TRANSIT COOPERATIVE RESEARCH PROGRAM

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TCRP Report 5

Guidelines for Development of Public Transportation Facilities and Equipment Management Systems

Transportation Research Board
National Research Council

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Report 5

Guidelines for Development of Public Transportation Facilities and Equipment Management Systems

PARSONS BRINCKERHOFF QUADE & DOUGLAS, INC.
Philadelphia, PA
and
New York, NY

Subject Area

Public Transit

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TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions,* published in 1987 and based on a study sponsored by the Urban Mass Transportation Administration—now the Federal Transit Administration (FTA). A report by the American Public Transit Association (APTA), *Transportation 2000,* also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes a variety of transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA, the National Academy of Sciences, acting through the Transportation Research Board (TRB), and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at any time. It is the responsibility of the TOPS Committee to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Committee defines funding levels and expected products.

Once selected, each project is assigned to an expert panel, appointed by the Transportation Research Board. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, TCRP project panels serve voluntarily without compensation.

Because research cannot have the desired impact if products fail to reach the intended audience, special emphasis is placed on disseminating TCRP results to the intended endusers of the research: transit agencies, service providers, and suppliers. TRB provides a series of research reports, syntheses of transit practice, and other supporting material developed by TCRP research. APTA will arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by urban and rural transit industry practitioners.

The TCRP provides a forum where transit agencies can cooperatively address common operational problems. The TCRP results support and complement other ongoing transit research and training programs.

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The members of the technical advisory panel selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and while they have been accepted as appropriate by the technical panel, they are not necessarily those of the Transportation Research Board, the Transit Development Corporation, the National Research Council, or the Federal Transit Administration of the U.S. Department of Transportation.

Each report is reviewed and accepted for publication by the technical panel according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

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FOREWORD

By Staff
Transportation Research Board

This report will be of interest to those involved in developing a Public Transportation Facilities and Equipment Management System (hereinafter referred to as PTMS) for a state department of transportion (DOT). These guidelines have been written to clarify the intent of the federal PTMS regulations and to assist in formulating systems that meet the needs of their states. A range of options is described for each of the components in a PTMS, and minimum requirements are clearly defined.

Under TCRP Project E-4, Parsons Brinckerhoff Quade & Douglas, Inc., was responsible for developing guidelines to assist agencies in meeting the federal regulations for PTMSs. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) requires the U.S. DOT to issue regulations on the development and implementation of six management systems, including a system for managing public transportation facilities and equipment. ISTEA requires that the results of these management systems be considered in making decisions under Title 23 of the U.S. Code and the Federal Transit Act. The Federal Transit Administration and the Federal Highway Administration published an Interim Final Rule on December 1, 1993. It required each state to develop a PTMS work plan by October 1, 1994. A subsequent memorandum dated July 20, 1995, signed by the Federal Transit and Federal Highway Administrators, changes the Federal Transit Administration and the Federal Highway Administration approach to implementing the six management and monitoring systems included in the ISTEA. The memorandum states:

> Development of a public transportation management system (PTMS) addressing the concepts in the interim final rule may be limited to transit assets acquired with Federal Transit Act funds in TMAs [transportation management areas]; in nonTMAs, the extent of a PTMS would be as determined appropriate by State and local officials and could be satisfied through the metropolitan and statewide transportation planning processes that consider preservation of existing transportation facilities and strategies for making efficient use of existing transportation facilities.

States should have the PTMS fully operational by October 1, 1997.

The researchers began by conducting interviews with a wide range of state DOTs, metropolitan planning organizations, and transit agencies to understand (1) how the initial PTMSs were being developed and (2) how the stakeholders anticipated the systems to make their capital investment decisions in the future. A PTMS process was then developed to allow the states to choose from a range of approaches, beginning with a basic system, which could be expanded in the future.

The guidelines begin with answers to basic questions about the federal regulations and the PTMS. A baseline approach to the establishment of a PTMS is discussed, and the potential benefits for each of the stakeholders are described. The guidelines then describe such specific components of the PTMS process as a master inventory and a system for rating the condition of all assets. The last chapter of the guidelines outlines the steps for implementing a PTMS—from establishing a PTMS organization to collecting, evaluating, and reporting data.

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GUIDELINES FOR DEVELOPMENT OF PUBLIC TRANSPORTATION FACILITIES AND EQUIPMENT MANAGEMENT SYSTEMS

SUMMARY

These guidelines are intended to be a useful and complete reference for those developing Public Transportation Facilities and Equipment Management Systems (PTMSs) throughout the United States. They are written specifically for the staffs of various stakeholder agencies in each state, including departments of transportation (DOTs), metropolitan planning organizations (MPOs), and transit agencies.

A PTMS is a tool to help states and regional planning agencies make sound investment decisions regarding their transit assets. While that is the overall purpose of the federal regulations and the objectives of the Federal Transit Administration (FTA) and the Federal Highway Administration (FHWA), there are significant benefits gained by developing a PTMS aside from satisfying those regulations. These guidelines were developed to identify those benefits and help stakeholders understand the PTMS process and their role in that process, determine which type of PTMS is appropriate to meet their specific needs, and provide some standardization or communication among the systems that are eventually implemented.

This summary provides a context for the reader by giving succinct answers to the questions asked most often regarding the PTMS process.

What Is a PTMS?

The Interim Final Rule (IFR) on Management and Monitoring Systems, issued jointly by the FTA and FHWA, states that a PTMS is "*a systematic process that collects and analyzes information on the condition and cost of transit assets on a continual basis. It identifies needs as inputs to the metropolitan and statewide planning processes, enabling decision makers to select cost-effective strategies for providing and maintaining assets in a serviceable condition.*"

Although a PTMS can take whatever form is most useful to the stakeholders of a particular state, its main function is as an informational tool for making investment decisions about the existing transit assets in that state. Stated simply, it is a summary of the needs of existing transit assets; however, those "needs" are defined by the stakeholders. A PTMS is not intended to be used to define the expansion requirements of a particular transit property or corridor; these are more appropriately defined through service performance measures of a Congestion Management System (CMS) or an Intermodal Management System (IMS).

The PTMS process can be as simple or as complex as the stakeholders desire, depending on the type of information needed to make the investment decisions. For example, if a state's buses are to be replaced after having been in service for 12 years (regardless of other factors), then the bus portion of this state's PTMS only needs to classify individual buses or bus fleets by age. In this example, the only analysis required in the PTMS would be the sorting of basic data. Other stakeholders—e.g., transit agencies—may want to make decisions on the basis of other parameters, such as the deterioration rate of certain buses according to service type (rural versus urban). In this case, the PTMS will require more information concerning the life cycle of buses and possibly component deterioration rates. These are the types of decisions that must be made by those developing the PTMS.

The following are the basic characteristics of a PTMS, regardless of the form it takes:

- A PTMS is an analytical process, not a computer program—While there are certainly advantages to be gained in the application of computer database technology and automated analysis tools, the PTMS process can be implemented without computers. A PTMS can be a box of notecards, a set of spreadsheets, or a sophisticated computer system.
- A PTMS is a planning tool for the states and MPOs, not a management tool for the properties—Basically, the PTMS is intended to provide a broad overview of a state's transit assets. Data from transit agencies are needed to develop the overview; these data can be in the form of answers to a short questionnaire or output from a sophisticated capital-planning process. The PTMS, however, does not overlap or replace an agency's maintenance management system.
- A PTMS is a decision support tool—The purpose of a PTMS is to provide decision makers with comprehensive, relevant information that (1) describes the current condition of assets and potential actions to address current deficiencies and (2) compares the long-term consequences of pursuing specific strategies.
- The level of detail for data collection for a PTMS is driven by output and reporting requirements—It costs money to collect, manage, and analyze data. Consequently, the process outlined in these guidelines focuses first on defining the reporting requirements to meet specific statewide and metropolitan planning processes.

What Are the Roles and Responsibilities of the Stakeholders?

While each state has a different set of agencies that are involved in the PTMS process, the principal stakeholders will typically be the state DOTs, the regional MPOs, and various transit agencies. The latter would include all former Section 16 (special transit services) and Section 18 (rural) properties and other agencies as necessary to ensure that the transit assets of a state are completely summarized.

The role of these stakeholders in making transit investment decisions obviously varies from state to state:

- In most cases, the state DOT is not the conduit for federal funds provided to the transit agencies, and it may or may not provide matching funds for transit projects. In many cases, the state has little involvement in making transit asset investment decisions. It is, however, charged with developing a state transportation improvement program (STIP), which requires, at a minimum, summary information on transit needs. The state is also responsible for ensuring that the PTMS is developed, but the intent of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) is that all stakeholders cooperatively develop the system.
- The role of the regional MPOs with regard to investment in transit assets has expanded considerably under ISTEA legislation. Indeed, it is intended that most transportation investment projects be decided on and advanced by the MPOs. The information from the PTMS can be used to complement that of the CMS or IMS to guide the MPOs in developing regional long-range transportation plans or a transportation improvement program (TIP).
- Transit agencies are the natural focus of the PTMS. They own or operate the assets, are most familiar with the condition of those assets, and are usually the ones re-

questing funds for specific improvements. Agencies will ultimately supply the data that are used in a PTMS, either through existing information sources or the collection of new data. Therefore, the primary issue for most transit agencies will likely be how to use existing data for the development of the PTMS in order to minimize the amount of new information to be collected. If the PTMS is developed properly, this issue will be addressed.

How Can a PTMS Benefit My Agency?

The primary benefit of a PTMS is that it provides a decision support tool for stakeholders at all levels. A further advantage is that the basis for this informational tool is a set of data that is standard across the state, which provides a "level playing field" for agencies that provide state service. Benefits vary, however, according to the requirements of each stakeholder:

- **States**
  - Comprehensive inventory of the state's rural and urban transit facilities
  - Consistent, reliable information regarding the capital needs of transit operators in the state
  - Considerably improved information that can be used to articulate needs to a state legislature and to develop budget requests
  - Mechanism for developing statewide or program maintenance and replacement strategies
  - Additional mechanism for coordinating U.S. Department of Health and Human Services, FTA Section 16, Section 18, and other special transportation service programs at the state level
  - Basis for sharing transit information with other states for comparison purposes
- **MPOs**
  - Mechanism for generating transit investment priorities or strategies for long-range transportation plans and TIPs
  - Improved information for regional planning efforts
  - Support for the CMS and IMS by determining the capacity and condition of existing capital stock
- **Transit Agencies**
  - Opportunity to present their investment needs on a regional and statewide platform
  - Articulation of transit capital needs in the same way as highway needs—providing a more level playing field
  - Opportunity for increased funding as a result of ISTEA provisions
  - Ability to expand into a larger asset management system
  - Integration of transit planning with state and regional transportation planning

Is There a Range of Approaches in Establishing a PTMS?

