rolling stock and infrastructure as needed to meet a certain level of service (e.g., avoiding slow zones on a rail system);
- Performing maintenance, repair, rehabilitation and renewal according to agency policy (e.g., replacing buses according to a set time interval); and/or
- Reducing or eliminating an agency's backlog of unmet capital needs.

The defining aspects of achieving SGR outlined above are consistent with the concepts of transportation asset management, a developing field that has received significant attention in the U.S. transportation industry in recent years. Much of the work in this area has to date been performed by state DOTs and by the American Association of State Highway and Transportation Officials (AASHTO). AASHTO has developed its Transportation Asset Management Guide (*2*), and defines "asset management" as "a strategic and systematic process of operating, maintaining, upgrading, and expanding physical assets effectively throughout their life cycle. 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" (*3*).

Figure 1.1 summarizes the basic asset management process presented in the AASHTO guide, highlighting issues of particular importance for transit asset management at each step of the process.

This study is based on a working definition for SGR that recognizes the common fundamental principles that underlie achieving a SGR and applying asset management concepts. In this context, SGR may be defined as "a state that results from application of transportation asset management concepts in which a transit agency maintains its physical assets according to a policy that minimizes asset life-cycle costs while avoiding negative impacts to transit service." In other words, a state of good repair is the condition that results from successfully managing transit assets based on asset management concepts.

Figure 1.1 Asset Management Process



Given the above definition of SGR, evaluating SGR essentially requires supporting an asset management process, and includes the following substeps:

- Collecting inventory and condition data for rolling stock and infrastructure;
- Establishing a life-cycle policy for system preservation, including maintenance, repair, rehabilitation and renewal activities, and modeling the application of the policy on physical assets; and

- Developing alternative capital programming scenarios that use the above steps together with projections of agency funding to characterize predicted future conditions and maximize the effectiveness of agency investments.

Implementing an asset management approach requires information resources that support asset management policies and decisions. The ideal asset management system provides data and decision support for each step in the asset management process outlined above, including functionality for:

- Storing a complete asset inventory;
- Recording condition and performance data for the inventory;
- Identifying deficiencies in existing assets;
- Providing decision support capability for predicting future conditions and needs;
- Tracking data on work accomplishments, including maintenance actions and capital projects; and
- Supporting monitoring and reporting.

As a practical matter the ideal, integrated asset management system that supports all of the functionality listed above does not currently exist. Instead, organizations typically use a combination of systems/approaches to implement asset management. Section 3.0 provides a set of case studies describing how different organizations have a utilized a combination of information systems and manual approaches to support an asset management approach.

1.3 Report Organization

The remainder of this report is organized into the following chapters:

- **Section 2.0** details the literature review conducted on the state-of-practice for transit asset management and SGR analysis;
- **Section 3.0** presents a set of case studies of U.S. and international transit agencies, as well as of the state transportation departments of Oregon and Virginia; and
- **Section 4.0** summarizes some of the best practices that agencies in the U.S. and abroad are applying to achieve a state of good repair.

2.0 Literature Review

A comprehensive literature review was conducted of the state-of-practice in transit asset management and approaches to achieving a state of good repair. The review encompassed English language materials on SGR/transit asset management practices in the United States and Europe published from 2003 to 2008. The sources for the literature review included: Federal agency publications; proceedings from the Transportation Research Board (TRB); Transit Cooperative Research Program (TCRP) and other organizations; and other published articles. In performing the literature search the project team reviewed all FTA, TRB, and TCRP publications, and performed literature searches using the Transportation Research Information Services (TRIS), JSTOR and WorldCAT databases. Search terms used for the database searches included "state of good repair," "asset management," "transit asset management," "fleet management," "transit capital needs," and "transit capital investment." The search yielded a total of 18 references published over the past five years, with a number published in the past year. These references can be grouped into three general categories: FTA publications, best practice examples, and modeling approaches and frameworks recommended for SGR/transit asset management. The following subsections describe references reviewed, organized based on these categories.

2.1 FTA Publications

The review included two FTA publications that discuss SGR analysis and/or transit asset management: *Transit State of Good Repair: Beginning the Dialogue (1)*, and *Useful Life of Transit Buses and Vans (4)*. Key concepts from these resources are summarized below.

Transit State of Good Repair: Beginning the Dialogue *(1).* The seven papers in this volume address several questions related to the state of good repair needs of the nation's rail and bus transit rolling stock and infrastructure. In the summer of 2008, FTA convened a two-day workshop with 14 public transportation providers and state DOTs. The objectives of the workshop were to define, measure and address the nation's transit state of good repair needs. Each of the following papers included in FTA's SGR report presents key observations from the SGR workshop:

1. **Current Conditions of the Nation's Transit Infrastructure –** This paper defines the current physical and service condition and reinvestment needs of the nation's transit assets by analyzing Transit Economics Requirements

Model (TERM)[1] results and agency assessments. Based on the analysis conducted with TERM, up to one-third of heavy rail and motor bus assets have either exceeded or are close to the end of their useful lives. Based on the TERM estimates, the highest reinvestment needs are projected to be in the following areas (listed in decreasing order): heavy rail and motor bus vehicles; heavy rail stations, systems and guideway components; and bus maintenance facilities. Based on projections developed using TERM, $10.7 billion is needed to bring all transit modes nationally to a SGR. Workshop participants noted that the asset types with the largest deferred investment needs are maintenance facilities, bridges, signals, and station amenities. The second part of the paper describes the relationship between conditions and performance. The analysis shows that vehicles in poor condition impact the level of service by increasing service disruption, increase maintenance costs and slow speed zones, and other service quality measures.

2. **Defining and Measuring State of Good Repair –** This paper begins by defining the term "state of good repair" as follows: "An asset or system is in a state of good repair when no backlog of capital needs exists – hence all asset life-cycle investment needs (e.g., preventive maintenance and rehabilitation) have been addressed and no capital asset exceeds its useful life." This paper describes four ways to measure a state of good repair: percent of assets in SGR; percent of service life remaining; asset condition ratings; and asset-specific condition measures. Participants of the workshop agreed that to measure SGR, it was preferable to use condition-based measures, with age as an alternative if condition data are lacking.

3. **Transit Asset Management –** This paper describes the asset management process to attain and maintain a state of good repair. The process must present the following components linked together: goals and objectives, asset inventory, condition assessment process, decision support tools (model), options and tradeoff analysis, decision-making and measurement. Next, the paper highlights the asset management components already adopted by transit agencies and what the agencies can learn by implementing a comprehensive asset management process: current asset conditions, investment required to maintain or improve these conditions, and how variations in funding will impact an agency's ability to address investment needs over various time horizons.

4. **Standards for Preventive Maintenance –** This paper makes the case that by applying better planned preventive maintenance activities, transit agencies could save money on their operating budget. Currently, on average approximately 27 percent of a transit agency's operating budget is dedicated to maintenance costs. These can be divided into two categories: scheduled

[1] TERM is FTA's tool for assessing national-level transit investment needs. Section 2.3 describes TERM in further detail.

maintenance and unscheduled maintenance. A transit agency can save money by replacing the assets before they fail because this will reduce unscheduled maintenance. A Maintenance Management System (MMS) can help a transit agency achieve this. Also, preventive maintenance will improve the assets' state of good repair. However, workshop participants agree that the industry should not set national standards for preventive maintenance, given that the needs and practices are different for each transit agency.

5. **Core Capacity of a Transit System –** This paper describes how to increase the capacity of a transit system without building new guideway, including improving operations, increasing vehicle capacity, increasing station capacity, and other approaches.

6. **Alternatives Approaches to Financing –** This paper discusses six alternative approaches to financing public projects: Public Private Partnerships (PPP) enable reduction in direct and indirect public costs due to the use of private capital and expedited project delivery; capital leases; revenue bonds; grant anticipation notes; debt service reserve; and the Federal credit program established under the Transportation Infrastructure Finance and Innovation Act (TIFIA).

7. **Research Needs –** This paper outlines the research needs to help the transit industry pursue a state of good repair. The workshop participants highlighted the following issues of particular interest to them: developing a simplified agency-level version of TERM; establishing working groups to share their approaches in asset inventory development; learning about linear asset management tools; MMS that combine all types of assets and could be used also for long-term capital programming; and developing technical assistance on MMS.

Useful Life of Transit Buses and Vans *(4).* The focus of this study was to assess the appropriateness of the bus minimum service life policy set by FTA. The policy was evaluated by interviewing transit operators, conducting an engineering analysis, and performing an economic analysis. The study recommends that FTA maintain its current service-life minimums and service-life categories, but review these regularly as vehicle designs, new technologies and new vehicle types may justify future revisions. The study found that actual retirement ages generally exceed FTA minimums and are constrained by capital funding availability rather than FTA policy. The engineering analysis showed that bus life ultimately is constrained by the life of the bus structure. The economic analysis examined the optimal replacement point for a number of bus types and operating scenarios. In all scenarios examined, the optimal replacement point was at or later than that stipulated by the FTA minimums. The report provides additional detail on bus maintenance and replacement practices at nine agencies.

Rail Modernization Study ***(5)*** The rail modernization study which was conducted at the request of the United States Congress focused on the capital reinvestment needs of the nation's seven largest transit operators. The seven agencies include Chicago Transit Authority, Massachusetts Bay Transportation Authority, Metropolitan Transportation Authority of New York, New Jersey Transit Corporation, San Francisco Bay Area Rapid Transit, Southern Pennsylvania Transportation Authority and Washington Metropolitan Area Transit Authority. In comparison with the industry total, these agencies account for 80% of annual passenger boardings, 51% of track miles, 57% of passenger stations and 74% of fleet vehicles. The report assessed the capital investments that will be required to bring the assets of the selected agencies to state of good repair. The study results showed that about $50 billion (in 2008 dollars) would be required today to replace all assets exceeding their useful life and to rehabilitate all stations, with an additional $5.9 billion (in 2008 dollars) a year to maintain the assets in good condition thereafter. The study also reviewed the asset management practices of the seven transit agencies and found out that all the agencies have some form of asset management in place albeit with different levels of maturity.

2.2 STATE OF GOOD REPAIR PRACTICES

Ten of the references identified through the review detail best practices in use for SGR analysis specifically, and/or transit asset management generally. These references are detailed below.

Caltrain

Caltrain Laying Solid Foundation ***(6)*****.** In this paper, the authors describe the actions taken by Caltrain to maintain its system in a SGR. Caltrain established a State of Good Repair database that forms an inventory of each Caltrain asset, and tracks the asset's status, maintenance record, maintenance schedule, and any relevant test results. Caltrain has established numeric scores for characterizing the condition of each asset, though the scoring approach is not detailed in the paper. Caltrain reviews conditions of each asset on a quarterly basis and uses the information from its reviews to develop a SGR program that includes track rehabilitation, vehicle replacement, grade crossing improvement, and other activities.

Metropolitan Transportation Authority (MTA)

The View from the Subway (Bus, Railroad, Bridge and Tunnel) – The Challenges of Maintaining and Operating a 100(+) Year Old System ***(7)*****.** This presentation stresses the challenges of maintaining the MTA's system. Years of disinvestment (termed by the MTA as the "death spiral" years) resulted in chronic unreliability in the system, as well as a litany of public safety issues. In the early 1980s the MTA established a reinvestment plan to help achieve a SGR. Since that time over $74 billion has been invested in the system in new rolling stock, station rehabilitation, tracks replacement/rehabilitation, signal improvements, and other equipment replacement and rehabilitation. For characterizing its progress towards achieving a SGR, MTA estimates the percentage of assets in good repair by asset type (e.g., buses, rail cars, track, stations). In its capital program it identifies SGR investments as those needed "to correct for past deferred maintenance or to replace equipment that is beyond its useful life," and distinguishes these investments from "normal replacement."

"Going Your Way"*(8).* This paper describes MTA Metro-North Railroad (MNR) plans for acquiring a new car fleet and making other SGR-related investments. MNR concluded it needed to replace its aging fleet based on observed decreases in Mean Time to Failure (MTTF) measured in miles between failures. In addition to plans for purchase of new rail cars, the paper describes other planned SGR projects, including overhaul of the Harmon Shop and Yard, laying a third track over a 3.2-mile section in New York, rehabilitating nine stations, and expanding the Woodbine Yard.

Metropolitan Atlanta Rapid Transit Authority (MARTA)

A Middle-Aged System: Metropolitan Atlanta, Georgia, Rapid Transit Authority's Transit Asset Management *(9).* This paper provides a brief description of a presentation from the TRB 6th National Conference on Transportation Asset Management on MARTA's asset management approach. As of the time of the conference, MARTA had developed a 10-year Capital Improvement Plan (CIP) to help maintain a SGR. To support development of the plan MARTA performed a condition assessment for its assets, estimated the available useful life of its asset inventory, and predicted capital requirements for a 40-year period. The condition assessment indicated that MARTA's assets had consumed 49 percent of their available useful life based on an asset value of $4.3 billion.

Sustaining a Successful Transit System through its Mid-Life *(10).* This paper details the approach followed by MARTA to perform a condition assessment in support of its Capital Improvement Plan (CIP), supplementing the general description provided in (*9*). Specific steps performed as part of this work included:

- Developing an asset breakdown structure (ABS) for MARTA assets. The ABS identifies 16 major asset categories. For each of these the ABS identifies three additional subcategories, termed systems, components, and types.
- Performing field assessments for selected asset types. For these assessments, multiple observations of an asset were made. For each observation the asset was categorized on a 5-point scale (new, very good, good, fair, and poor). Each point in the scale corresponded to a particular range for remaining life. For instance, "new" refers to assets with 91 to 100 percent of their life

remaining, while "poor" refers to assets with less than 25 percent of their life. Field assessments were not made for assets for which MARTA already had data, or for vehicles, for which asset age was used as a proxy for condition.

- Estimating the condition of other assets, based on MARTA assessments and inspection results, as well as asset ages in the case of vehicles. MARTA assessments and inspection results were used to characterize the condition of track, public structures, elevators, escalators, and building roofs.
- Predicting capital investment needs. For each asset a replacement cost, rehabilitation cost, and useful life were estimated, as well as the number of times the asset would need to be rehabilitated over its life. This information was combined with the data collected as part of the condition assessment to predict capital investment needs over a 40-year period.
- Developing a capital plan based on the predicted needs and projected budget. This was performed as a manual process.

New Jersey Transit (NJT)

Fix-it Central *(11).* This paper describes the Meadows Maintenance Complex (MMC), which centralizes the repair and upkeep of the NJT rail fleet. The paper details the impacts of maintaining its fleet in antiquated facilities prior to completion of the MMC, and describes the benefits of the new facility. With the MMC NJT has reduced costs incurred from moving equipment between different shops used previously, and has realized cost savings from consolidating staff and shops in one central location.

Port Authority of New York and New Jersey (PANYNJ)

A Mature System: Port Authority of New York and New Jersey's Maintenance Management Improvement Program *(12).* This paper provides a brief overview of PANYNJ's perspective on asset management issues and challenges. It describes PANYNJ's asset management vision of achieving "sound, secure, state-of-the-art infrastructure." The paper alludes to a more detailed unpublished presentation presented at the TRB 6th National Conference on Transportation Asset Management with details on PANYNJ's condition assessment approach, performance measures, and work process improvements.

Regional Transportation Authority (RTA)

The Framework for a Regional Transit Asset Management System *(13).* This paper describes the RTA's Regional Transit Asset Management System (RTAMS). RTA oversees public transportation systems in the Chicago area and is responsible for fiscal planning and policy oversight of the three Chicago area service boards. RTA implemented RTAMS with the goal of presenting integrated information to enable managers to make resource allocation decisions. The initial version of RTAMS described in the paper provides a web-based interface for viewing summary data on Chicago-area transit assets, as well as operating statistics and information on planned projects. Further, the paper describes the full concept for RTAMS, which includes integration of the CTA's condition assessment approach (developed in the 1990s and subsequently adapted for use in TERM), which characterizes assets on a 5-point scale, predicting future conditions using a set of decay curves.

Southeastern Pennsylvania Transportation Authority (SEPTA)

Use of Statistical Process Control in Bus Fleet Maintenance at SEPTA *(14).* This paper describes the use of Statistical Process Control (SPC) to monitor the quality of bus fleet maintenance at SEPTA. Prior to implementing SPC SEPTA had a two-part maintenance procedure that involved an "In-Process Inspection" and a "Final Inspection." Specific activities were defined for each type of inspection, but SEPTA made no attempt to analyze data collected through its inspections to improve maintenance effectiveness. With implementation of SPC SEPTA began to track bus defects monthly by defect type. This required defining what constitutes a defect, and establishing an approach for defect reporting. The paper reports that SPC has proven to be useful in managing the quality of SEPTA's bus maintenance, and provides example diagrams and reports used for monthly monitoring.

Washington Metropolitan Area Transit Authority (WMATA)

Sustaining Washington Metro: Meeting the Twin Challengers of Aging and Growing Pains *(15).* This paper describes WMATA's efforts to maintain its system in a SGR. WMATA has established an Infrastructure Renewal Program (IRP) to renovate its oldest facilities and replace equipment that has reached the end of its useful life. WMATA's policy is to rehabilitate its rail cars at an age of 17 to 18 years, and replace them at 35 years. WMATA considers its buses to have a useful life of 15 years, provided they are overhauled at an age of 7.5 years. Further, the paper summarizes WMATA assessment of its capital needs for overall and/or replacement of its systems for traction power, AC power, train control, communications, and information technology, as well as for other facilities. The paper also lists a set of 14 measures WMATA uses in its employee performance plans. Measures directly related to achieving a SGR include mean distance to failure for rail cars and buses, as well as availability (expressed as a percentage) for elevators and escalators.

2.3 Models and Frameworks

This section describes models and frameworks detailed in the literature for SGR analysis and/or supporting transit asset management. The review yielded six references in this area. These are described below, organized by models for predicting SGR requirements, and conceptual frameworks.

Models for Predicting SGR Requirements

Transit Economic Requirements Model (TERM). FTA uses TERM, an economic and engineering-based model, to estimate the national transit capital needs for the transit industry. TERM is used by FTA to support its reporting. For instance, FTA uses the system in developing estimates of transit investment needs in the biannual *Report to Congress on the Conditions and Performance of the Nation's Highways, Bridges, and Transit* (the C&P Report). Further, FTA used TERM for its *Rail Modernization Study (5).* TERM functionality has been summarized in a variety of documents, including *(1)*. In developing the C&P Report FTA uses TERM to analyze four basic investment scenarios:

1. **Maintain Asset Conditions –** Assets are replaced and rehabilitated over a 20-year period such that the average asset condition remains the same at the end of the period as at the beginning of the period;
2. **Maintain Performance –** Asset investments are undertaken to accommodate the increase in ridership over a 20-year period such that the average vehicle utilization and average vehicle speed remain the same at the end of the period as at the beginning of the period;
3. **Improve Conditions –** Asset investments are undertaken so that each existing asset type reaches a specified threshold level by the end of 20 years; and
4. **Improve Performance –** Asset investments are undertaken to increase average vehicle speeds and lower average vehicle occupancy to threshold levels by the end of the 20-year period.

TERM is comprised of four different modules, which together project needs for achieving a SGR, as well as for expanding transit service. The Asset Rehabilitation and Replacement Module predicts capital investment needs required for existing assets to maintain their physical condition. In this module asset conditions are represented on a 5-point scale. Data on existing conditions comes from the National Transit Database (NTD), as well as from supplemental data for fixed guideways and other assets not detailed in NTD. The condition of each asset on the 5-point scale is estimated based on asset age, and a set of decay curves is used for predicting change in condition over time. When running the Asset Rehabilitation and Replacement Module, one specifies the condition level at which assets are replaced, and TERM uses this information to predict asset maintenance, rehabilitation and replacement costs over a 20-year period.

A Rural Transit Asset Management System *(16).* This paper describes the transit asset management system and prediction model that the University Transportation Center for Alabama developed for Alabama Department of Transportation (ALDOT). The system is designed to support ALDOT management of FTA grants to Alabama transit agencies, including Section 5310 grants to fund public transportation for elderly and disabled passengers, and Section 5311 grants to fund public transportation for rural residents. The system includes a database with approximately 40 data items on each vehicle purchased through one of the grants, including information on vehicle type, age, and condition. ALDOT assesses vehicle condition based on on-site inspections. Conditions are assessed on a 5-point scale that considers engine starting trouble, running condition, interior condition, air conditioning, wheelchair lift operation, exterior condition, and mileage. A linear regression was performed to develop a model for predicting future conditions. The independent variables in this model include age, total mileage of the vehicle, annual mileage over unpaved roads, wheelchair accessibility of the vehicle, and percent of population over age 65 in the county in which the vehicle operates. The system uses information on current conditions and future predicted conditions to simulate replacement of vehicles over time given a projected budget. Where the available budget is insufficient to replace all vehicles meeting FTA minimums, replacements are prioritized based on vehicle condition.

Asset Management and Preventive Maintenance: Setting Priorities to Improve Efficiency *(17).* This presentation describes the SGR model developed for the Massachusetts Bay Transportation Authority (MBTA). The MBTA uses the model to estimate current needs, estimate the level of funding necessary to maintain a SGR, predict the system's condition if current funding levels remained the same, and predict the level of funding necessary to eliminate backlog in 20 years. The system relies upon a set of candidate investment projects entered by the end user. These are scored and ranked using a weighted scoring method that takes into consideration asset age as a percentage of service life, operational impact (e.g., are assets essential to system operations), and cost-effectiveness. The system simulates selection of projects each year of an analysis, with unfunded projects becoming candidates for next year. The presentation shows example results from the model, and discusses its potential applicability to other systems.

An Asset Management Strategy for State DOTs to Meet Long-Term Transit Fleet Needs *(18).* This paper prepared for the Transportation Research Board (TRB) presents an asset management strategy for state DOT to use to allocate funds in an equitable manner to their constituent agencies for bus replacement, rehabilitation, and remanufacturing. The asset management strategy is a two-stage process, with a model for each stage. The first model seeks to minimize the weighted fleet life of the buses having reached their FTA minimum service lives within the constraints of a fixed budget and of the number of buses required. The output of the first model is the optimum allocation of resources between replacement, rehabilitation, and remanufacturing (i.e., the total number of buses which will either be replaced, rehabilitated or remanufactured). The second model helps in the allocation of funds between constituent agencies. Each agency's current weighted remaining fleet life is calculated. In this model, the totality of the buses is considered and remaining life is defined as the number of years left for a bus before it reaches its minimum service life. The age of the vehicle is used as a proxy for the quality of the vehicle. The optimization model allocates funds so that the sum of each agency's weighted remaining fleet life is maximized after replacement, rehabilitation, and remanufacturing of the buses. The constraint of the model is the output of the first model (i.e., the total number of buses which can be replaced, rehabilitated, and remanufactured with the available resources). The proposed asset management strategy is compared to the current methodology used by state DOTs (i.e., replace a fraction of the buses having reached their minimum service life within the constraints of a fixed budget). The weighted average remaining life of the entire bus fleet is calculated in each case, as well as the savings of using one method over the other. The proposed asset management strategy viability is demonstrated for the entire fleet of medium sized buses in the state of Michigan and shows significant net benefits over the approach used previously.