Federal regulations for development of a PTMS are discussed fully in Chapter 1. Both the regulations and subsequent guidance provided by the FTA give states a high degree of flexibility in the form and content of a transportation management system; this flexibility should be taken advantage of when designing a PTMS.

The basic concept of a PTMS can be thought of as a pyramid (see Figure 1).

Capital Investment Decisions. The types of decisions that must be made vary according to the roles of each stakeholder. These decisions should be the focal point for designing

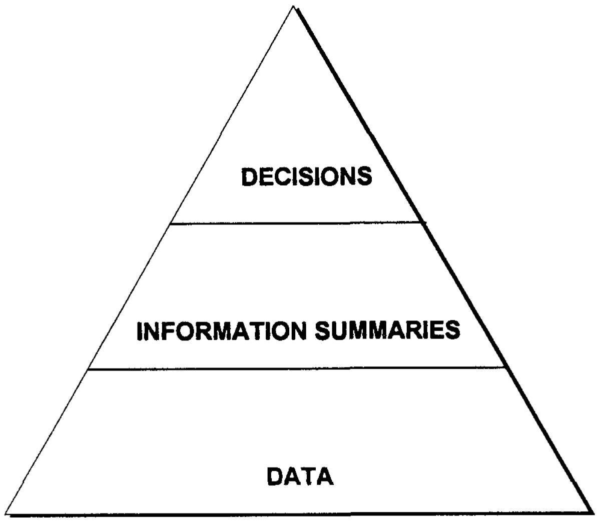

Figure 1. The basic concept of a PTMS.

a PTMS. In essence, three categories of investment decisions must be made regarding the transit assets in any region:

- Capital improvements to existing assets needed to maintain the current level of service (or higher levels if capacity exists)
- Acquisition of new assets to improve or expand service
- Retirement of existing assets to reduce service

The first category of decisions can be made with information from the PTMS because the key issues are the capacity and condition of existing assets. The other two categories would be more appropriately addressed by information in the CMS or IMS or the major investment study for major capital investments because these categories involve analysis of service levels and performance measures.

Data Summaries and Analyses. To make decisions concerning capital improvements to existing transit assets, information is required that summarizes the status of existing assets and estimates the cost of bringing the state's transit assets to a good condition. This information could include the following:

- The existing condition of the state's bus fleets and their replacement needs
- The number of vehicles in the state (or region) that have marginal condition ratings
- Among all the buses currently in operation in the state, information on the specific type of bus that has the lowest maintenance costs and the highest fuel efficiency
- The life cycle of different buses or rail cars under various conditions
- The condition of the transit agencies' maintenance facilities and their adequacy to maintain the vehicle fleets
- The condition of the stations and bus stops
- The prioritized investments that are required to maintain a favorable condition rating for the assets of each agency

Stakeholders will require a different level of information depending on their vantage point in the decision-making process; however, the point being emphasized is that this information will be critical in deciding where to invest federal, state, or local funds to attain the greatest benefits.

Data Needs. A database must be available to provide the summary information cited previously, and some amount of data must be collected for that purpose. The type and level of detail for that data should be tailored to respond to the specific information needs of a state's stakeholders and should use existing data collected by agencies.

Three fundamental categories of data are required for the PTMS:

- **Master Inventory of Assets**—This is a complete inventory of transit assets in the state.
- **Condition of Assets**—Each of the assets must be rated against a set of condition standards and, possibly, functional standards (e.g., efficiency and reliability).
- **Background Engineering Data**—Information is required to evaluate the asset and its condition and develop strategies to maintain the asset. Such information may include unit costs for replacement and life cycles of various assets.

These three categories are explained in greater detail in Chapter 2 of the guidelines. The primary issue for the stakeholders, however, is deciding on the level of detail to be collected for each of the assets. The types of analyses will vary according to the level of data that is collected. For example, a sophisticated analysis comparing the economics of rehabilitation versus replacement for a set of assets on the basis of their actual conditions would require a more detailed level of data than a listing of all buses that are beyond a 12-year service life. In making these decisions regarding the level of data and analysis, it should be recognized that a PTMS can and will most likely evolve during a number of years—starting small and expanding as stakeholders see the value of PTMS information and ask for additional data to support their decision-making processes.

One more issue needs to be mentioned with regard to data collection. Data supporting the PTMS can be gathered from a number of sources; these sources do not necessarily need to reside in the PTMS. For instance, data can be supplied from a short questionnaire filled out by a transit agency or can be supplied directly from a system that an agency uses in its daily asset management efforts. Both are valid sources, even though a different level of information is supplied, and both sources could be used as part of the same PTMS.

What Is the Minimum Approach to Meeting the Federal Requirements?

This is one of the most asked questions by stakeholders in every state. The question is important because most states would like to start by developing a basic PTMS. Because a PTMS is a new concept, a phased development program would be a sensible approach acceptable to the FTA and FHWA.

The following are the basic required components of a PTMS as cited in the ISTEA regulations:

1. Data collection and system monitoring—These require development of a base-year inventory of transit assets with information regarding age, condition, remaining useful life, replacement costs, quantity, and ridership data for dedicated transit rights of way.
2. Identification and evaluation of proposed strategies and projects—These required strategies relate to the capital needs of existing transit assets.
3. Implementation of strategies and projects—It is required that the costs, potential funding sources, and priorities of a capital program for existing assets be developed.

These three requirements are included in the concept of the PTMS pyramid (see Figure 1), and the following description defines a minimum-level approach to satisfying these requirements.

Database. A PTMS requires a base level of information either centralized at the state level or decentralized at the regional or agency level. This database need not be computerized, but it must contain the basic inventory and condition information cited in the ISTEA regulations. Although there is not a single model for a minimum-level PTMS, the following descriptions illustrate the level of detail that might be expected for the database components:

- **Master Inventory**—In general, there are two different types of transit assets—vehicles and facilities. While the list of vehicles might include buses, rail cars, or even work equipment, a simple approach would be to categorize either individual vehicles or bus types as "assets." Information on individual buses is generally available at transit agencies, and it simplifies the condition-rating process. With regard to facilities, a list of all major facilities individually and a summary of minor facilities (e.g., bus stops) by category would satisfy the regulations.

  It is necessary to collect basic information for each asset. In addition to the three types of information cited as basic components in the previous section, the amount of additional data required would vary by stakeholder. Some basic information—which for buses might include vehicle type, type of fuel used, or whether a vehicle complies with Americans with Disabilities Act (ADA) regulations—would be useful in understanding the capital needs of the assets and is typically available from an agency.
- **Condition of Assets—**The condition of each asset must be included in the PTMS, and there must be a standard for making this assessment. One of the simpler methods would involve the use of a condition index, which is defined later in these guidelines. This rating of vehicles and buildings could be quickly performed by the transit agencies because their staffs are responsible for the daily maintenance of these assets.

  If a condition rating of each vehicle involves more data than desired by the state, then an alternative is to evaluate each type of bus. For instance, to simplify the condition-rating process, all buses for a transit agency that are of the same type and purchased in the same year could be considered an "asset." Because the condition of specific buses in one fleet may vary significantly, this approach would limit the type of analysis that could be performed. This limitation must be considered.
- **Background Engineering Data**—It is necessary for the background data to include information that enables the development of strategies and cost estimates for restoring the transit assets to a state of good repair. At a minimum, this includes unit cost for the rehabilitation or replacement of deficient assets, standard life cycles for primary assets (to be compared against current age), and possibly criteria for rating the priority of projects.

Data Summaries and Analyses. To be of use to the stakeholders, a PTMS must produce a list of transit assets that are not in a state of good repair and strategies for correcting the condition of those assets. This can be achieved in a number of ways, most simply by taking the unit costs developed previously and applying them to those assets that have been judged to be in need of replacement. For instance, the PTMS could sort the assets in each category by age or condition, then the unit costs can be applied to calculate the investment needs of the transit agencies. The issue of analyses is discussed extensively in Chapters 1 and 2 of these guidelines. The stakeholders in each state must decide what level of analysis is appropriate for their needs.

A PTMS that meets ISTEA requirements may produce at least four types of analyses:

- **Unconstrained Needs**—The unconstrained needs report provides for the full inventory of transportation assets, budgetary requirements for refurbishment, rehabilitation, and replacement. This report answers the often-asked question: "How big is the problem?"
- **Life-Cycle Replacement Requirements—**Through forecasting methods, a PTMS can identify future life-cycle replacement requirements over a multiyear planning horizon.
- **Prioritized Needs**—Because the budget necessary to address the full list of unconstrained needs and forecasted life-cycle replacement requirements usually exceeds the funding available, a PTMS can employ a prioritization method to help decision makers identify the urgency and importance of capital requirements.
- **Evaluation of Alternative Strategies—**Finally, a PTMS can provide a systematic approach to evaluating the effects of pursuing various refurbishment, rehabilitation, and replacement strategies.

How Can a PTMS Be Established?

Chapter 3 of these guidelines discusses the steps involved in establishing and implementing a PTMS. It is important to stress again that when establishing a PTMS, it would be best to keep it simple and appropriate for the state or region. The steps include the following:

1. Developing a state-specific PTMS methodology
   - Define the range of modes of transportation in the state
   - Define the assets that support these modes
   - Determine the data required for all assets
   - Determine which data are already available
   - Define data that must be collected

2. Establishing a data collection system
   - Determine the level of detail for the inventory
   - Develop inspection standards and methods (if required)
   - Establish condition-rating criteria

3. Developing methods of analysis
   - Define potential actions to address asset deficiencies (e.g., rehabilitation or replacement)
   - Determine standard costs and life expectancy
   - Define engineering data hierarchy (if necessary)
   - Define type of analysis required

4. Implementing the PTMS
   - Collect data
   - Generate unit cost and standard life information
   - Perform analysis and distribute results to each stakeholder
   - Fine-tune PTMS for successive years

CHAPTER 1

BACKGROUND

OVERVIEW

There has been extensive publicity given to the advanced state of deterioration of the nation's public infrastructure—its bridges, highways, and transit systems. Recognizing that the nation is not going to build a new infrastructure of the magnitude that now exists, it is essential to keep what exists in service.[1] A primary requirement of keeping the existing infrastructure in service is access to quality information about the components that make up the infrastructure system and the condition of these components.[2] Because of the large amount of information required to describe the components of a transit infrastructure, processes are necessary to speed the collection of and access to information. Once developed and implemented, these processes can increase the effectiveness of asset management.[3]

Enactment of ISTEA legislation and subsequent regulations and guidance from the FHWA and FTA provide the opportunity for states—in cooperation with MPOs, transit operations, and other agencies—to develop tools to assist decision makers. One of these tools is a PTMS.