Decision-Making Modeling for Rural and Small Urban Transit Asset Management *(19).* This paper, also prepared for TRB, describes an asset management system for rural and small urban transit agencies. The system can help transit agencies in their maintenance budget allocation process for transit vehicles. The deterioration process, embedded in the asset management system, is simulated using an Ordered Probit Model (OPM), which predicts the probability of a vehicle's future condition. Several independent variables are selected. A correlation analysis determined that maintenance, age and maintenance expenditures accounts for 81 percent of the total variance of vehicle condition. Consequently, these variables are good predictors of the condition state. The OPM has the capability to account for interdependencies among explanatory variables. A marginal analysis was conducted to determine the vehicle condition change per unit change in each independent variable. This sensitivity analysis can be useful to evaluate several maintenance policies or what-if scenarios. The estimated probabilities of a vehicle's future condition are the input of an optimization module which helps the user determine the optimal maintenance solution. The optimization module maximizes the benefit/cost ratio of the sum of weighted extended life years to the associated maintenance/ repair spending to determine the optimal maintenance solution for an individual vehicle or a group of vehicles having similar usage.

Conceptual Frameworks

Guidelines for Development of Pubic Transportation Facilities and Equipment Management Systems *(20).* This TCRP report provide guidelines to assist states in developing Public Transportation Facilities and Equipment Management Systems (PTMS) that meet their needs. The report also helps to clarify the federal regulation that requires each state to develop, establish, and implement a PTMS to cover all transportation management areas (TMAs). The guidelines provided that, a PTMS is a decision support and a planning tool for the states and MPOs, not a management tool for the transit properties. The basic required components of PTMS include (i) data collection and system monitoring, (ii) identification and evaluation of proposed strategies and projects, and (iii) implementation of strategies and projects. The report provides a definitions and descriptions of a minimum-level approach to satisfying these requirements.

Applying the Lessons Learned in Asset Management Around the World to the Development of the AMPLE Tool *(21).* This paper describes the Asset Management Program Learning Environment (AMPLE) tool, a web-based system intended to support an asset management approach. AMPLE includes a set of seven modules, including a quality framework module, gap analysis tools, benefits module, improvement plan module, implementation module, and training module. The modules are intended to help an agency implement assessed management concepts. AMPLE has been used by government agencies in Australia, and has been released in the U.S. by the Water Environment Research Foundation. The paper notes that a rail-specific variant of the system is under development.

Development of Asset Management Evaluation Framework in Rail Transit Environment: London Underground Public-Private Partnership *(22).* This paper describes an asset management framework developed by Lloyd's Register (LR). The framework was developed as a result of the privatization of London Underground (LU). LR developed the framework for use by an independent arbiter evaluating the performance of a Public-Private Partnership (PPP). The paper reviews asset management evaluation approaches developed worldwide, and then proposes an asset evaluation framework based on the review. The framework entails 12 asset management elements which should be considered in an evaluation of asset management practice, as well as evaluation tables which evaluate each asset element to assess the maturity of the organization's asset management. The asset management elements are divided into two categories: process elements and enabling elements.

Process elements relate to an organization's asset management process, and include:

- External influences;
- Planning;
- Delivery;
- Review;
- Information management; and
- Risk management.

Enabling elements relate to the way an organization is managed, and include:

- Active leadership;
- Continuous improvement management;
- Responsibility, authority, and accountability;
- Competency;

- Communications; and
- Explicit model.

The evaluation tables identify key areas for each of the elements, and list important considerations in each area. The authors propose an approach to rating an organization on a scale of 0 to 5 for each of the elements using the areas and considerations as a guide.

3.0 Case Studies

This section describes a set of case studies prepared to provide additional information on existing practices related to achieving a state of good repair. Case studies were prepared for 11 agencies, including six U.S. transit agencies, three international agencies, and two state transportation departments. A mix of telephone interviews and review of published documents were used to prepare the case studies.

The telephone interview guide used for the transit agency interviews is included in Appendix A. Table 3.1 details the interviewees in each agency. In conducting the interviews, a research team member first contacted the organization to determine the appropriate agency contact. The research team member then contacted the designated interviewee by telephone to discuss the objectives of the study, and followed the phone call by sending the appropriate interview guide. The research team then conducted the interview by telephone at an agreed-upon time, contacting the interviewee again with any follow-up questions. Table 3.1 lists the interviewees.

Table 3.1 Transit Agencies Interviewees

Organization	Contact	Title
U.S. Transit Agencies		
Chapel Hill Transit	Carl Rokos	Maintenance Superintendent
Chicago Transit Authority (CTA)	Michael Connelly	Manager of Capital Improvement Program Development
Greater Richmond Transit Commission (GRTC)	Larry Hagin	Director of Planning
Metro St. Louis	Carl Thiessen	Chief Mechanical Officer
Metropolitan Atlanta Rapid Transit Authority (MARTA)	David Springstead	Senior Engineer of Rail System Engineering
Metropolitan Transportation Commission (MTC)	Glen Tepke	Transit Capital Properties Manager
International Transit Agencies		
London Underground (LU)	Kevin Dunning	Head of Asset Management Strategy and Service Development
Toronto Transit Commission (TTC)	Jennifer Ambronyo	Funding Program Coordinator
	Mariel Guerra	General Superintendent, Rail Cars and Shops
	Jim Teeple	General Superintendent, Track and Structures
Victoria Department of Transport (DOT)	Paul O'Halloran	MR3 – Technical Manager

For the case studies of U.S. transportation departments – Oregon and Virginia – the interview guide was not immediately applicable. Instead, research team members utilized materials prepared through prior projects to prepare the case studies.

The following subsections present the case studies. For each, a brief overview of the organization is provided followed by a description of relevant business practices. Finally, noteworthy state of good repair practices that emerged from the case study are summarized.

3.1 U.S. Transit Case Studies

Chapel Hill Transit

Background

Chapel Hill Transit provides fixed route bus and demand responsive service to Chapel Hill and Carrboro in North Carolina. The system includes 25 bus routes, with 99 buses and 34 nonrevenue vehicles. Chapel Hill Transit maintains five park-and-ride lots, as well as a central maintenance and administration facility built in 2007. Annual ridership is over 5.7 million passengers.

Practice Overview

Maintaining its buses and facilities is an important goal for Chapel Hill Transit. For Chapel Hill Transit, the term "state of good repair" implies maintaining the system such that it remains functional and operational, while remaining in good condition. Chapel Hill Transit's state of good repair strategy can be summarized as follows:

- Maintenance policies are established for each new bus fleet based on best practice and manufacturer recommendations.
- Preventive maintenance policies vary with each fleet, but typically involve inspections every 6,000 miles at a minimum.
- Buses are replaced in accordance with FTA guidelines, subject to available funds. Ideally buses are replaced on a 12-year cycle, but in practice the replacement cycle is approximately 14 years.
- Chapel Hill Transit uses the TMW system TRANSMAN for fleet maintenance. This system tracks inventory, and helps schedule and track maintenance. Chapel Hill Transit has experimented with using the system to track other assets beside vehicles, but concluded a separate system is needed for this. Currently the agency expects to transition to using AssetWorks for tracking both vehicles and fixed assets.

The major challenges faced by Chapel Hill Transit regarding achieving a state of good repair include uncertainty about future funding, and complications arising from new technologies and requirements, most notably the 2010 emissions requirements. Further, while its vehicle fleet is not particularly large, Chapel Hill Transit operates a large number of different vehicle makes and models, and for each fleet must review and establish appropriate maintenance policies.

Noteworthy Aspects

Noteworthy aspects of Chapel Hill Transit's practices include:

- Establishing written maintenance policies for each bus fleet;
- Experimenting with use of a fleet management system for tracking fixed assets, ultimately resulting in transition to a new comprehensive asset management system.

Chicago Transit Authority (CTA)

Background

CTA operates Chicago's transit system, including buses and rapid transit. CTA is one of three service boards providing transit service in Chicago. The other two are Metra, which operates commuter rail, and Pace, which operates the Chicago area suburban bus system.

CTA's bus system includes 153 routes using approximately 2,018 buses. CTA's rail system includes eight routes and over 240 miles of track. There are 144 stations in the system, and service is provided using approximately 1,190 rail cars. Parts of CTA's elevated routes date back to the early 1900s. CTA's subway routes were initiated in the 1930s. Annual ridership on the bus and rail systems exceeds 525 million.

Practice Overview

Achieving a state of good repair is a major focus area for CTA. CTA defines state of good repair in terms of the following standards:

- Rail lines should be free of slow zones and have reliable signals;
- Buses should be rehabilitated at 6 years and replaced at 12 years;
- Rail cars should be rehabilitated at quarter and half-life intervals and replaced at 25 years; and
- Maintenance facilities should be replaced at 40 years (70 years if rehabilitated).

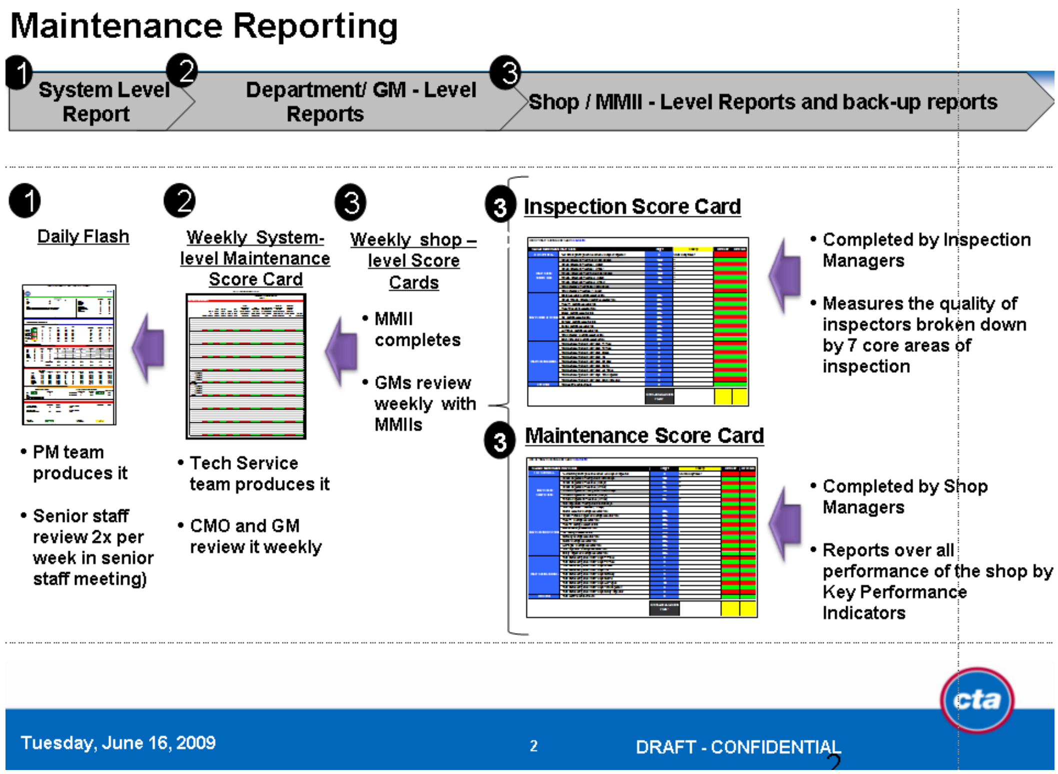
CTA has established a comprehensive performance management program that helps the agency monitor asset conditions and performance, as well as a range of other measures. CTA has established key performance measures for each aspect of its organization. Performance measurement data are collected daily, and reviewed across the organization on a weekly basis. Key measures include on time performance, miles between in-service failures and defect rates for vehicles, extent of slow orders for track, station/vehicle cleanliness, and a range of other measures. Figure 3.1 illustrates the approach implemented for maintenance reporting. Based on review of its performance CTA focuses on improvements to areas where performance is lagging, such as through diagnosing and correcting the causes of repeat failures on vehicles.

For its buses and rail cars CTA has established maintenance strategies specifying intervals for quarter and half-life overhauls. Inspections are performed on a daily basis. For track CTA performs inspections weekly and uses a track geometry car to collect detailed track data approximately twice a year for each section of track. Station inspections are conducted weekly, and inspections of other assets are performed on a periodic basis. A 5-point scale, similar to that in TERM, is used for characterizing physical conditions of all of CTA's assets.

To support its asset maintenance CTA has implemented separate systems for managing vehicles and fixed guideways. For vehicles, CTA uses the Maximus Maintenance Management Information System (MMIS). For fixed guideways, CTA has implemented the Infor Enterprise Asset Management (EAM) system. Ultimately CTA intends to manage maintenance of its stations and other facilities using this system. These systems all track asset data, maintenance work orders, and related data.

In addition to managing its maintenance activities on a day-to-day basis, CTA performs periodic 20-year needs assessments to support capital planning. The approach used for the needs assessment is to calculate an ideal, unconstrained distribution of funds that would be required to overhaul or replace its assets at specified time intervals. This information is used to establish the backlog of state of good repair needs, which is then used with additional information on critical short-term needs and available funding to develop the capital plan.

Figure 3.1 Maintenance Reporting System at CTA



Source: Chicago Transit Authority.

Noteworthy Aspects

Noteworthy aspects of CTA's practices include:

- Implementation of a comprehensive performance management initiative;
- Development of a 5-point scale for reporting asset conditions; and
- Use of a structured approach for performing periodic needs assessments.

Greater Richmond Transit Commission (GRTC)

Background

GRTC provides bus and demand responsive service to the City of Richmond, Henrico County, and parts of Chesterfield County in Virginia. The system includes 48 bus routes, with approximately 101 buses and 77 other vehicles. GRTC is currently constructing a new maintenance and administration facility to replace its current one. In addition, GRTC uses a satellite maintenance facility for maintaining its paratransit vehicles and passenger vans. Annual ridership is over 10 million passengers.

Practice Overview

Achieving a state of good repair is an important objective for GRTC, and the agency has made a great deal of progress in this regard, particularly through reducing its average bus age and securing funding for the new maintenance facility. GRTC's state of good repair strategy can be summarized as follows:

- GRTC has established a set of maintenance policies for its buses and other vehicles, with specific milestones specified at 6,000-mile intervals.
- GRTC performs preventive maintenance inspections every 6,000 miles for buses, and every 3,000 miles for other vehicles. Oil samples are taken for each inspection. In addition, GRTC uses AVM2 vehicle monitoring devices on all of its newer buses, and is retrofitting its older buses with this technology.
- Decisions about major overhauls are made on an as-needed basis, in part based on review of oil sample results. GRTC estimates it performs approximately 20 to 24 overhauls per year.
- Buses are replaced on a 12-year cycle in accordance with FTA guidelines, subject to available funds.
- Assessment of facilities are performed on an as-needed basis. In recent years GRTC performed a needs assessment for its existing facility, and based on this assessment performed electrical work that could not be deferred. In addition, GRTC estimates conditions of assets worth over $5,000 and purchased with grant money in accordance with FTA guidelines.
- GRTC uses the RTA Fleet Management System for vehicle maintenance. This system tracks inventory, and helps schedule and track maintenance. GRTC is investigating implementation of a facility management system as it moves to its new maintenance facility.

The major challenges faced by GRTC regarding achieving a state of good repair include uncertainty about future funding, and adapting to new technologies (e.g., the agency potentially may implement hybrid fuel vehicles in the future).

Noteworthy Aspects

Noteworthy aspects of GRTC's practices include:

- Implementation of AVM2 to improve vehicle maintenance; and
- Flexible policy for vehicle overhauls, based on oil sample analysis.

Metro St. Louis

Background

Metro St. Louis provides transit service for the St. Louis metropolitan area. The system serves four counties in Missouri and Illinois, including the City of St.

Louis. Its services include: MetroLink, the region's light rail system; MetroBus, the region's bus system; and Metro Call-A-Ride, a paratransit van system.

MetroBus operates approximately 411 buses on 153 routes. MetroLink operates approximately 87 light rail vehicles (LRVs) on two lines. The system has 37 stations and includes 46 miles of track. In addition, Metro St. Louis has 130 vans, 300 nonrevenue vehicles, three bus maintenance facilities, two LRV maintenance facilities, and a headquarters facility, as well as additional parking and other facilities. Annual ridership for the system is over 53 million trips.

Practice Overview

In recent years Metro St. Louis has been successful in improving the state of repair of its system, particularly with respect to its buses and LRVs. In 2002 the agency established a preventive maintenance program for its vehicles. Key elements of the program include:

- Establishment of a set of standards for maintaining vehicles, with schedules for key inspection and maintenance activities based on a combination of time and mileage intervals.
- Development of a maintenance plan for detailing Metro's plans for maintaining existing assets consistent with its standards, and a capital acquisition plan for the purchase of new assets.
- Implementation of the MAXIMUS M5 program (now AssetWorks) to manage the fleet. The system is being implemented for managing facilities, ordering parts, and supporting other maintenance-related activities.
- Independently from M5, Metro estimates its capital needs using a spreadsheet approach that calculates the cost of performing recommended maintenance and replacements based on the maintenance and capital acquisition plans.

For its track and related assets, Metro performs regular inspections, but does not integrate the data with the fleet and facilities management information in M5. For all of its business areas, Metro has established a performance reporting system, which tracks measures such as mean distance between failures, customer complaints, inspection performance, and other measures used for high-level oversight of the organization. The key challenge Metro faces is uncertainty about future funding and service. The agency has experienced recent cuts in funding and service. In the short term, service reductions lessen demand on Metro's vehicles and infrastructure, but at the cost of increased uncertainty concerning long-term plans.

Noteworthy Aspects

Noteworthy aspects of Metro's practices include:

- Implementation of a new preventive maintenance program and fleet management system for its buses and LRVs; and
- Use of performance measures, including measures of asset condition and performance, as part of an agencywide performance management initiative.

Metropolitan Atlanta Rapid Transit Authority (MARTA)

Background

MARTA provides transit service to the City of Atlanta, as well as Fulton and DeKalb Counties. MARTA operates 132 bus routes covering approximately 1,000 route miles, with 621 buses. Also, the agency operates approximately 175 paratransit vehicles and 450 nonrevenue vehicles. The MARTA rail system began operation in 1979. It includes four lines serving 38 stations. The system includes approximately 48 miles of track, and operates with 318 rail vehicles. Annual ridership is over 105 million trips, or approximately half a million per day.

Practice Overview

MARTA's system is a maturing one, and many of its assets, particularly on the rail system, are approaching the point at which they require overhaul or replacement. Based on MARTA's definition of state of good repair, which emphasizes maintaining assets in a functioning condition (versus eliminating the backlog of investment needs or replacing assets based soley upon their age), approximately 80 to 90 percent of MARTA's assets are estimated to be in a state of good repair. However, MARTA expects maintaining a state of good repair to be a continuing challenge in the future.

For maintaining its buses, vans and nonrevenue vehicles, MARTA has established a set of maintenance/rehabilitation activities, and maintains a bus fleet management plan describing planned vehicle purchases. MARTA performs regular condition assessments of its vehicles, and stores condition data, inventory data, maintenance work orders, and other asset management-related information in its maintenance mangement information system (MMIS). MARTA has implemented the MAXIMUS (now AssetWorks) FA Suite for managing its buses, as well as all other assets.

For its rail cars, MARTA has established the Life-Cycle Asset Rehabilitation and Enhancement (LCARE) program. This program details maintenance actions to be performed over the life of a rail car. A key aspect of LCARE is that a rail car is treated as a set of systems (e.g., propulsion, car body, interior, etc.), each of which may have a different life. LCARE is supported using the MMIS. Using this system, rail cars are inspected regularly, and represented at the subcomponent level to allow for distinguishing between parts of the car with different component lives. MARTA's rail fleet management details capital investments required in addition to the maintenance activities detailed in LCARE.

In establishing this program, MARTA maintenance staff coordinated with their accounting and procurement staff to adjust the vehicle depreciation schedule and procurement plans accordingly. The end result is that MARTA has an approach to maintaining its rail cars longer, and that is coordinated between different groups in the agency.

Regarding its fixed assets, MARTA performs a visual inspection of its track twice per week and uses a track geometry car for each section of track one to two times per year. Track inspection data are stored in the MMIS. Further, MARTA has worked with MAXIMUS and Bentley to build a linear asset model integrated with its MMIS for managing track-related data, OPTRAM. Data on other fixed assets are not currently stored in the MMIS, but MARTA's intent is to integrate all asset data in this system.

MARTA periodically performs a condition assessment, and then uses the results of the assessment to maintain an ongoing projection of its capital needs, updating its Capital Improvement Program (CIP) database on a quarterly basis. The initial assessment performed in 2000 is described in (*9*). The 2000 assessment was conducted prior to the implementation of the MMIS, and thus performed external to MARTA's systems. Moving forward, MARTA's intent is to use a combination of its MMIS and the CIP database to support its future needs assessments.

Noteworthy Aspects

Noteworthy aspects of MARTA's practices include:

- Development of LCARE for rail car maintenance, addressing varying asset lives for different subsystems of a rail car;
- Use of a single MMIS for characterizing maintenance of vehicles and track; and
- Implementation of OPTRAM to support track management.

Metropolitan Transportation Commission (MTC)

Background

MTC is the Metropolitan Planning Organization (MPO) for the San Francisco Bay Area. Although MTC is not a transit agency, it is the designated recipient of funds from the FTA for Bay Area transit agencies. In this role it screens requests for state and Federal grants, and sets transportation priorities for the Bay Area.

A total of 26 transit agencies are located in the nine-county area for which the MTC is responsible. Of these, 22 are eligible for FTA funding. These include: Bay Area Rapid Transit (BART), which runs a rapid transit system throughout the Bay Area; San Francisco Municipal Railway (MUNI), which runs light rail, trolleys, buses, and electric trolley buses in San Francisco; the Santa Clara Valley Transportation Authority (VTA), which runs light rail and bus service in the Santa Clara area; the Caltrain commuter rail service; the Altamont Commuter Express (ACE) commuter rail service; and additional agencies providing a range of bus and ferry services. Together these agencies have ridership over 500 million trips annually.

Practice Overview

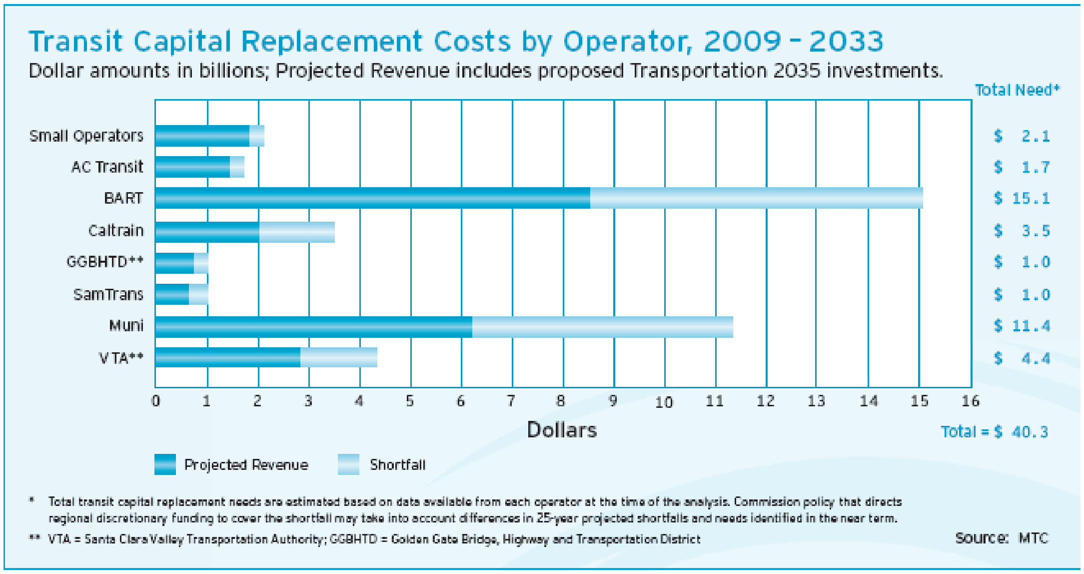
MTC is responsible for regularly updating the Transportation Improvement Plan (TIP) for the Bay Area, which details planned projects for transit, highway, airport, seaport, railroad, bicycle, and pedestrian facilities. Every four to five years, MTC prepares an updated Regional Transportation Plan (RTP). This plan provides a 25-year projection of transportation needs.