These guidelines review the legislative history of the PTMS, and its benefits and relationship to the other management systems. The guidelines address the characteristics of a PTMS and describe a generic application focusing on the PTMS components and process. Implementation steps are set out, and an example of a PTMS is described.

These guidelines are intended to assist those responsible for developing their state's PTMS, whether they represent the state, MPOs, transit agencies, or other agencies. The purpose of the guidelines is to (1) provide information on data collection on public transportation assets, (2) assist in developing the means to determine the condition of those assets and their useful life, and (3) assist in developing the strategies to maintain and replace those assets.

ISTEA MANAGEMENT AND MONITORING SYSTEMS

ISTEA requires the U.S. DOT to issue regulations on the development, establishment, and implementation of six systems for managing the transportation infrastructure: the pavement of federal-aided highways (PMS); bridges on and off federalaided highways (BMS); highway safety (SMS); traffic congestion (CMS); public transportation facilities and equipment (PTMS); and intermodal facilities and systems (IMS). ISTEA requires states to take the lead in developing, establishing, and implementing these management systems as well as traffic monitoring systems (TMSs) for highways.

The intent of the management systems is to develop—cooperatively with state, regional, and local interests—organized, pertinent information to assist decision makers in selecting cost-effective policies, programs, and projects that improve the efficiency and safety of the nation's infrastructure and protect investment in it. According to the IFR on Management and Monitoring Systems, a management system includes: identification of performance measures, data collection, and analysis; determination of needs; evaluation and selection of appropriate strategies or actions to address the needs; and evaluation of the effectiveness of the implemented strategies or actions. The needs and strategies identified by the individual management systems must be considered in the development of metropolitan and statewide transportation plans and improvement programs.

In the IFR, the specific roles and responsibilities of affected agencies in developing the management systems are flexible. The states and their respective MPOs, regional agencies, local governments, recipients of funds under the Federal Transit Act, and other entities are to determine cooperatively how to develop, establish, and implement each system. The state, however, is responsible for overseeing and coordinating such activities. The IFR on Management and Monitoring Systems requires states to begin implementing the management systems during federal Fiscal Year 1995. A state must annually certify its compliance with the federal requirements and summarize the status of implementation of each management system. Failure to comply with these requirements could mean withholding of a portion of FHWA and/or FTA funds.

Certain federal funding sources can be used to develop and implement the management systems, including the National Highway System, Surface Transportation Program, FHWA state planning and research funds, metropolitan planning funds, and Federal Transit Act Metropolitan Planning (formerly Section 8), Urbanized Area Formula (Section 9), and State Planning and Research (Section 26) funds. Congestion Mitigation and Air Quality Improvement Program funds may also be used for those management systems that contribute to improving air quality.

INTRODUCTION TO PTMS

The IFR on Management and Monitoring Systems includes requirements for the development, establishment, implementa-

[1] Building Futures Council White Paper to the Financial Accounting Standards Board (1991).

[2] K. R. Maser, "Inventory, Condition, and Performance Assessment in Infrastructure Facilities Management," *Journal of Professional Issues in Engineering,* ASCE 114(3); 271–275.

[3] Fadi A. Karaa, "Infrastructure Maintenance Management System Development," *Journal of Professional Issues in Engineering,* ASCE 115(4); 422–432.

tion and continued operation of a system for managing public transportation facilities and equipment in each state. A PTMS is defined as a systematic process that continually collects and analyzes information on the condition and cost of transit assets. Transit assets are defined as public transportation facilities (e.g., maintenance facilities, stations, terminals, and transitrelated structures), equipment, and rolling stock.

The shear volume of transit assets to be monitored is immense. For example, throughout the United States, there are 59,753 motorbuses; 10,419 heavy rail vehicles; 913 light rail vehicles; 832 trolley buses; 16,222 demand-response vehicles; 119 ferry boats; 4,415 commuter rail vehicles; and 1,079 other types of transit vehicles. The total number of transit vehicles used for local transportation is 93,752.[4]

A PTMS establishes a process for data collection on the age, condition, useful life, and replacement value of transit facilities and equipment in a particular state. Such data will assist the state in selecting the most cost-effective strategies for maintaining transit assets. The intent of the PTMS is to facilitate ongoing statewide assessment of the condition of major capital transit assets to identify and prioritize needs. The management system will support statewide and metropolitan planning and programming processes by identifying capital needs and providing strategies to meet those needs.

The federal government, through recent general guidance addressing the development of a PTMS, strongly encourages the inclusion of assets of non-FTA fund recipients in the PTMS. Although not required by federal regulation, the inclusion of these assets will ensure that decision makers have the information on capital assets to identify overall needs accurately. The system is most useful as a tool in capital asset management of public transportation when it includes all assets used in providing public transportation, not just those purchased with federal funds.

The development and implementation of the PTMS represents a particular challenge for states. Prior to ISTEA and subsequent regulations, many states were only indirectly involved in inventorying and assessing public transit capital needs and developing strategies to meet those needs. Local and regional transit operators, as well as Section 18 and Section 16 rural and paratransit operators, are the main repositories of asset inventories and the condition data for those assets. As a result, cooperation among the different planning and transportation agencies is essential to ensuring the development of an effective system. The PTMS regulations stress cooperation in developing, establishing, and implementing the system among all affected agencies.

FEDERAL REQUIREMENTS FOR THE PTMS

The following is a summary of the federal requirements on the implementation of the PTMS as mandated by ISTEA and as required by the December 1993 IFR on Management and Monitoring Systems:

- Each state shall develop, establish, and implement—on a continuing basis—a PTMS that covers urban- and ruralarea public transportation systems in all transportation management areas (TMAs). These systems may be operated by the state, local jurisdictions, public transportation agencies and authorities, and private (for profit and nonprofit) transit operators receiving funds under Federal Transit Act (capital and operating funds) and public transportation systems operated by contracted service providers with capital equipment funded under Federal Transit Act (capital and operating funds). A state may enter into agreements with local governments, regional agencies (such as MPOs), recipients of funds under the Federal Transit Act, or other entities to develop, establish, and implement appropriate parts of the PTMS; however, the state shall be responsible for overseeing and coordinating such activities.
- The PTMS shall be developed, established, and implemented in cooperation with recipients and subrecipients of federal transit capital and operating funds.
- In nonTMAs, the extent of a PTMS would be as determined appropriate by state and local officials and could be satisfied through the metropolitan and statewide transportation planning processes that consider preservation of existing transportation facilities and strategies for making efficient use of existing transportation facilities.
- In developing and implementing the PTMS, the state shall cooperate with MPOs in metropolitan areas. Within the metropolitan planning areas, the PTMS shall, to the extent appropriate, be part of the metropolitan planning process. In metropolitan areas that have more than one MPO or that include more than one state, the establishment, development, and implementation of the PTMS shall be coordinated among the state(s) and MPO(s) to ensure compatibility of the systems and their results.
- Because of their interrelationship, the development, establishment, and implementation of the PTMS shall be coordinated with the development, establishment, and implementation of the CMS and the IMS.
- Federal regulations for a PTMS outline very specifically the components that must be addressed and included in the system:

  - Measures and standards must be developed to evaluate the condition of the transit assets. Those standards should reflect the stakeholders' goals for safety, efficiency, reliability, and the ability to maintain those assets in a state of good repair.
  - Data collection and system monitoring must be coordinated with the CMS, IMS, and TMS and include the following, as a minimum:

    1. Base-year comprehensive inventory of the transit assets. For each type of asset in the inventory, information collected should include age, condition, remaining useful life, and replacement cost. Transit asset data must be collected in cooperation with MPOs and transit operators at a frequency and level of detail appropriate to the type of capital stock of the transit system.

[4] Harrington, Patricia, "National Transportation Statistics Annual Report, 1992," US DOT/Research and Special Programs Administration, 1992.

2. Number of vehicles and ridership data for dedicated transit rights of way (e.g., rail lines and busways), at the maximum load points for the peak period in the peak direction and for the daily time period. Data related to highway transit vehicles and ridership should be collected as part of the highway TMS.

- Information provided by data collection and system monitoring activities should be used to determine the condition of all transit assets previously inventoried, the needs and schedules for major maintenance or replacement, and the estimated replacement costs.
- The costs, potential funding sources, and priorities of proposed strategies and projects need to be identified. The strategies and projects are then evaluated for potential inclusion in metropolitan and statewide transportation plans and improvement programs.

By October 1, 1994, each state was required to develop a work plan identifying major activities and responsibilities, including a schedule demonstrating how full operation was achieved. By October 1, 1995, condition assessment measures and data system structures were to be established and data collection under way. By October 1, 1997, the PTMS must be fully operational and able to identify projects and programs for consideration in developing metropolitan and statewide transportation plans and improvement programs.

States must be implementing each management system beginning in federal fiscal year 1995. They must certify, before January 1 of each fiscal year, that the systems are being implemented, or the Secretary of Transportation may withhold up to 10 percent of funds apportioned under Title 23, U.S.C., or under the Federal Transit Act for any fiscal year beginning after September 30, 1995.

TYPES OF PTMSs

Federal regulations and subsequent guidance provide states a high degree of flexibility in the form and content of the management systems. The PTMS Section 500.605 (a) of the IFR states that "each state shall develop, establish, and implement on a continuing basis a PTMS that covers urban and rural areas..." This statement has been interpreted by most implementing agencies to mean a statewide inventory of transit capital assets and the adoption of consistent evaluation criteria for assessing the condition of those assets. It is also possible, however, to develop a PTMS where the consistent inventorying and evaluation of transit assets is not applied statewide but rather on a regional level or within distinct classes of public transportation systems.

Statewide Versus Decentralized

The FTA and FHWA have encouraged a statewide approach to the establishment of a PTMS as the most comprehensive and useful way to determine the range of public transit assets, their condition, and the capital needs to maintain these assets. However, the FTA and FHWA have acknowledged that in some situations a more decentralized approach may be preferred by a state, its transit operators, and its planning agencies. The wide range of arrangements and relationships between state DOTs, MPOs, and public transportation providers with regard to resource allocation procedures may dictate a decentralized approach.

Whether the system is statewide in scope or decentralized, the following requirements must be considered and met:
The decision on the type of system to be developed must be made cooperatively and have the endorsement of affected MPOs and public transportation providers.

- The system must comply with the requirements for the PTMS defined in the IFR, including operator and asset coverage and meeting the implementation schedule.
- The system must be developed in coordination with the CMSs and IMSs (regional and metropolitan PTMSs should, in particular, be closely linked to metropolitan CMSs).
- Data and outputs—even if maintained at substate levels—must be made available as needed throughout the state, and there must be formal agreements ensuring this availability.

The FTA and FHWA have pointed out that all system types must also identify transit needs and strategies for input into decision-making and planning processes. They must also provide for consistent evaluation of transit capital assets to determine regionwide needs and strategies to meet these needs, whether on a regionwide or statewide basis.

A key requirement of decentralized as well as statewide systems is that they identify transit needs and deficiencies as an input to transportation planning and decision-making processes. To generate the information necessary to prioritize needs among transit systems, it is essential to have consistent criteria and procedures for evaluating the condition of defined transit capital assets. If the PTMS serves regional decision making, for example, then the system must at least provide for the consistent evaluation of transit capital assets within the region. Instead of being the sum total of individual operator's capital plans within the region, a regional PTMS would facilitate the establishment of uniform measures, standards, and inventories among all covered transportation providers for determining regionwide needs and strategies to meet identified needs. Regional or metropolitan PTMSs may be appropriate for urbanized areas that cover two or more states or for urbanized areas where the public transportation network is far more comprehensive and the demands placed on it far more intensive than other systems throughout a state.

Distinguishing Systems by Other Common Traits

For the purposes of state oversight of urban and rural transit systems, some DOTs may have established transit system classes to distinguish types of services being provided. These classes may be distinguished by system fleet size, service area, vehicle revenue miles or hours, and so on. The assumption behind such distinctions is that systems of various sizes operate under different environments and that their investment needs are thus dictated by different criteria. A decentralized PTMS may distinguish transit systems by classes, each with different data structure, condition evaluation criteria, and evaluation procedures, provided that these components are consistent among operators within each class to ensure the compatibility and comparability of system outputs. Such classes are perhaps more appropriate for (1) larger states with particularly diverse ranges (both urban rail and significant rural) of services; (2) states that have a state agency providing significant public transportation services; or (3) states with a historically strong relationship between the DOT and public transportation operators, which facilitates the exchange of information, and is manifested in a cooperative partnership with well-defined, mutually determined responsibilities.

RELATIONSHIP TO OTHER MANAGEMENT SYSTEMS

The PTMS, similar to the PMS and BMS, is primarily an asset management system. The CMS, IMS, and SMS are primarily performance management systems. In simple terms, the PTMS evaluates the condition, capital needs, and deficiencies of transit assets, while the CMS and IMS evaluate the performance of the transit investments. The PTMS provides the information needed on the condition and capacity of assets and facilities that will support the evaluation of public transit strategies identified by the CMS. It will also support the public transit components of the intermodal transportation facilities and systems required by the IMS.

A clear, comprehensive, and coordinated approach to the management systems—particularly the PTMS, CMS, and IMS—initially will require extra time, effort, and cooperation by affected agencies, including the state, MPOs, and transit agencies. Early planning and continuing dialogue between the agencies and across management systems in developing and implementing the systems will provide a series of valuable decision-making tools to support statewide and metropolitan transportation planning and programming.

ORGANIZATION OF REPORT

The remainder of this report includes the following:

Chapter 2, Description of the PTMS Process, provides an overview and general understanding of a PTMS and the underlying assumptions that form a basis for developing such a system.

Chapter 3, Implementing a PTMS, defines the issues related to successfully implementing a PTMS and describes common implementation steps.

Appendix A presents broad categories for all types of transit assets.

Appendix B presents a system for categorizing the subsystems of various transit assets. Appendixes A and B are intended as guides to define transit assets and determine the level of detail to be used in a PTMS.

Appendix C presents a list of reference documents that were used in developing the PTMS guidelines.

Appendix D presents a list of published standards for transit assets.

Appendix E contains the bibliography.

Appendix F contains a glossary of acronyms and terms mentioned in this report.

CHAPTER 2

DESCRIPTION OF THE PTMS PROCESS

OVERVIEW

This chapter provides an overview of a PTMS, an approach to the development process, and a discussion of the underlying assumptions that formed the basis of the approach. It outlines the major activities that may be undertaken in developing a PTMS and describes components that would comprise a PTMS database. These components include the inventory of assets, the assessment of their condition, and the development of the actions and establishment of priorities needed to maintain or replace the assets. This comprehensive section may be too detailed for states that are beginning to develop a PTMS; therefore, for each part of a PTMS, those developing the system will need to determine the appropriate level of detail.

Asset management is a technical discipline requiring precise terminology. Clear definitions need to be adopted by those developing a PTMS. Because a PTMS is a process with roots in the capital asset management and engineering management system disciplines, many of the terms used in this report are from these disciplines. A glossary of terms is included in Appendix F of these guidelines.

THE DEVELOPMENT PROCESS

A PTMS is a process more than a product; this section describes the steps of the PTMS development process (see Figure 2). The steps for implementing a PTMS process are provided in Chapter 3, but the major activities involved in establishing a PTMS program are the following:

Determining the Roles, Responsibilities, and Goals of States, MPOs, and Transit Operators—Each state, in cooperation with MPOs and FTA recipients and subrecipients, must develop a PTMS that will best accommodate the needs and institutional relationships of all affected agencies. To ensure a useful PTMS, the roles, responsibilities, and unique goals of all affected parties must be addressed to implement and monitor the system, determine the level of detail, identify the condition measures to be used, and collect the data.

Establishing or Updating a Master Inventory of Transportation Assets—Because the entire PTMS process focuses on capital assets and their maintenance, it must include an inventory of assets to be recorded and tracked. These assets must be described at an appropriate level of detail so that statewide or regional planning can be used to determine policies, projects, and schedules for future capital investments. The master inventory is a complete record of all public transit assets. It can be compiled on a broad scale, such as by fleet or rail line, or at a greater level of detail, such as by addressing systems and components that comprise transit assets.

Preparing a Condition Database Describing the Current Condition of the Transit Asset or Inspection Units Comprising the Asset—Establishing condition assessment measures for evaluating transit assets provides the basis for determining capital asset deficiencies and needs and prioritizing those needs. The condition of each inventory asset must be assessed; ratings can be based on criteria ranging from age to current physical condition. Just as in the inventory, condition can be established on a broad scale or at a greater level of detail.

Developing a Record of Potential Actions to Address Current Deficiencies and Forecasted Requirements—Once the condition of the assets is determined, potential actions can be developed to address the deficiencies that are found. A list of potential actions for correcting these deficiencies would include refurbishment, rehabilitation, and replacement, along with the estimated cost of the action and expected benefit of the action.

Evaluating and Analyzing the Effects of Various Strategies—Given the range of potential actions to address a given asset's deficiencies, strategies including one or more of the potential actions are evaluated for priority, life cycle, and costs in this activity. The determination of asset condition, age, useful life, and replacement cost that results from this evaluation indicates to decision makers the overall unconstrained recapitalization needs for maintaining current transit assets and supports planning efforts for major maintenance and replacement actions.

Organizing the Information and Reports—The PTMS data must be organized to support the needs of the stakeholders and decision makers. The results of PTMS analyses must be communicated to the stakeholders in useful formats and in level of detail so that the overall recapitalization needs and priorities of transit are included in state and metropolitan transportation plans.

Collecting Feedback—To remain relevant, the PTMS process must evolve on the basis of feedback from a variety of people, including those using the PTMS information and the participants in the PTMS process.

The PTMS activities previously described should be performed repeatedly to support statewide and MPO planning cycles. When capital transit projects are programmed and implemented through TIPs and STIPs, the information concerning these projects must be fed back into the PTMS and the planning process as part of a continuously evolving process. Major new capital facility and equipment investments need to be included in PTMS inventory updates to reflect accurate capital needs and deficiencies.

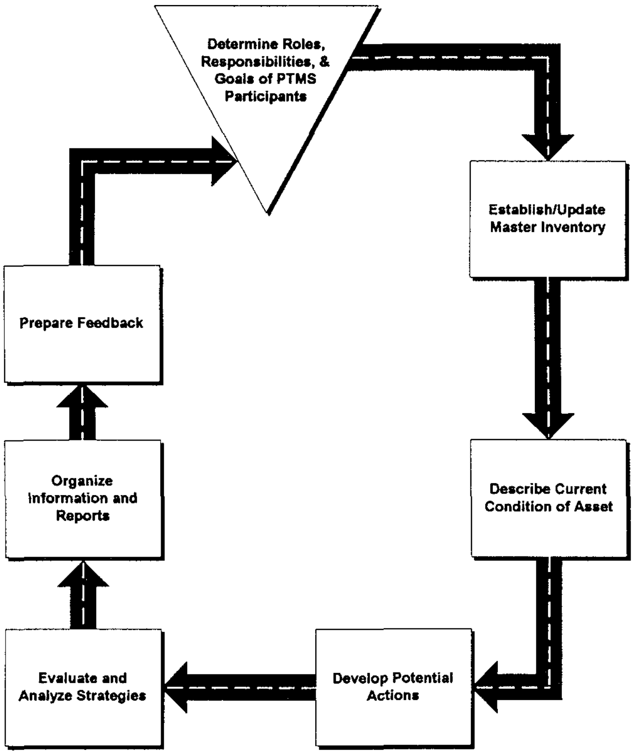

Figure 2. PTMS development cycle.

Assets
RTS-08 Bus
Kennedy Class Ferry
Fleet of 345 Bombardier R62A Subway Cars

Figure 3. Various types of assets.

Asset 'Maintenance Facility' consists of

Inspection Unit 'Architectural.Exterior.Roof.Asphalt'
Inspection Unit 'Architectural.Exterior.Walls.Brick'
Inspection Unit 'Architectural.Exterior.Windows. Aluminum'
Inspection Unit 'Architectural.Interior.Doors.Hollow Metal'
Inspection Unit 'Mechanical.All'
Inspection Unit 'Electrical.All'

Figure 4. Various types of inspection units.

Inspection Unit
Fleet of 124 New Flyer 35-Foot Buses

Figure 5. An entire fleet considered an inspection unit.

COMPONENTS OF THE PTMS DATABASE

Each activity in the development process involves the creation or analysis of data. Ideally, relevant transit asset data should reside in a single database available to support PTMS planning activities. "Database" here means simply a collection of relevant data, not a computer program or combination of computer files. This section provides an overview of the structure and data needed to (1) identify an asset, its current condition, and function, (2) describe and quantify potential actions that can be taken to address deficiencies, (3) prioritize the needed actions, and (4) evaluate the alternatives.

Categories of Transit Asset Information

Useful asset information can be divided into two categories: fixed data and variable data. Fixed data are the attributes of the inventory that do not change over time, e.g., serial number, model number, and manufacturer's name. Variable data are attributes of the facility asset that change over time including, but not limited to, performance and condition. Fixed data change only when the inspection unit is replaced.