As part of the process of developing the RTP, MTC recently updated its assessment of transit needs. For this process MTC developed the Regional Transit Capital Inventory (RTCI) to quantify what transit assets are being maintained by Bay Area transit agencies, and estimate the cost of achieving a state of good repair for those assets. For MTC, achieving a state of good repair is defined as replacing all transit assets at the end of their useful life.

The RTCI contains the following information grouped into asset categories: name of the asset, date the asset was placed in service, replacement and rehabilitation costs, and ages at which the asset needs to be rehabilitated and replaced. The level of detail contained in the RTCI varies significantly by transit agency. Some agencies provided detailed asset data, including estimated rehabilitation and replacement costs. Others provide less detailed data, and for these MTC develops default cost estimates. Also, MTC develops assumptions for average useful life for each asset type.

MTC uses asset age as a proxy for the condition of the asset. Because the RTCI is intended to help develop an unconstrained needs estimate for the RTP, if an asset's age is greater than its useful life age, then the projection assumes it will be replaced the first year of the 25-year RTP. Figure 3.2 shows an example projection of transit needs developed by MTC to achieve a state of good repair.

Figure 3.2 Example Transit Capital Replacement Cost Estimate



Source: Metropolitan Transit Commission.

The key measure MTC uses for summarizing the analysis is the Average Age of Assets as a Percentage of their Useful Life (AAAPUL). Currently the AAAPUL is approximately 75 percent for the Bay Area, and MTC's goal is to reduce this measure to 50 percent, consistent with replacing all assets at the end of their useful life.

Given the RTCI needs projections exceed the available funds (by approximately $22 billion over a 25-year period), MTC uses a separate process, agreed upon by the Bay Area transit agencies, to prioritize investments.

Noteworthy Aspects

Noteworthy aspects of MTC's practices include:

- Integration of asset data from a large number of transit agencies in a single analysis;
- Definition of asset categories and service lives for the full range of transit assets; and
- Development of a single performance measure, AAAPUL, for characterizing transit state of good repair.

3.2 INTERNATIONAL CASE STUDIES

London Underground (LU)

Note: information received from LU was supplemented by review of the Transport for London Investment Program (*23*) and audit of the privatization of LU (*24*).

Background

The London Underground, also referred to as “the Underground” or “the Tube,” provides metropolitan rail service for the London area. LU runs 11 tube lines over approximately 243 miles of track. The system includes 276 stations. LU has a fleet of approximately 4,070 rail cars. Annual ridership is approximately 1.01 billion passengers per year. LU is a subsidiary of Transport for London (TfL), which manages all London area transportation services, including roadways, buses, commuter rail, and the Docklands Light Rail (DLR).

In 2003 London Underground was privatized. The system was divided into three private sector infrastructure companies (Infracos). Tube Lines was selected for the JNP Infraco contract, including the Jubilee, Northern, and Piccadilly lines. Metronet was selected for the BCV and SSL Infraco contracts, consisting of the remaining lines. The Infracos took responsibility for maintenance, renewal, and upgrades of the rolling stock and infrastructure on each of their lines, including trains, tracks, tunnels, signals, and stations for a 30-year period. LU was responsible for operations, and provided oversight for the Infracos. In 2006 one of the Infracos – Metronet – went bankrupt. Subsequently LU took over management of the BCV and SSL contracts, maintaining the performance and asset management specifications established for the Infraco contracts.

Practice Overview

Achieving a state of good repair is a high priority for LU and its parent agency TfL. Two of TfL’s five key objectives, as stated in its annual investment plan, include “ensuring current service levels are supported” and “achieving a state of good repair, addressing a backlog of maintenance or asset replacement.”

To a large extent, LU’s approach to achieving a state of good repair has been established through its Infraco contracts. In the contract LU required the Infraco to develop an asset register detailing inventory and conditions of the rolling stock and fixed infrastructure. LU also specified an approach for measuring the “residual life” life of an asset, and stipulated that the assets managed by the Infraco collectively must have at least half of their residual life at the end of the 30-year contract period. Further, LU established measures for making performance-based adjustments to the monthly payments due to the Infracos. As part of its “asset management regime,” LU established measures in the following areas:

- Ambience of trains and stations;
- Availability of the infrastructure, with reductions in availability due to maintenance measured in terms of lost customer hours averaged over a three-month period;
- Capability of the infrastructure to provide service, measured in terms of passenger journey time; and
- Fault rectification, measured based on response time established by type of defect.

For the JNP contract, LU's role is to provide oversight over Tube Lines. For the BCV and SSL contracts, LU has taken over responsibility from the Infraco Metronet, and is now performing all inspection, maintenance, renewal, and upgrade work. Regarding the rolling stock covered under these contracts, LU performs visual inspections of each car for each shift, and has a maintenance policy established for "light" and "heavy" inspection. Track walks are performed for each section of track on a daily basis, and the track is inspected using a Track Recording Vehicle (TRV) on an eight-week cycle. Maintenance of rolling stock, track, and other assets is performed according to the asset group strategy established for each type of asset. These policies generally have been established separately for each line based on time between interventions. Most assets are inspected and maintained according to LU's "Category 1 Standards," established based on review of best industry practice and considering "best whole life asset management."

Asset performance, measured in terms of the measures in the asset management regime, is reviewed every four weeks at the Asset Performance Review Maintenance (APRM) meeting. Key measures include mean time and mean distance between in-service failures, as well as lost customer hours.

In addition to monitoring asset performance on a regular basis, LU prepares an annual asset management plan for its assets, in which it reviews past performance and recommends asset investments based on available funding. This plan is then incorporated in the TfL investment plan. An example from the 2005-2010 plan is shown in Figure 3.3. In the plan, asset conditions are summarized by the percentage of the asset in each of five different residual life categories (A to E). Category A assets are estimated to have at least 10 years of residual life, Category B have six to 10, and C have one to five. Category D assets are estimated to require overhaul or replacement in less than one year, and Category E assets represent safety issues requiring immediate attention.

LU uses the Mincom ELLIPSE Enterprise Resource Planning system for tracking conditions, maintenance actions, and other information for all of its assets. Generally assets are represented at the asset and sub-asset level. The track is divided into 100 meter sections in the system. Handheld devices integrated with ELLIPSE are used for inspection. Tube Lines maintains a separate asset register for its contract. LU has developed a separate system for predicting future needs.

LU performs a 10-year projection of costs that would be incurred following the recommended asset group strategy. Also, the system recommends an allocation of resources based on a user-specified budget. Where the available budget is insufficient for funding the recommended work the system prioritizes work based on the objectives of minimizing customer delay (lost customer hours) and reductions in asset life.

Noteworthy Aspects

Noteworthy aspects of LU's practices include:

- Development of a comprehensive asset register, including condition measures for all of its assets;
- Measurement of lost customer hours to support evaluation of maintenance effectiveness and link maintenance to user costs; and
- Development of an annual asset management plan considering available funding and explicitly calculating agency and user costs of deferred maintenance.

Figure 3.3 Example Summary Data from the 2005-2010 TfL Investment Plan

Portfolio: LU track – PPP SSL

Primary category: State of Good Repair

Project locations: District, Metropolitan, Circle, Hammersmith & City, East London lines

Manager: Geoff Virrels

Title: PPP Contract Director BCV/SSL

Programme: LU track

Projects: Various

Outputs

This portfolio covers upgrade and renewal of the track and track bed on the sub-surface lines.

The SSL network incorporates around 300km of track, mainly open section and cut and cover. The track asset includes some of the oldest track formations on the Underground, which are in urgent need of enhanced renewal.

The following asset condition benchmarks are used:

A: Will last at least 10 years
B: Overhaul in 6–10 years
C: Overhaul in 1–5 years
D: Requires immediate replacement
E: Fail to meet requirements and require mitigation measures
Grey: Status unknown

Works involve renewal of track and track bed, including sleepers, ballast, drains, etc.

Justification

A well maintained track (which includes ballast, sleepers, drainage etc.) is essential to deliver a safe and reliable service.

Key milestones

Replace 8km of track	2005
Replace 12km of track	2006
Classification of grey assets and elimination of category E assets	2010
Reduction in category D assets	2018
All assets category C or better	2025

These milestones are based on the Metronet SSL's AAMP.

Cost breakdown for 2007/08

The PPP contracts specify levels of performance rather than particular inputs. The precise ordering of works is, therefore, at the discretion of the infracos, subject to meeting LU's safety and performance standards.

Outcomes

- Reliability improvements through improved asset availability and fewer speed restrictions relating to condition of track
- Improved ride quality

Narrative on cost changes

No significant cost changes from 2006/07 plan. Expenditure based on 2005/06 AAMP, due to 2006/07 AAMP not yet agreed.

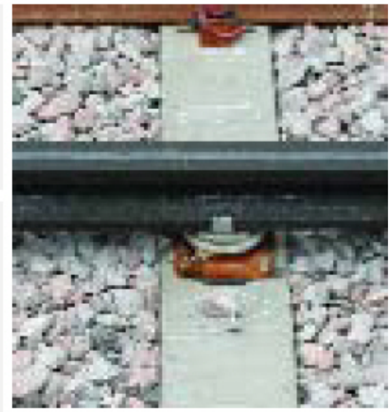
It should be noted that the cost figures included here are indicative only of the level of investment the infracos will be making.

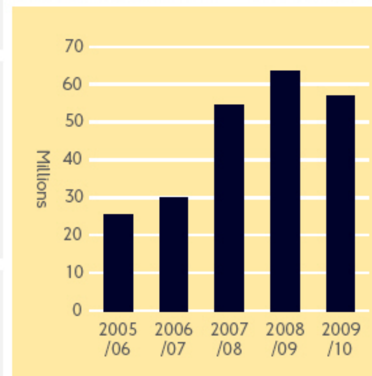
Environmental impacts

- Works are sensitive to lineside biodiversity
- Improved track condition leads to reduced ambient noise
- Old ballast etc. recycled

E&I impacts

- Benefits for all customers – ride quality effects may be of more benefit to particular groups





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Source: Transport for London. *Investment Programme 2007*, 2006.

Toronto Transit Commission (TTC)

Note: information received from TTC was supplemented by review of the TTC Annual Plan (*25*) and additional background information (*26*).

Background

The TTC is owned and operated by the City of Toronto, and is responsible for providing transit service in the Toronto area, including rail, streetcar and bus service. TTC's rail service includes four rail lines. Three of these are subway lines. The fourth, the Scarborough Rapid Transit Line, operates with advanced rapid transit vehicles powered by linear induction motors and is termed an Intermediate Capacity Transit System (ICTS). Together the four lines operate over 42 route miles and include 69 stations. In addition, TTC operates a streetcar system of over 189 route miles. TTC has a fleet of 678 subway cars, 28 ICTS cars, 248 light rail vehicles operating on its streetcar system, and 1,737 buses. Annual ridership is over 466 million trips, or approximately 1.5 million revenue trips per day.

Practice Overview

Maintaining its system in a SGR has been an important goal for TTC for over a decade. Achieving a SGR became TTC's major focus under the leadership of David Gunn, who served as General Manager of TTC from 1995 to 1999. Shortly after his tenure began, TTC suffered the tragic Russell Hill accident, in which three people died and 36 were injured in a collision between two subway trains attributed to a combination of human error and failure in the TTC's signal system. Following the accident, TTC significantly streamlined its management structure, increasing emphasis on maintenance and operations. Also, TTC committed to a SGR funding policy, in which establishing a "life-cycle approach to maintenance" took precedence over system expansion, leading to deferment of a number of expansion initiatives.