Fixed data collection can be a one-time activity to create a database describing the current inventory; such a database requires updating only as facility assets and elements are replaced or added. Collecting and maintaining relevant variable data requires the commitment of resources over time, but potentially yields more useful results. Cycles for updating asset condition and life-cycle information may vary depending on asset deterioration rate, criticality of the asset or its components, and planning and funding cycles for assets.

Master Inventory

A comprehensive inventory is the cornerstone of the PTMS process—you must know what you have before you can monitor it. This inventory includes fixed data describing the assets that comprise the state's public transit infrastructure. In PTMS, **asset** can be applied to a single item, such as a bus, or to a collection of items, such as a fleet of rail cars, as shown in Figure 3.

The asset or piece of the asset that is assigned a condition rating is the **inspection unit.** As with the asset, the level of detail for an inspection unit can vary greatly. For example, a maintenance facility can be broken into a number of assets—such as the roof, walls, and doors—each having a condition rating. The description of the inspection unit would include a physical breakdown structure (PBS) that allows a generic description of the inspection unit by 'discipline.system.subsystem.component.material/type'. Note the example of a maintenance facility and its components labeled as inspection units in Figure 4.

Another example (see Figure 5) of an inspection unit is an entire fleet of buses, which is considered one inspection unit

Asset 'Fleet of 345 Bombardier R62A Subway Cars' is composed of

Inspection Unit 'Bombardier R62A Subway Car number 1'
Inspection Unit 'Bombardier R62A Subway Car number 2'
etc.
Inspection Unit 'Bombardier R62A Subway Car number 345'

Figure 6. Vehicles within a fleet considered an inspection unit.

if the fleet of buses is going to be assigned a single condition rating.

An inspection unit can also consist of each vehicle within a fleet, such as a fleet of subway cars where each car (inspection unit) is assigned a condition rating as shown in Figure 6.

In each example, note that the complete asset is described by the sum of the inspection units. The level of detail can vary between inspection units; for example, exterior architectural components are shown separately, while the interior is a single inspection unit. Likewise, the entire mechanical and electrical disciplines in the maintenance facility or in a fleet of buses are considered single inspection units. Chapter 3 discusses issues to consider in establishing the level of detail for assets and inspection units.

Prioritizing the Assets

Developing a method for ranking inspection units by priority may assist stakeholders in considering transit asset investments. This section discusses an approach to prioritizing that is not required in developing a PTMS, but may be helpful. The basis of the approach is to include key information in the database concerning the importance of the asset to maintaining the safety and operations of the transit services. A three-level scale, as outlined below, provides the information that will allow extensive priority analysis when developing actions and strategies for maintaining or replacing assets.

At the **asset** level, data should indicate the function of the asset relative to transit service:

- Directly delivers service
- Supports assets directly delivering service
- Does not directly support delivery of service

For example, the asset "Fleet of 124 New Flyer 35-Foot Buses" would have a function priority of "directly delivers services."

At the **inspection unit** level, data should indicate the criticality of the inspection unit to operations:

- Failure of inspection unit severely affects safety or operations
- Failure of inspection unit affects operations
- Failure of inspection unit does not affect operations

For example, inspection unit "Fleet of 124 New Flyer 35-Foot Buses" would receive an inspection unit criticality rating "failure of the inspection unit severely affects safety or operations."

At the **final** level—the purpose of the proposed action—the reason for addressing the deficiency of an inspection unit should be noted:

- Safety
- Code
- Functional
- Operations efficiency
- Maintenance and repairs

The final level, purpose of potential action to the inspection unit, will be described more fully in this chapter in the section titled Potential Actions.

Condition Database

An assessment of the current condition of the inspection units comprising the assets is necessary to develop and analyze the needs of the transit assets. Assigning physical condition, functional, life-cycle, and descriptive ratings to an inspection unit provides the basis for developing actions necessary to maintain or improve the asset.

Condition Rating—The physical condition rating summarizes the current condition of the inspection unit with a single qualitative rating (see Figure 7).

Functional Rating—The functional rating describes the degree to which an inspection unit meets its designed function (see Figure 8). It is given here as an option to provide information on an asset's condition, efficiency, and reliability.

Life-cycle Rating—Assessing the expected remaining life for the inspection unit is a key element for the analysis described subsequently. Depending on the type of inspection unit and the skill level of the field inspector, life-cycle input can range from the year the inspection unit was installed or purchased to the expected remaining life, assuming proposed repair actions. Issues related to such life-cycle ratings are described in Chapter 3.

Descriptive Rating—In addition to these summary ratings, records of descriptive ratings help convey what the field inspector observed that led to the overall rating. Ideally, inspectors should be given lists of potential deficiencies expected for the inspection unit. The standards identify significant observable and measurable phenomena that can be used to predict the future condition of the asset and inspection units. For each observed event, the field inspector records the severity and the extent of the deficiency.

The deficiencies noted in the inspections provide objective data about the current condition of the inspection unit. Whereas the ratings are subjective measures of the overall condition of the inspection unit, a comprehensive list of deficiencies supports discussion on the appropriateness of the final rating assigned. Issues associated with who should be doing the assessment and developing of event lists are covered in Chapter 3 of these guidelines.

Rating	General Description
Bad	In sufficiently poor condition that continued use presents potential problems.
Poor	Requires frequent major repairs (less than 6 months between majors repairs).
Fair	Requires frequent minor repairs (less than 6 months between repairs) or infrequent major repairs (more than 6 months between major repairs).
Good	Elements are in good working order, requiring only nominal or infrequent minor repairs (greater than 6 months between minor repairs).
Excellent	Brand new, no major problems exits, only routine preventive maintenance.

Figure 7. Physical condition rating of an inspection unit.

Rating	General Description
Bad	The inspection unit has significant shortcomings in its ability to support its function.
Substandard	The inspection unit has shortcomings in its ability to support its intended function that are deemed by the operator to be below industry standards. These deficiencies impact the efficiency and/or effectiveness of the operation.
Adequate	The inspection unit has shortcomings in its ability to support its intended function, but these do not significantly impact transit performance.
Good	The inspection unit meets most reasonable requirements, but may have some less than optimum characteristics.
Excellent	The inspection unit exceeds the reasonable requirements based on its intended function.

Figure 8. Functional rating of an inspection unit.

Potential Actions

A potential action is defined as an action that may be taken to address specific inspection unit deficiencies. Potential actions describe treatments for the inspection units that may be necessary during the life of an asset to address condition or functional deficiencies. Types of potential actions include, but are not limited to, the following:

- Maintenance
- Repair
- Refurbishment
- Rehabilitation
- Overhaul
- Replacement
- No action

The importance of the potential action to the inspection unit is the final piece of the three-part PTMS prioritization scheme. The following ranked categories are used to determine the importance of a potential action:

- Structural
- Safety
- Security
- Regulation/code
- Operations/maintenance savings
- Operations reliability
- Cost avoidance
- Betterment
- Patron service
- Aesthetics
- Community relations

Qualitative or quantitative consequences of taking a variety of potential actions can feed the alternatives evaluation process. One such measure is estimating the remaining life given the

Example #1 **_Asset—Maintenance Facility_**	
Inspection Unit:	Architectural.Exterior.Roof.Asphalt
Year Inspected:	1995
Functional Rating:	Good
Condition Rating:	Poor
Standard Life:	20 Years
Remaining Useful Life:	5 Years
Potential Action #1:	Refurbishment of the roof
Importance:	Operations and maintenance savings
Consequence:	Estimated useful life extended to 10 years
Potential Action #2:	Replacement of roof in kind
Importance:	Operations and maintenance savings
Consequence:	Estimated useful life extended 20 years

Figure 9. Estimating remaining life of an inspection unit (Example #1).

Example #2 **_Asset—Fleet of 124 New Flyer 35-Foot Buses_**	
Inspection Unit:	New Flyer 35-Foot Bus #7
Year Inspected:	1995
Functional Rating:	Adequate
Condition Rating:	Poor
Standard Life:	12 Years
Remaining Useful Life:	6 Years
Potential Action #1:	Perform bus overhaul at the recommended scheduled interval (once every 2 years)
Importance:	Operations reliability
Consequence:	Ensures the expected standard life is achieved
Potential Action #2:	Increase the time interval between scheduled overhauls (once every 3 years)
Importance:	Operations reliability
Consequence:	Asset will not achieve the expected standard life

Figure 10. Estimating remaining life of an inspection unit (Example #2).

action. The following two examples illustrate the data that would be included at this point (see Figures 9 and 10).

Engineering Data

These examples illustrate how a PTMS analysis can benefit from an underlying engineering database that includes unit costs for asset replacement, inspection-unit life cycles, and unit costs for inspection-unit potential actions.

An engineering database can be applied across many assets and inspection units. The database can be established at the same time as the PBS (described in Chapter 3), which defines an asset or inspection unit by "discipline.system.component.material/type," so that the most appropriate unit cost structure can be planned. In addition, a hierarchical system of many different costs can be established if appropriate. A fully automated PTMS could refer to the database by using a set of hierarchical rules to select the most applicable engineering data. Using the examples presented in Figures 9 and 10, unit costs for the potential actions can be added to the database as follows (see Figures 11 and 12).

Evaluation and Analysis

The following paragraphs describe the types of analysis that could be performed using a PTMS process.

Example #1 ***Asset—Maintenance Facility***	
Potential Action #1:	Refurbishment of the roof
Unit Cost:	**$2.00/sq ft of roof (refurbishment cost)**
Potential Action #2:	Replacement of roof in kind
Unit Cost:	**$9.00/sq ft of roof (replacement cost)**

Figure 11. Unit costs for potential actions (Example #1).

Example #2 ***Asset—Fleet of 124 New Flyer 35-Foot Buses***	
Potential Action #1:	Perform bus overhaul at the recommended scheduled interval (once every 2 years)
Unit Cost:	**$10,000/bus per overhaul**
Potential Action #2:	Increase the time interval between scheduled overhauls to once every 3 years
Unit Cost:	**$12,000/bus per overhaul (the increased unit cost is due to the additional wear and tear)**

Figure 12. Unit costs for potential actions (Example #2).

Asset—Maintenance Facility	
Inspection Unit:	Architectural.Exterior.Roof.Asphalt
Year Inspected:	1995
Functional Rating:	Good
Condition Rating:	Poor
Standard Life:	20 Years
Remaining Useful Life:	5 Years
Potential Action #1:	Refurbishment of the roof
Importance:	*Operations and maintenance savings*
Consequence:	*Estimated useful life extended to 10 years*
Unit Cost:	*$2.00/sq ft of roof (refurbishment cost)*
Total Quantity:	**30,000 sq ft**
Total Cost:	**$60,000**

Figure 13. Unconstrained requirements analysis for the roof example.