The interviews of TTC staff focused on maintenance of its rail and streetcar systems. For maintaining is rail cars and LRVs TTC has established a policy for preventive maintenance and vehicle overhauls based on manufacturer recommendations and TTC experience. Rail vehicles are assumed to last 30 years, with major overhauls approximately every five years. Rail cars and LRVs are inspected monthly. TTC has a set of items that are covered during an inspection, but has not established an overall condition rating for its vehicles. Also, TTC has defined a month-by-month cycle of preventative maintenance activities. The Subway Maintenance System (SMS) is used to track vehicle maintenance for rail cars and LRVs, as well as for the nonrevenue fleet, some facilities, tools, and other assets. This system was developed in-house.

For track and structures, as with vehicles, TTC has a well-defined set of maintenance and rehabilitation policies. Also, TTC has a well-defined asset inventory with defined asset types and subtypes for each asset type and subtype. For instance, for track the basic asset types are track and substructure. Track is further subdivided into ties (concrete or wood), fasteners, and rail (tangent – straight, tangent – curved and special track work). Substructure is further subdivided into ballasted and direct fixation. TTC has applied similar logic in its inventory of structures, dividing these into types including tunnels, rail carrying, spanning rights-of-way, and ancillary structures, and further defining subtypes for each of these (e.g., bridge joints and bearings). Inspection cycles and asset lives are specified by asset type/subtype, with adjustments for use, geography, and environment. In addition to performing periodic visual inspections, with cycles varying by asset type, TTC performs an annual condition assessment to support development of its 10-year capital program, and collects data with a track geometry car approximately every three years. Also, TTC performed nondestructive testing (NDT) to test for rail defects every 18 months.

No overall performance measures have been defined for characterizing conditions of track and structures, or for monitoring conditions. However, given TTC's management structure, accountability is clearly established for asset maintenance. Also, TTC conducts biannual audits of each of its departments, and periodically conducts peer reviews of its practices (e.g., a recent peer review of structures inspection practices).

TTC uses three different systems for track and structures maintenance. TTC uses IBM's Maximo for tracking work performed on its streetcar network, with track divided into 100-foot sections in this system. This system works well for work order tracking, but is not designed for tracking linear assets. Also, TTC uses the Zetatech systems Maintenance of Way Information System (MOWIS) and Structures Maintenance Database (SMD) for tracking subway track and structures inspection data. These systems are used to track inspections and inspection-related data (e.g., defects found during inspections), but are not used for tracking maintenance work.

For projecting future capital needs, TTC prepares a 10-year needs forecast and budget-constrained capital program on an annual basis. The program includes budgets for subway track, surface track, power/electrical, signals, buildings and structures, yards and roads, bridges and tunnel, and vehicles (further broken out by buses, subway cars rail cars, ITCS vehicles, and LRV). Future needs are estimated based on a set of assumptions regarding asset lives specified for each asset type (and subtype, in the case of assets such as track and structures described above). The needs forecast and capital plan are submitted to the City of Toronto and summarized in TTC's annual report.

Noteworthy Aspects

- Early leadership in, and continuing institutional focus on achieving and maintaining a SGR;
- Structured asset inventory incorporating asset types and subtypes; and
- Well-defined approach to inspection, maintenance, and information systems, particularly for subway track and structures.

Victoria Department of Transport (Melbourne Rail/Tram System)

Note: information received from the Victoria Department of Transport was supplemented by review of Victoria's policy on asset management (*27*), reviews of the agency and its privatization efforts (*28, 29*), and additional information on PASS Assets (*30, 31*).

Background

Victoria DOT (formerly Department of Infrastructure) is responsible for performance of the public transport system in Victoria, Australia, including rail, trams, and buses. The Victoria rail system is comprised of approximately 5,000 miles of track, with 17 routes with over 225 miles of track in and around Melbourne, as well as additional intrastate and interstate routes throughout Victoria carrying a mix of passenger and freight traffic. In addition, a separate tram system runs in Melbourne, consisting of 26 routes with over 150 miles of track. In Melbourne passenger rail service is provided using approximately 900 rail cars (operating in 6-car trains) and 209 stations. Tram service is provided using approximately 530 trams and 1,740 tram stops. Annual ridership for the train and tram systems in Melbourne totals approximately 262 million passenger trips.

Victoria's public transport system was privatized in 1999. This arrangement, which broke the passenger transport system into five franchises, ended with three of the franchises in receivership and the remaining two franchisees facing severe financial difficulty. The franchises were restructured substantially in 2004. At present, the Victorian Rail Track Corporation (VicTrack) owns the railway land and infrastructure on behalf of the state, and leases it to Victoria DOT. Victoria DOT, in turn, contracts with a number of organizations to provide transportation services. Connex holds a lease to operate, maintain, and renew the rail network of metropolitan Melbourne. Yarra Trams leases the tram system. Metlink, a new publicly owned corporation, provides information and integrates ticketing for passenger travel in Melbourne for Connex, Yarra Trams, and Melbourne-area bus operators. Freight Victoria Limited, owned by Pacific National, leases the intrastate (primarily broad gauge) rail network outside of Melbourne, and the Australian Rail Track Corporation (ARTC) leases the standard gauge interstate routes of the system. V/Line Passenger operates passenger services in regional Victoria. A variety of entities own different portions of the inventory of rolling stock, including individual franchisees and the state-owned corporation Rolling Stock Holdings Victoria.

Practice Overview

The Victoria government's asset management policy is described in its 2000 report *Sustaining Our Assets (27)*. This report provides a set of objectives and principles regarding asset management for Victoria government agencies. While primarily a high-level statement of policy, as in the case of LU described previously, the approach taken to privatizing the passenger rail transportation system, as well as the details of the privatization agreements, are important in shaping practices related to achieving a state of good repair.

Rail infrastructure is defined to include track, catenary, signaling, depots, stations, bridges, subways, service roads, the central train control facility, and the central electrical supply facility. In the original franchising agreements, Victoria DOT established a set of conditions indices for summarizing physical conditions of the infrastructure. These indices were measured on a scale of 0 to 100, with 100 representing the best condition. Victoria DOT performed a condition assessment of the rail and tram networks in 1999, and committed to update the condition assessment every three years. Franchisees committed to maintain their average conditions. In practice, implementing the original methodology was problematic. Victoria DOT concluded that: the condition indices were too subjective, and difficult to reproduce; franchise holders were put at a disadvantage by not having information on asset conditions in the three-year periods between assessments; and the methodology was too complicated, creating opportunities for confusion and "gaming the system." Consequently, Victoria DOT restructured their approach in 2004 when modifying the franchise agreements.

Victoria DOT's current approach to maintaining its rail infrastructure is to require an Asset Management Plan (AMP) covering the entire franchise period from each franchise-holder. The plan describes the franchisee's approach to inspection, maintenance, and quality assurance, as well as performance standards and response times. The franchisee is then required to perform as detailed in the AMP (in the previous arrangement an AMP was submitted, but condition measures rather than adherence to the AMP were the primary focus). In addition, each franchisee submits an Annual Works Plan specifying planned capital projects.

For rolling stock, each franchisee is required to prepare a Rolling Stock Management Plan and an Annual Rolling Stock Maintenance Plan, which are updated on an annual basis. These describe the franchisee's maintenance policies, as well as plans for rehabilitation/overhaul for each type of rolling stock.

In addition to following their plans, franchisees report quarterly on a set of key performance indicators (KPI) for infrastructure and rolling stock, including condition indices and other measures. The infrastructure measures include functional (related to asset performance), asset condition, and maintenance effectiveness KPI. The rolling stock measures include availability (proportion of time each unit is available), planned versus actual maintenance, mean distance or time between in-service failures, and number of in-service failures or deferred maintenance incidents attributed to key systems.

An important component of Victoria DOT's approach is to maintain an asset register that details the inventory and condition of the rail infrastructure. Note that this register does not include plant and equipment or rolling stock – franchisees are required to maintain a register of these assets separately. To build its asset register, Victoria DOT commissioned the Victorian Rail Infrastructure Survey, a detailed survey of track centerline and geometry, driver's view imagery, aerial imagery, limited condition data, and additional asset information (geospatial data and additional attributes on over 40 asset types, including ties, points, signals, signs, stations, utilities, bridges, road crossings and others). The results of the rail infrastructure survey were used to populate the Privatized Assets Support Systems (PASS) Assets Database. This web-based geospatial system provides detailed asset data to over 800 users, including Victoria DOT, franchisee, and other staff. Figure 3.4 shows a representative screen shot from the system.

Noteworthy Aspects

- Comprehensive asset management approach documented through government policy and franchise agreements;
- Experience establishing condition measures for rail infrastructure and rolling stock; and
- Comprehensive, integrated web-based inventory of rail infrastructure.

Figure 3.4 Example PASS Assets Screen

Source: Victoria Department of Infrastructure.

3.3 State Transportation Department Case Studies

Oregon Department of Transportation

Background

The Oregon Department of Transportation (ODOT) is responsible for 8,067 miles of state highway, several airports, and two short-line railroads. State highways constitute less than 10 percent of the total road and street miles in the state, but carry approximately 60 percent of the traffic – more than 57 million vehicle miles per day. Annually, trucks travel more than two billion miles and move an estimated 250 to 300 million tons of goods on Oregon highways.

Practice Overview

ODOT faces three key asset management challenges:

- An aging highway infrastructure which requires more maintenance and funds;
- The growth of the population (1.2 million more people by 2020) concentrated mainly in one area, which will increase stress on already crowded highways and bridges and cause safety concerns; and
- State and Federal highway funding sources have not increased in more than a decade.

The Oregon Transportation Plan (OTP) includes goals and strategies to guide decision-making and prioritization of transportation improvements for ODOT's assets. These include, in order of priority: 1) protect the existing system; 2) improve efficiency and capacity of existing highway facilities – making minor improvements to existing facilities such as widening shoulders; 3) add capacity to the existing system – making major roadway improvements such as adding lanes; and 4) add new facilities to the system.

ODOT's approach to asset management relies heavily on the use of management systems. ODOT maintains all of the management systems originally required by the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. According to ODOT, all of these systems are "critical to facilitate sound decision-making and cost-effective investments." The management systems used by ODOT to support asset management include:

- Pavement Management System (PMS): ODOT uses its system to monitor pavement conditions and predict future conditions and needs. Pavement data are collected annually;
- Bridge Management System (BMS): ODOT inspects its bridges annually, monitors bridge conditions and predicts future needs and conditions using the Pontis BMS;
- Maintenance Management System (MMS): used to track maintenance activities;
- R2SIGN – Sign inventory database; and
- TransGIS – Web-based GIS inventory.

ODOT inspects its roads and bridges on an annual basis. Where possible, ODOT uses automated means to improve data collection. Data collection technologies used by ODOT include: digital video log (DVL) for the inventory of the state highway systems, linear field data collection using GPS, laser sensors for pavement roughness and bridge clearance data, remote cameras for bridge inspections, web-based bridge inspection reporting applications, GIS-mapped projects, and the TransGIS web-based mapping tool.

Performance measurement is an important aspect of ODOT's asset management approach. Through its Oregon Shines initiative, the State of Oregon has established benchmarks for state agencies to measure progress in their own actions to meet state-level goals in the categories of economy, education, civic engagement, social support, public safety, community development, and environment. ODOT has established a set of Key Performance Measures (KPM) based on the state benchmarks, and reports on these annually. Figure 3.5 provides an example from the report illustrating trends in bridge conditions. As part of this effort ODOT tracks conditions of bike lanes and pedestrian facilities, as well as average condition of bus fleets, estimated based on vehicle age.

Noteworthy Aspects

Noteworthy aspects of ODOT's practices include:

- Emphasis on asset management concepts in agency goals and objectives;
- Use of an extensive set of management systems to support an asset management approach; and
- Establishment of Key Performance Measures across the agency, and reporting on these measures annually.