Unconstrained Requirements — The unconstrained requirements analysis ensures that each inventory asset receives an independent evaluation of the cost and timing of required potential actions to address current deficiencies. The results can be rolled up to an appropriate level of detail, but the initial numbers should be created at the inspection level. The unconstrained needs report considers all actions that should be performed to meet current requirements; it is a full statement of the current needs, even if the needs exceed the available funds of the agency or state. The goal of the unconstrained needs report is to identify the scope of the problem, i.e., the actual needs of the transit infrastructure. Figure 13 shows an example of the unconstrained requirements analysis for the roof example. In this figure, the total cost or unconstrained need to refurbish the roof is $60,000 based on the unit cost of refurbishing 30,000 sq ft of roof at $2.00 per sq ft.

Forecasted Life-cycle Replacement Requirements—This analysis uses a life-cycle replacement forecast model to project requirements for inspection units. The model can forecast 5, 10, or more years depending on the planning horizon. The model projects multiple occurrences of actions for items where current life-cycle replacement forecasts and future standard life cycles fall within the planning horizon. The purpose of this analysis is to identify the future large-

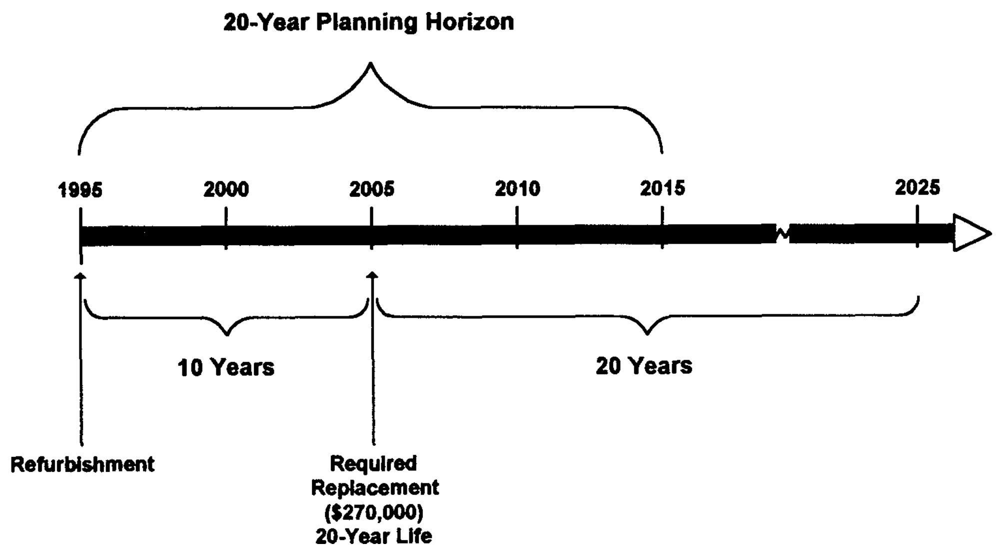

Figure 14. Twenty-year analysis of life-cycle replacement requirements for the roof (example).

scale expenditures in order to give the funding authorities adequate time to plan for the expenses. A 20-year analysis of life-cycle replacement requirements for the roof follows (see Figure 14).

Given that the roof has a 20-year standard life and the refurbishment of the roof leads to an estimated remaining life of 10 years, a life-cycle replacement cost can be calculated.

The forecasted cost for **life-cycle replacement** is the lifecycle replacement cost calculated at the cost per unit for action multiplied by the inspection unit quantity

The unit cost to replace a roof in kind is
($9.00/sq ft of roof)
× (a total quantity of 30,000 sq ft)
= $270,000

The first **life-cycle replacement year** based on *potential* action "Refurbish Roof" is as follows:

(analysis year) + [estimated remaining life
– (analysis year – inspection year)]
+ (estimated remaining life of 10 years)
– (analysis year 1995 – inspection year 1995)
= 2005

The second **life-cycle replacement year** based on *potential* action "Replace Roof in Kind" is as follows:

(analysis year is 1995) + (potential action's (i.e., replace roof in kind) standard remaining life 20 years)
– [(analysis year is 1995)
– (replacement year 2005)]
= 2025

Assuming the PTMS covers a 20-year analytical period, the second life-cycle replacement is outside the analytical window of 20 years.

In the example of a New Flyer 35-Ft bus (Bus #7), the following data are known:

- The standard life is 12 years
- The bus is overhauled at recommended intervals (once every 2 years)
- Remaining useful life is 6 years
- The replacement cost per bus is $230,000

The life-cycle replacement years based on this information are as follows:

- 1995 + 6 years = 2001—first replacement cycle
- 2001 + 12 years = 2013—second replacement cycle
- 2013 + 12 years = 2025—third replacement cycle

Because the planning horizon is 20 years or until the year 2015, Bus # 7 will go through two replacement cycles during the next 20 years.

Prioritized Needs—Because the unconstrained needs and forecasted life-cycle replacement needs in most cases exceed available funds, the prioritized needs report attempts to assist planners in determining what potential actions should be addressed first. The three-level system considers the priority of the asset to transit service delivery, the criticality of the inspection unit to the asset, and the importance of the potential action to the inspection unit. The goal is not to use an algorithm to make difficult decisions, but rather to allow the total budget to be filtered to consider the amounts required at each priority level. In Table 1, the priority rating for the example roof is compared to that for a vehicle.

Decisions regarding allocation of funds must consider constraints as well as organizational goals and objectives; however, decision makers can make informed decisions on the basis of the information provided. A priority analysis can consider that the roof and the subway car are equally critical and the potential actions for either asset are an "operation/maintenance savings." Yet the subway car directly supports transit service delivery, while the maintenance facility supports assets that directly deliver the service.

TABLE 1 Comparison of priority ratings (roof vs. vehicle)

Item	Roof	Vehicle
Asset	Maintenance Facility	Fleet of 345 Bombardier R62 Subway Cars
Function	Supports asset directly delivering service	Directly delivers service
Inspection Unit	Architectural.Exterior.Roof.Asphalt	Bombardier R62A Subway Car #1
Criticality	Failure of inspection unit severely affects safety or operation	Failure of inspection unit severely affects safety or operation
Potential Action	Refurbish roof	50,000-mile overhaul
Importance	Operation/maintenance savings	Operation/maintenance savings

Evaluate Alternatives—The analysis with the highest degree of sophistication evaluates the long-term effects of choosing one alternative instead of another. For this type of analysis, life-cycle projection models should be created. After potential actions have been assigned to inspection units, several steps need to be taken. These analysis steps are cyclical and constantly being reviewed to optimize the outcome according to the model specified. Each strategy has life, cost, objective, and funding constraints that must be considered when determining which strategy best meets the planners' objectives.

Two strategies for the roof example are shown in Figure 15. From the asset information collected on the roof, it is possible to consider the impacts of different actions or strategies to address the roof's deficiencies by using life-cycle projection models. In this example, assuming an escalation rate for potential actions of 5 percent per year, a discount rate of 6 percent per year, and a 20-year time line, the impacts of adopting a strategy of taking no action to improve the roof versus refurbishing the roof can be analyzed (see Table 2).

The life-cycle replacement year for each action should be determined as described previously in this section. The following is a step-by-step analysis of two strategies proposed for the roof. The first strategy (Strategy #1) is to take no action for the roof now and to replace the roof when the life cycle ends. The second strategy (Strategy #2) is to refurbish the roof now to extend the useful life and replace the roof when the life cycle ends. The example compares both strategies on the basis of present value for all costs over a period of 20 years.

Strategy #1 has a total present value cost of $257,502 whereas Strategy #2 "Refurbish Roof" has a total present value cost of $305,583. Therefore, Strategy #1 is more economical than Strategy #2.

In evaluating the two different life-cycle strategies for the bus (New Flyer 35-Ft Bus), a step-by-step analysis similar to the roof example should be undertaken. The first strategy (Strategy #1) would involve performing overhauls at recommended intervals (once every 2 years). Performing overhauls at the recommended intervals ensures that the full potential life of the asset is realized (12 years); because the remaining useful life of the bus is currently 6 years, the bus would require replacement in 2001 and 2013.

The second strategy (Strategy #2) would involve increasing the interval between overhauls from once every 2 years to once every 3 years. This reduces the standard life of the bus to 6 years and, in this particular example, reduces the remaining useful life of the bus to 3 years. Under this strategy, the bus would require replacement in the years 1998, 2004, and 2010.

Evaluating the two strategies on a present worth basis over 20 years yields the following results (see Table 3):

As shown, the present value cost of Strategy #1 is $485,288, whereas Strategy #2 has a present value cost of $676,427. This analysis indicates that it is not cost-effective over a 20-year planning period to increase the overhaul time (Strategy #2) and that Strategy #1 should be undertaken.

Each of these analyses are data driven, in that the level of data needed is directly related to the level of detail required for the reports and the evaluation processes to be followed.

Output and Reporting

Once the specific elements of the PTMS are developed, the key to its successful use will be presenting the information in a simple, easily comprehensible format. The format must consider the different end users of the system and why those users need the information. The reporting requirements of each state should reflect that state's need for information management. Two levels of reporting schemes are suggested—executive level and working level. In addition to output associated with the analyses already described in this section, the following standard reports that could be generated in the PTMS process include:

- Asset inventory, including inspection units

Asset—Maintenance Facility	
Inspection Unit:	Architectural.Exterior.Roof.Asphalt
Year Inspected:	1995
Functional Rating:	Good
Condition Rating:	Poor
Standard Life:	20 Years
Remaining Useful Life:	5 Years
Strategy #1:	Do not refurbish the roof now Replace the roof after the end of its useful life (5 years) with a new roof
Importance:	Operations and maintenance savings
Consequence:	Estimated useful life extended to 20 years
Unit Cost:	$9.00/sq ft of roof (replacement cost)
Total Quantity:	30,000 sq ft
Total Cost:	$270,000
New Life-Cycle Replacement Year:	**2000**
Life-Cycle Replacement Cost:	**$270,000**
Strategy #2:	Refurbish the roof now Replace the roof after the end of its useful life (10 years) with a new roof
Importance:	Operations and maintenance savings
Consequence:	Estimated useful life extended to 10 years
Unit Cost:	$2.00/sq ft of roof (replacement cost)
Total Quantity:	30,000 sq ft
Total Cost:	$60,000
New Life-Cycle Replacement Year:	**2005**
Life-Cycle Replacement Cost:	**$270,000**

Figure 15. Two strategies for roof repair.

- Current condition reports
- Potential action reports

Another output consideration is the interface of the PTMS with the CMS and the IMS. The formats for presenting information in a PTMS must also consider such basic elements as whether the output of the information is on paper or in a computer and the comparability of the information in a PTMS to a CMS or an IMS.

Feedback and Updating a PTMS

To remain relevant, a PTMS needs periodic input addressing both the PTMS assets and the PTMS process itself. Updates to the asset data should include the following:

- Inventory for new and retired assets
- Condition data for new assets
- Periodic reinspection of assets already in the inventory
- Potential actions to address new deficiencies identified
- Unit-cost and life-cycle information to address new deficiencies
- Review of cost factors for labor, equipment, and material
- Record of actions taken and strategies pursued to address previously identified requirements

To fine-tune the PTMS process, participants and stakeholders should be questioned periodically about the PTMS—its effectiveness in providing the information used for state and regional planning processes and as a vehicle for articulating the public transit capital needs of a state or region.

TABLE 2 No-action strategy versus refurbish-now strategy for the roof example

Item	Year	Strategy #1 (no action)	Strategy #2 (refurbish roof now)
Refurbishment	1995	N/A	$60,000
Replacement	2000	Escalated cost at the replacement year (cost)x(1+escalation rate)$^{\#\ years}$ = [\$270,000x(1+0.05)^5] = \$344,596 Present value of cost = (Future cost)/(1+discound rate)$^{\#\ years}$ = [344,596/(1+0.06)^5] = \$257,502	N/A
Replacement	2005	N/A	Escalated cost at the replacement year = (cost)x(1+escalation rate)$^{\#\ years}$ = [\$270,000x(1+0.05)^{10}] = \$439,802 Present value of cost = (future cost/(1+discount rate)$^{\#\ years}$ = [\$439,802/(1+0.06)^{10}] = \$245,583
Total Present Value Cost		**$257,502**	**$305,583**

TABLE 3 Evaluating Strategy #1 and Strategy #2 for the New Flyer 35-ft bus

Item	Year	Strategy #1	Strategy #2
Overhaul	1995	$10,000	$10,000 (The initial overhaul for both strategies are equivalent)
Overhaul	1997	\$10,000 (1.05)^2 = 11,025 $\frac{11,025}{(1.06)^2}$ = \$9,812	N/A
Replacement	1998	N/A	230,000 (1.05)^3 = 266,254 $\frac{266,254}{(1.06)^3}$ = \$223,552
Overhaul	1998	10,000 (1.05)^4 = 12,155 $\frac{12,155}{(1.06)^4}$ = \$9,628	N/A
Replacement	2001	230,000 (1.05)^6 = 308,222 $\frac{308,222}{(1.06)^6}$ = \$217,284	N/A

TABLE 3 Evaluating Strategy #1 and Strategy #2 for the New Flyer 35-ft bus (continued)

Item	Year	Strategy #1	Strategy #2
Overhaul	2001	N/A	$12{,}000\,(1.05)^6 = 16{,}081$ $\frac{16{,}081}{(1.06)^6} = \$11{,}337$
Overhaul	2003	$10{,}000\,(1.05)^8 = 14{,}775$ $\frac{14{,}755}{(1.06)^8} = \$9{,}270$	N/A
Replacement	2004	N/A	$230{,}000\,(1.05)^9 =$ 356,805 $\frac{356{,}805}{(1.06)^9} = \$211{,}193$
Overhaul	2005	$10{,}000\,(1.05)^{10} = 16{,}289$ $\frac{16{,}289}{(1.06)^{10}} = \$9{,}096$	N/A
Overhaul	2007	$10{,}000\,(1.05)^{12} = 17{,}959$ $\frac{17{,}959}{(1.06)^{12}} = \$8{,}925$	$12{,}000\,(1.05)^{12} =$ 21,550 $\frac{21{,}550}{(1.06)^{12}} = \$10{,}710$
Overhaul	2009	$10{,}000\,(1.05)^{14} = 19{,}799$ $\frac{19{,}799}{(1.06)^{14}} = \$8{,}757$	N/A
Replacement	2010	N/A	$230{,}000\,(1.05)^{15}$ 478,153 $\frac{478{,}153}{(1.06)^{15}} = \$199{,}517$
Overhaul	2011	$10{,}000\,(1.05)^{16} = 21{,}829$ $\frac{21{,}829}{(1.06)^{16}} = \$8{,}593$	N/A
Overhaul	2013	N/A	$12{,}000\,(1.05)^{18} =$ 28,879 $\frac{28{,}879}{(1.06)^{18}} = \$10{,}118$
Replacement	2013	$230{,}000\,(1.05)^{18} = 553{,}522$ $\frac{553{,}522}{(1.06)^{18}} = \$193{,}923$	N/A
Total Present Value		**$485,288**	**$676,427**

CHAPTER 3

IMPLEMENTING A PTMS

OVERVIEW

This chapter defines issues related to successfully implementing a PTMS and describes common implementation steps. To be successful, the PTMS process needs strong ownership. The owner should be the primary beneficiary of the system capabilities and should have responsibility for implementing the process to meet the PTMS goals and objectives. In addition, a successful PTMS must be sustainable. To accomplish this, it must have the following attributes:

- Reflective of transit assets—is capable of describing transit assets using consistent formats
- Responsive to input—is a flexible process that considers priorities that are changing in order to produce viable alternatives
- Useful—produces analyses and reports that support statewide and MPO planning and that helps people do their jobs
- User-friendly—is accepted into organizations of all sizes
- Financially feasible—includes only the data required to support the decision-making process

These guidelines have been developed to assist in implementing the PTMS process consistent with the success factors previously listed. Discussion is divided into four topics:

- Establishing a PTMS organization
- Developing a state-specific PTMS methodology
- Implementing the PTMS planning cycle
- Potential enhancements

ESTABLISHING A PTMS ORGANIZATION

Although organizational issues are as varied as the states, there are two fundamental roles required if a PTMS is to be successfully developed and implemented:

Champions—The champions must establish the PTMS's mission, commit necessary human and financial resources, and endow the resources with appropriate authority to carry out the established mission.

Owners—The owners must develop goals and objectives to meet the mission and make the system their own.

The next critical consideration is stakeholder participation in the PTMS process. States have the mandate to create a PTMS, but the assets are owned, operated, and maintained by

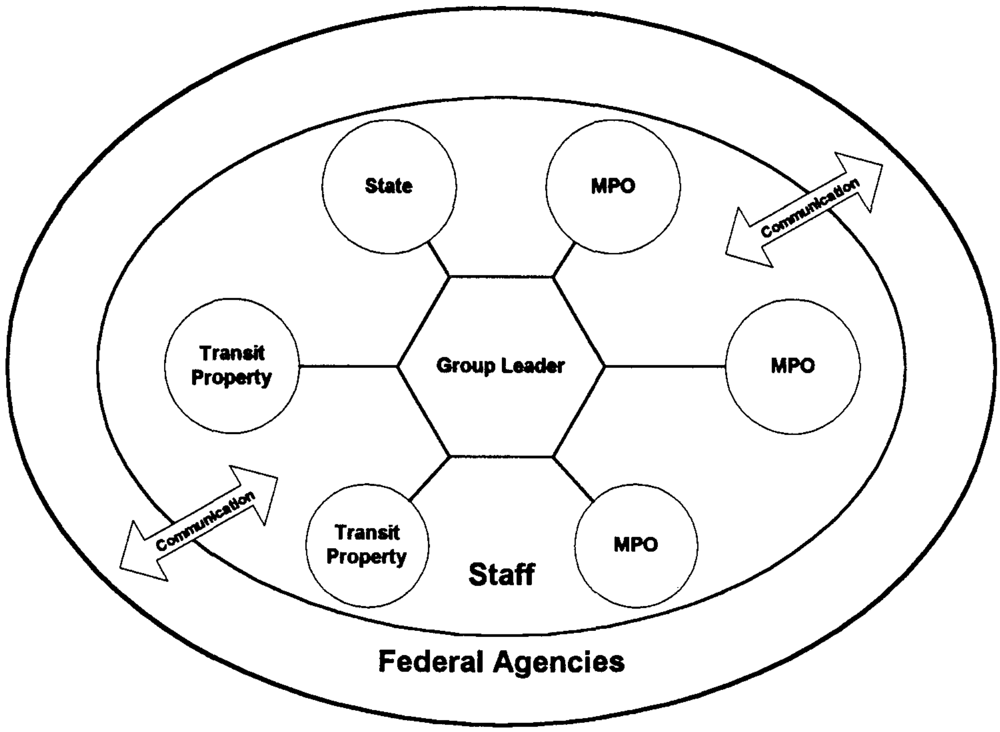

Figure 16. PTMS participants.

one or more transit agencies. The MPOs prepare transportation improvement plans addressing regional transportation objectives and needs. The concerns of these diverse stakeholders can be accommodated by well-planned participation in the PTMS process. Figure 16 depicts the range of players in a PTMS organization.

As recent FTA general guidance on the PTMS pointed out, states—in cooperation with MPOs and FTA recipients and subrecipients—must develop a PTMS that best accommodates the needs and institutional relationships of all affected agencies. The affected agencies should mutually and cooperatively determine the roles and responsibilities of the agencies in the development, implementation, and monitoring of the system as well as the information to be collected.

Implementation teams in each state will be designing the process, using it to create the first cycle of PTMS analysis, providing feedback for process fine-tuning and enhancement, establishing long-term procedures, and assigning staff to perpetuate the PTMS cycle. The initial implementation is an exciting period; it is a little like designing and building a bicycle while riding it. Staffing needs will shift as the early emphasis on designing the PTMS moves toward applying the completed process. Future plans for organizational changes should consider this need for shifting emphasis, and staff should fully participate for a smooth transition.

It is also important to organize and plan the PTMS from its earliest stages in cooperation with the development and implementation of other management systems, particularly CMS and IMS, because both these management systems will include transit performance information.

The next section describes in detail the steps to be taken in developing a state-specific PTMS methodology.

DEVELOPING A STATE-SPECIFIC PTMS METHODOLOGY

Once a PTMS team has been established, given a mission, and authorized to make a PTMS work, the first order of business should be to define what the PTMS needs to produce. In interviews with states, MPOs, and transit agencies, it became clear that there are many views of what a PTMS is and what it should accomplish. Although the enacting legislation gives broad definitions of the requirements, it allows each state to define its own PTMS process.

TABLE 4 Standard classification codes of transit activities by mode

Mode Code	Description
AG	Automated Guideway
CC	Cable Car
CR	Commuter Rail
DR	Demand Response
FB	Ferry Boat
IP	Inclined Plane
JT	Jitney
SC	Street Car or Light Rail
MB	Motorbus
RR	Rapid Rail or Heavy Rail
TB	Trolleybus
TR	Aerial Tramway
VP	Vanpool
OR	Other

Rail Rolling Stock	**Locomotive** **-diesel** **-electric** **-alternative fuel** **-dual mode** **Self-Propelled** **-electric** **-diesel** **-dual mode** **Coaches** **Work Equipment** **Track Geometric Car**

Figure 17. Asset types for rail rolling stock.