Figure 3.5 Example from the ODOT Performance Report

OREGON DEPARTMENT OF TRANSPORTATION

III. KEY MEASURE ANALYSIS

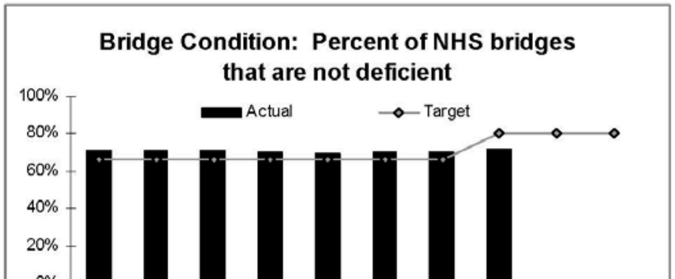
Agency Mission: To provide a safe, efficient transportation system that supports economic opportunity and livable communities for Oregonians.

KPM #16	BRIDGE CONDITION Percent of State National Highway System (NHS) bridges that are not deficient	Measure since: 1998
Goal	MOVE PEOPLE AND GOODS EFFICIENTLY	
Oregon Context	OREGON BENCHMARK #72(b) (i) PERCENT OF STATE BRIDGES IN "FAIR" OR BETTER CONDITION	
Data source	Bridge Engineering Section, Highway Division, ODOT	
Owner	Bridge Engineering Section, Highway Division, ODOT, Bruce Johnson, 503-986-3344	

1. **OUR STRATEGY**

   In order to improve the condition of the state's bridges, ODOT has adopted the strategy of effective management of bridge maintenance and highway improvement projects by monitoring factors that have a direct impact on the load capacity and serviceability of bridges. ODOT has targeted bridge projects to meet these identified needs through both the process of selected projects for the Statewide Transportation Improvement Program (STIP) and the OTIA III bridge repair and replacement program. Additionally, Oregon received special federal funding that has allowed it to move ahead in addressing needs on the most critical routes.

   ODOT is also in the process of upgrading the bridge management system by implementing Pontis for the purpose of storing and analyzing data on bridge conditions more effectively and efficiently. In the development of the 2010-2013 Statewide Transportation Improvement Program (STIP) during the winter of 2007-2008, an analysis using Pontis is being conducted to compare the results of traditional STIP development process with projects selected by Pontis.



	00	01	02	03	04	05	06	07	08	09
Actual	71%	71%	71%	70%	69%	70%	70%	72%		
Target	66%	66%	66%	66%	66%	66%	66%	80%	80%	80%

2. **ABOUT THE TARGETS**

   A higher percentage of bridges with "not deficient" condition ratings is desired. Bridges "not deficient" means that the bridges have not been rated as either structurally deficient or functionally obsolete based on criteria established by the Federal Highway Administration (FHWA). The Minneapolis bridge collapse has heightened the awareness of bridge conditions nationwide. Yearly we re-examine our bridge conditions and compare our results with those in the rest of the nation. Based on 2006 data from FHWA, the national average of National Highway System (NHS) bridges "not deficient" is 80%. While Oregon falls considerably below the average today, the national average is the target beginning in 2007.

Annual Performance Progress Report, FY 2006-07 43 2007-09 Budget Form 107BF04c

Source: Oregon Department of Transportation, *2007 Annual Performance Report*, 2007.

Virginia Transportation Secretariat

Overview

The Virginia Transportation Secretariat refers to the set of transportation departments, agencies, and authorities within the Commonwealth of Virginia. The Secretariat is led by the Commonwealth Transportation Board, which establishes administrative policies for Virginia's transportation system and allocates funds, and a set of modal agencies. Other organizations within the secretariat include the Virginia Department of Transportation (VDOT), with responsibility for state-owned roads, bridges and other highway infrastructure, the Department of Rail and Public Transit (DRPT), Virginia Port Authority (VPA), and Department of Aviation (DOAV), and others.

Collectively, the organizations within the Virginia Transportation Secretariat own, manage, and/or oversee a significant amount of the transportation infrastructure in the Commonwealth of Virginia. VDOT maintains over 120,000 lane-miles of road. VDOT's network is particularly large, as it owns most of the local, or secondary, road system (in contrast to other states that have a large percentage of city- or county-owned roads). Also, VDOT maintains over 19,000 bridges, six tunnels, 11 ferries, and extensive roadside assets. DRPT does not operate transit service, but provides technical assistance and supports over 57 transit systems, as well as additional human service providers and regional commuter assistance programs. The VPA manages the Newport News, Newport International and Portsmouth Marine terminals, as well as the Virginia Inland Port. DOAV provides support to Virginia's 66 public use airports.

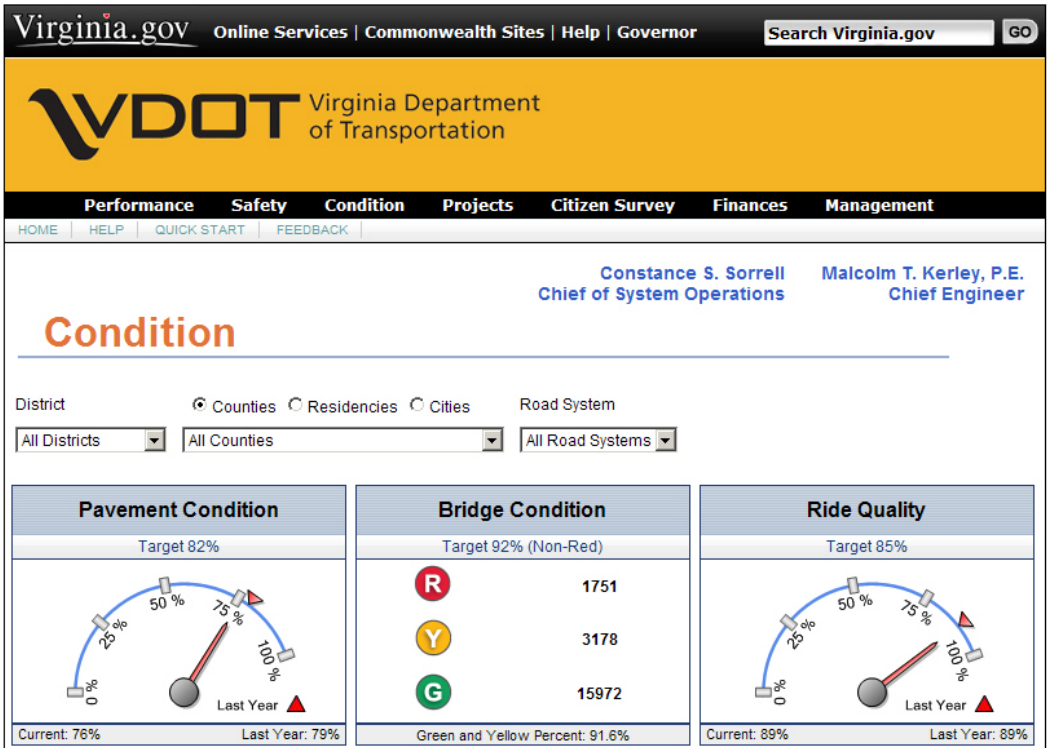
Practice Overview

Preserving the condition of transportation assets is an important objective for Virginia transportation agencies. Virginia's statewide transportation plan, VTrans 2025, identifies a set of asset management strategies for Virginia transportation departments, including:

- Continue implementation of a "maintenance first" policy;
- Increased use of new materials, technologies, and strategies that reduce long-term maintenance costs;
- Support continued development of Asset Management Systems, including inventories, performance criteria, and condition evaluation for all modes; and
- Reduce disruption due to maintenance.

A valuable source of information on the performance of the transportation system is the statewide Virginia Performs initiative. As part of this program all of the agencies in the Transportation Secretariat report on their objectives and key performance measures. As part of this initiative VDOT has developed a performance dashboard, shown in Figure 3.6.

Figure 3.6 VDOT Performance Dashboard – Condition Summary



Source: Virginia Department of Transportation.

Asset condition-related measures on the dashboard and included in Virginia Performs are as follows:

- Percent of "nondeficient" interstate and primary roadway pavement lane-miles (including pavement in fair or better condition);
- Percent of lane-miles with fair or better ride quality; and
- Percent of bridges not classified as Structurally Deficient.

Besides the reporting performed through Virginia Performs, Virginia has additional reporting on asset conditions and performance. VTrans publishes *Virginia's Transportation Performance Report*. Further, the Virginia legislature has established requirements for VDOT to report biennially on the condition performance of the surface infrastructure of Virginia, and to report annually on the condition of the transportation infrastructure and measures of performance in the following areas:

- Condition of infrastructure and initiatives to improve operations;
- Actions and accomplishments in the previous fiscal year involving outsourcing, privatization and downsizing; and
- Enumeration of the status of major bridge maintenance and replacement projects and Federal highway bridge rehabilitation and replacement apportionments.

In support of an asset management approach, as well as to fulfill state and Federal requirements, VDOT has developed a detailed asset management methodology to measure performance, manage assets using a life-cycle approach, and allocate maintenance funding using a Needs-Based Budget approach. As detailed in the methodology report, VDOT's approach incorporates the following primary components:

- Asset Management System (AMS);
- Pavement Management System;
- Bridge Management;
- Random Condition Assessment;
- Other Infrastructure Assets;
- Equipment Management; and
- Snow Removal.

The AMS is used to develop the Needs-Based Budget. It includes modules for asset inventory (this is being populated over time), Random Condition Assessment, planning, work accomplishments, and a Decision Tree Builder for specifying asset maintenance decision logic. VDOT performs inspections of its pavements and bridges on an annual basis, and uses commercially available pavement and bridge management systems to summarize conditions, predict future conditions given alternative budget and operating assumptions, and support resource allocation. Certain assets and activities, including equipment, winter maintenance and selected other assets, are handled outside of the Asset Management System, but needs for these are nonetheless incorporated in the Needs-Based Budget. As VDOT moves forward it plans to further strengthen its asset management methodology through steps such as a fully quantifying its asset inventory (thus discontinuing use of random samples to establish conditions) and developing a performance-based budget.

Regarding transit, individual transit agencies report data on transit assets to the FTA through the National Transit Database. Also, DRPT collects data on transit agency vehicle fleets, and uses this information to analyze average bus age, a proxy for remaining bus service life. Recently DRPT has implemented the Program Guidance and Grant Evaluation System (PROGGRES) for predicting capital needs of Virginia transit agencies requesting grants from DRPT. This system is designed to assist DRPT in evaluating grant applications from Virginia transit agencies. It has functionality for:

- Predicting capital needs for DRPT grantees based on inventory information and asset management principles;
- Evaluating grant applications for consistency with the capital needs analysis;

- Collating and organizing quantitative evaluations using public benefit models (developed separately) and qualitative evaluations from DRPT grant program managers;
- Presenting summary scores and rankings for individual capital grant line items; and
- Evaluating the impact of different options associated with the DRPT capital grant funding policies.

The initial release of PROGGRES focuses on buses. Nonetheless, the system supports analysis of other public transportation asset types, including:

- Passenger rail rolling stock;
- Facilities;
- Infrastructure items (e.g., track, signage, bus shelters);
- Communications, security and computer equipment; and
- Miscellaneous parts, tools, and items.

Regarding port assets, VPA calculates the financial value of its port assets in accordance with General Accounting Standards Board (GASB) Statement 34 using a straight-line depreciation approach for depreciating capital assets. For aviation assets, the Virginia Department of Aviation (DOAV) focuses on helping maintain pavement conditions for airside pavement at the 66 public use airports in Virginia. DOAV characterizes pavement in terms of Pavement Condition Index (PCI). DOAV has recently implemented a pavement management system to track conditions, and has populated the system with data from over 55 airports thus far.

Noteworthy Aspects

Noteworthy aspects of Virginia's practices include:

- Statewide performance reporting, supported by VDOT's Performance Dashboard;
- VDOT's implementation of an approach to predicting pavement, bridge and maintenance needs, and reporting on these needs annually; and
- Development of PROGGRES for use in supporting evaluation of transit grant applications.

4.0 Summary of Findings

The literature review and case studies provide a number of examples of existing practices in transit asset management and how transit agencies are working towards achieving a SGR. Also, the review and case studies provide several examples of practices that could be described as "state-of-the-art." Table 4.1 below summarizes representative existing practices and benchmark state-of-the-art practice in selected key areas. The representative existing practices describe practices followed in multiple agencies identified in the review and/or case studies.

Table 4.1 Existing Practice Summary

Subject Area	Representative Existing Practice	Benchmark – State-of-the-Art Practice
Establishing Policy, Goals, and Objectives	Agency has a working definition of SGR and has identified achieving SGR as a goal	Virginia, Victoria DOT: agency policy goals and objectives are aligned with an asset management approach that identify achieving SGR as an objective, and provide a context for why this important.
Performance Measures	Performance measures have been established for reporting, including average age of assets and mean time/ distance between in-service failures.	Oregon, Virginia, LU: comprehensive set of performance measures is established and reported regularly. Measures reported relate maintenance effectiveness to user impacts.
Asset Inventory	Agency has an asset inventory, with information stored at the vehicle level for buses and rail cars, and by track section. Data on structures and facilities is stored at varying levels of detail.	Caltrain, LU: an asset inventory (register) is established for all assets, specifying data items for each asset and data collection protocols. Complex assets, such as rail vehicles, facilities, and structures are represented at the component and subcomponent level.
Condition Assessment	Condition assessments are performed on a regular basis for vehicles and track, and on a periodic basis for other assets. Defects are logged during inspections, but the agency lacks an overall condition measure.	Virginia, LU, CTA: the condition assessment approach is well-established for all assets, and includes condition assessment measures as well as defect tracking.
Maintenance Policies	Written policies for asset rehabilitation and replacement are established for vehicles and track based on time and/or mileage intervals.	MARTA (LCARE Program); Chapel Hill Transit, GRTC (bus maintenance): agency has developed a comprehensive policy intended to minimize life-cycle costs and maximize asset serviceability.

Subject Area	Representative Existing Practice	Benchmark – State-of-the-Art Practice
Information Systems	A maintenance management system is established for vehicles and track.	MARTA, LU: the maintenance management system is implemented for all asset inventory and maintenance. Track and other linear assets are represented geospatially.
Scenario Analysis	Unconstrained needs assessments are performed periodically through projecting required rehabilitation and replacement work based on time or mileage-based intervals.	Virginia, LU: scenario analysis is performed annually. The agency should have the ability to calculate unconstrained needs, as well as to project the distribution of work given likely funding, and estimate the impacts of any deferred maintenance.

As noted in Section 1.0, organizations typically rely on information systems to support an asset management approach, though the ideal system that supports all functionality needed for asset management does not currently exist. Table 4.2 describes the approaches the U.S. transit agencies detailed in Section 3.0 are using for supporting key functional areas related to asset management, noting in particular where these areas are supported by information systems.

Table 4.2 Support for Asset Management Functional Areas

Functional Area	CHT	CTA	GRTC	Metro St. Louis	MARTA	MTC
Inventory	Uses TRANSMAN for bus inventory, manual means for other assets	Uses MAXIMUS MMIS for vehicles, Infor EAM for fixed guideway	Uses RTA Fleet Management System for bus inventory, manual means for other assets	Uses MAXIMUS MMIS for all vehicles and maintenance facility, other assets tracked separately	Asset inventory stored in MAXIMUS MMIS	Established RTCI for asset inventory, level of detail varies by agency
Inspection	Inspects buses every 6,000 miles at a minimum, tracks inspections/ deficiencies using TRANSMAN	Inspects vehicles daily, track and stations weekly, other assets periodically, stores inspection data in MMIS/EAM. Established 5-point scale for summarizing conditions	Inspects buses every 6,000 miles at a minimum, tracks inspections/ deficiencies using RTA system	Performs regular inspections of vehicles, maintenance facilities, storing data in MMIS	Inspection data stored in MMIS, frequency varies by asset	Varies by agency
Identifying Deficiencies	Deficiencies identified manually through inspection	Deficiencies identified manually through inspection	Deficiencies identified manually through inspection	Deficiencies identified manually through inspection	Deficiencies identified manually through inspection	RTCI predicts replacement/ rehabilitation needs based on asset age
Decision Support	Needs projected external to TRANSMAN	Needs projected external to MMIS/EAM	Needs projected external to RTA system	Needs projected external to MMIS	Needs projected external to MMIS	RTCI used to project future needs
Tracking Work	Maintenance work tracked in TRANSMAN, capital projects tracked externally	MMIS/EAM track maintenance work, capital projects tracked separately	Maintenance work tracked in RTA system, capital projects tracked externally	MMIS tracks maintenance work, capital projects tracked separately	MMIS tracks maintenance work, CIP tracks capital projects	Varies by agency
Monitoring and Reporting	TRANSMAN used for maintenance reporting	Integrating monitoring/ reporting system established	RTA system used for maintenance reporting	Overall performance reporting system established	MMIS used for maintenance monitoring	Varies by agency

The review suggests the following conclusions:

- **Implementation of Asset Management Concepts –** A number of organizations are following practices that are consistent with the concepts of asset management in many respects. Further, several organizations have implemented a range of state-of-the-art practices, as detailed in both the literature review and case studies.
- I**nspection Approaches –** All of the transit agencies described in the literature and profiled in the case studies have well-developed approaches for asset inspection, and use information systems to support their inspection programs and store inspection results. Inspection frequencies vary by asset use and the rate at which failures are projected to occur. However, generally, vehicles and track are inspected most frequently, with weekly or even daily inspections. Generally, inspections are used to identify deficiencies and/or flag issues on a pass/fail basis. Thus, in most cases agencies are not collecting overall condition measures through their inspections.
- **Performance Measures –** The performance measures most commonly used for characterizing transit asset conditions and performance include measures of age or remaining life, as well as mean time/distance between vehicle failures. Outside of the 5-point scale initially established for CTA and incorporated in TERM, there are few other examples of quantitative approaches being used for characterizing asset conditions identified through the literature or case studies.
- **Decision Support –** The review yielded several examples of models for predicting asset needs over time and assisting in resource allocation. Examples include FTA's TERM, the MBTA SGR database, MTC's RTCI, the bus model developed for ALDOT, and others. However, in practice, most agencies lack a decision support model. Maintenance needs typically are identified solely through the inspection process, and to the extent that agencies make projections of future asset needs, they typically rely upon time and/or mileage intervals.
- **Monitoring Performance –** Many agencies are using their asset management systems for monitoring inspections and maintenance performance. Monitoring of capital projects is handled external to these systems. Agencies such as CTA and Metro St. Louis have established supplemental performance management programs that leverage their information systems to provide data to agency managers on conditions and performance on an ongoing basis.

While the review shows many examples of existing practices in transit asset management that are consistent with the state-of-the-art in transportation, for U.S. transit agencies as a whole there is room for improvement in asset management practice, particularly in terms of aligning agency policy goals and objectives with achieving an SGR, establishing condition and performance measures that effectively communicate asset conditions, and developing the systems and processes that can best optimize scarce agency funds for preservation and improvement of transit assets.

Selected state DOT and international transit agencies provide valuable examples of where U.S. transit agencies can realize improvements. In a number of U.S. states, achieving a SGR for highway infrastructure has been an important objective for some time. Agency policies, performance measures, and analysis approaches in states such as Oregon and Virginia have evolved accordingly. Internationally, privatization efforts have had a range of positive and negative impacts, but have inarguably served as a catalyst for developing structured approaches for inspecting and maintaining transit assets, particularly in the case detailed here of LU and Victoria DOT. Moving forward, as they improve their approaches to managing their assets, and working towards a SGR, U.S. transit agencies have the opportunity to leverage best practices followed in the U.S. and abroad to help attain a state of good repair for the U.S. transit system.

Appendix A – Interview Guide

INTRODUCTION

One challenge transit agencies face is in maintaining their systems in a state of good repair (SGR). There is growing concern that a significant proportion of the nation's public transportation assets are in need of capital reinvestment to maintain SGR. This situation is not limited to public transportation assets, but extends to many other transportation assets as well, including highways, bridges, facilities, and other assets. To address this issue, a number of transit agencies and other asset owners have invested in asset management systems to more effectively manage their physical assets. Ideally these systems use quality inventory, condition data, and well-defined objectives to provide a systematic process for improving resource allocation decision-making.

The Federal Transit Administration (FTA) is interested in compiling good practices in Transit Asset Management. This will generate ideas on how to use asset management concepts to help achieve SGR. In particular, FTA is interested in compiling information on the data that transit agencies use to support decision-making, the systems and approaches which facilitate SGR analysis, and the major challenges and benefits of implementing asset management/SGR analysis improvements.

Cambridge Systematics is supporting this effort by performing a literature review, supplemented with interviews of selected organizations. The following pages describe the topics we would like to address through the interview with your agency. We may have additional follow-up questions detailing specific issues. We appreciate your participation in the interview process. For more information on the research, please contact:

Chris Nutakor

Federal Transit Administration

chris.nutakor@dot.gov

(202)-366-6106

General

1. Name
2. Position
3. Organization

Overall Experience with SGR

1. Does your organization have a working definition for "state of good repair"? If so, what is it?
2. Would you characterize your system as being in a state of good repair? If not, how would you characterize the physical state of the system?
3. Please describe your agency's efforts to achieve SGR for its transit assets.
4. Please describe your agency's efforts to analyze investment needs required to achieve SGR? Who is responsible for these efforts?
5. What future challenges do you foresee with respect to managing your transit assets?
6. Do you use an analytical tool such as TERM (Transit Economic Requirements Model) to evaluate long-term capital needs?
7. How are you addressing your investment needs given the gap between needs and available funding, to the extent there is a gap? What are the assets with the largest deferred investment needs?
8. Besides increased funding, what additional information, tools, and/or data would best help your organization better maintain its physical assets?

Buses

1. Please summarize your agency's bus inventory (e.g., number of buses by type).
2. What data and systems do you maintain for tracking inventory and condition data for these assets?
3. What data and systems do you maintain for tracking maintenance data for these assets?
4. Do you use any analytical tools for predicting future asset conditions? If so please describe.
5. Please describe the process used to allocate funds for maintenance and renewal of buses.
6. How do you determine when a vehicle needs to be serviced? (e.g., service life, asset condition, business process, etc.)?
7. How do you determine when a vehicle needs to be replaced (e.g., service life, asset condition, business process, etc.)?

Rolling Stock

1. Does your agency manage other rolling stock besides buses? If so please describe?
2. What data and systems do you maintain for tracking inventory and condition data for these assets?
3. What data and systems do you maintain for tracking maintenance data for these assets?
4. Do you use any analytical tools for predicting future asset conditions? If so please describe.
5. Please describe the process used to allocate funds for maintenance and renewal of rolling stock.
6. How do you determine when a vehicle needs to be serviced? (e.g., service life, asset condition, business process, etc.)?
7. How do you determine when a vehicle needs to be replaced (e.g., service life, asset condition, business process, etc.)?

Fixed Guideway

1. Does your organization manage any fixed guideway, include at-grade rail, elevated structures, or tunnels? If so please describe.
2. What data and systems do you maintain for tracking inventory and condition data for your fixed guideway?
3. What data and systems do you maintain for tracking maintenance data for these assets?
4. What policies have you established for inspection of fixed guideways?
5. What policies have you established for maintenance and renewal of fixed guideways?
6. Do you use any analytical tools for predicting future asset conditions? If so please describe.
7. Please describe the process used to allocate funds for maintenance and renewal of fixed guideways.

Other Facilities

1. Please describe any other fixed facility your organizations maintains, such as stations, maintenance facilities, parking garages, and other structures.
2. What data and systems do you maintain for tracking inventory and condition data for your facilities?
3. What data and systems do you maintain for tracking maintenance data for these assets?

4. What policies have you established for inspection of facilities?
5. What policies have you established for facility maintenance and renewal?
6. Do you use any analytical tools for predicting future asset conditions? If so please describe.
7. Please describe the process used to allocate funds for maintenance and renewal of facilities.

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