Set the Direction

Because the entire PTMS process focuses on assets, the first steps in establishing a methodology involve the definition of an asset within the PTMS context. These initial steps include the following:

- Define the range of modes of transportation in the state
- Define assets supporting the modes
- Group assets based on similarities
- Physical breakdown structure
- Determine data needs for all assets
- Evaluate existing data
- Define additional data to be collected

Each of these steps is described below.

Define Range of Modes of Transportation in the State— FTA Section 15 reporting requirements provide a high-level classification of transit activities by mode in the United States. These definitions (see Table 4) are standard in the industry and provide a potential cross reference from the PTMS to Section 15 Report Tables.

Define Assets Supporting Modes—Within each mode and among modes, numerous physical assets are necessary to support transit service delivery. Appendix A lists sample asset types necessary to support one or more modes of transit. "Asset" is a flexible concept. In PTMS, the asset is one or more items of that particular asset type. The level of information to be used for each asset will be determined by the level of detail stakeholders expect to receive from the PTMS to assist them in making investment decisions. It may not be necessary to include each asset type.

For example, Figure 17 shows the assets types within the commuter rail mode, of the asset category "Rail Rolling Stock."

Group Assets Based on Similarities—Appendix A presents categories of assets that have common physical characteristics and that can be described and assessed using common definitions and standards. These assets may also include a number of systems that are common to many types of assets. An example of these common systems is shown in Figure 18. Appendix B provides a more complete list of these systems.

Assets in a category will not necessarily contain all the systems listed in Appendix B; however, any asset in the category should be able to be completely described by this type of system analysis. The purpose of the subdivision is to allow for the description and assessment of the pieces of any asset. In a PTMS, as described previously, the asset or piece of an asset that is evaluated is called the inspection unit. Like the asset itself, the level of detail used to evaluate the asset can vary greatly. The whole asset could be rated, the major systems, or even components of the major systems. Again, it will depend on the level of detail that the PTMS is designed to produce.

Physical Breakdown Structure—A PBS approach is highly recommended to subdivide the asset for easy assessment and cost estimation (see Figure 19). In simple terms, developing a PBS means breaking the equipment or facility into smaller pieces. Because a PBS describes the physical characteristics of an item, it does not have to be unique. For example, the power unit of an RTS-08 bus purchased by the New York City Transit

Rail Rolling Stock	**Propulsion Unit**
	Passenger Cabin
	Mechanical and Electromechanical Equipment
	Electrical
	Communications

Figure 18. Major systems common to different asset types.

Authority can have the same PBS as the power unit for the same type of bus purchased by the Capital District Authority in Albany. The subject power units cost the same, have the same standard life expectancy, and will likely go through similar repair, rehabilitation, and replacement life cycles.

Figure 19 illustrates a PBS for the asset category "buildings." Starting at the highest level, each additional level contains more detail. The convention used in these guidelines is to write a PBS "discipline.system.component.material." For example, the PBS highlighted in the diagram would be written "architectural.exterior.exterior.wall.concrete." The PBS becomes the primary key into unit-cost and standard-life databases. An example of a PBS for a vehicle is shown in Figure 20.

The PBS in Figure 20 would be written "Bus #1.PropulsionUnit.PowerUnit.Diesel." With data on common PBS assets (such as the power units for the RTS-08 buses), statewide conditions and life-cycle trends can be analyzed.

Determine Data Needs for All Assets—With the assets grouped into categories of similar characteristics, it is necessary to determine the level of data to be collected for the assets. There are two key issues that must be considered in this decision. First, the information required to meet the PTMS needs at the state level will be rolled-up into a summary format. This summary will be created from objective data describing each of the assets, which can be as diverse as buildings or buses. The data underlying the summary must be (1) flexible enough to record meaningful attributes or characteristics for each specific asset class if desired and (2) structured enough to accommodate the roll-up summaries. Second, a successful PTMS must have the ability to accommodate various levels of detail—determined by the stakeholders—regarding the condition of the assets. Some states and properties will only have overview asset information at the beginning of the PTMS process, while others may have detailed asset information.

The PTMS structure outlined in this section can use data

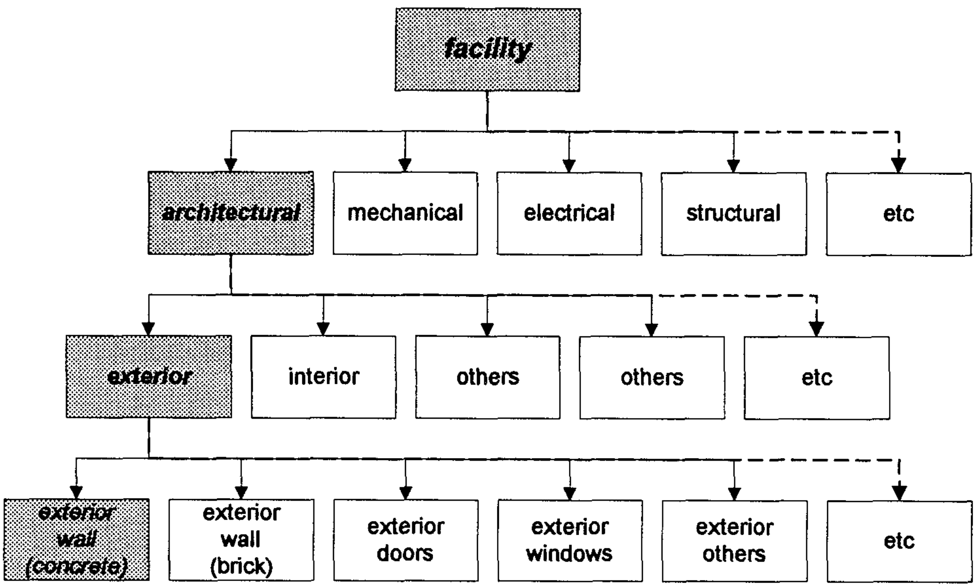

Figure 19. PBS for a facility asset.

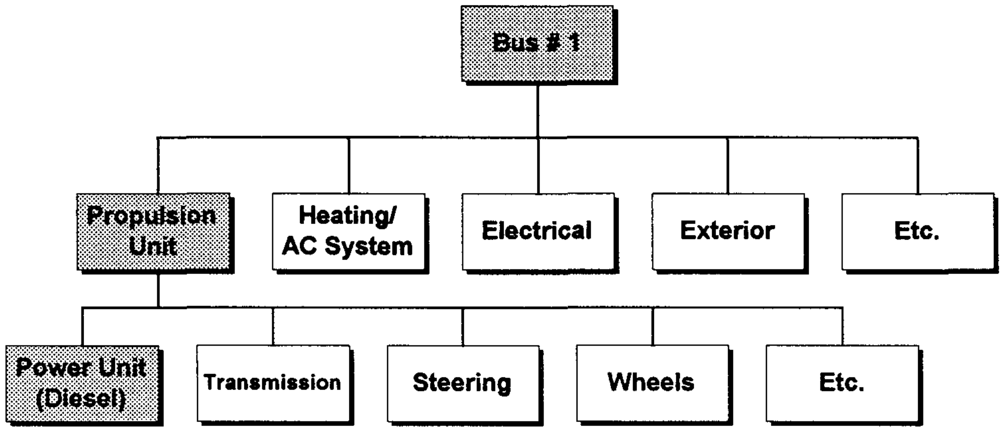

Figure 20. PBS example for a vehicular asset.

TABLE 5 A sample of a detailed inventory data list

Inventory Data	Example
Owner	New Jersey Transit
Operator	New Jersey Transit
Mode(s) Supported	Bus
Asset Category	Vehicles (Rubber Tired)
Use Type	Revenue Service
Relation to Service	Directly delivers service
Year Purchased	
Year Rehabilitated	1992
Manufacturer	Transportation Manufacturers Corporation (RTS)
Model Number	RTS-08
Serial Number	T 80606
Capacity	47 passengers
Design Life	450,000 miles; 15 years
Quantity	1
Asset Name	Transit Bus, 40-Foot
Location	Oradell Facility, Newark, NJ

TABLE 6 A sample of inventory data for an inspection unit

Inventory Data	Example
Associated Asset	Transit Bus, 40-Foot
IU Description	Power Unit
IU Purpose	Power Bus
PBS	bus 1. propulsion unit. power unit. diesel
Importance To Asset	Failure of inspection unit severely affects safety or operations
Year Purchased/ Constructed	May 1990
Manufacturer	Detroit Diesel
Model Number	Series 50V
Serial Number	8V83258631
Capacity	250 HP
Quantity	1
Standard Life	215,000 miles
Location	N/A

TABLE 7 Bus power-unit condition ratings

Condition Data	Example
Associated Inspection Unit	Power Unit
Inspection Date	October 23, 1994
Inspector	JVD
Overall Functional Rating	Good
Overall Condition Rating	Fair
Estimated Life Remaining With Action	220,000 miles
Estimated Life Remaining Without Action	55,000 miles

having a minimum level of detail, while still allowing the use of highly detailed data if available or desired. This section will describe two types of data: inventory and condition. The inventory addresses the asset and systems comprising the asset. Condition data are the record of deficiencies, required repairs, and life-cycle expectations for each asset.

Table 5 is a sample of a detailed inventory data list to be collected for the assets. The element or elements of the asset that are assigned condition and functional ratings are called the inspection units (as explained in Chapter 3). The inspection unit (IU) may be at varying levels of detail, as broad as the asset level (e.g., a bus) or as detailed as the component level (e.g., a bus power unit). Table 6 is a sample list of inventory data for an inspection unit that is part of the bus in the previous example.

The condition of each inspection unit can be described by condition ratings and deficiency descriptions as outlined in Chapter 2. Table 7 and Table 8 show bus power-unit condition ratings and deficiency descriptions, respectively.

Evaluate Existing Data—Having determined the desired level of detail of asset data to be collected, the next issue is assembling the information. One potential source for inventory data is FTA Section 15 Reports; in addition, the PTMS teams should research existing historical data at the state and transit agency level. Potential sources include the following:

- Asset management or real property inventories
- Maintenance inventories
- Maintenance and repair history
- As-built drawings and specifications
- Operations and maintenance manuals
- Reports from ongoing inspection programs

The PTMS plans prepared by each state, Washington, DC, and Puerto Rico are also of potential use to the other states. A

TABLE 8 Bus power-unit deficiency descriptions

Deficiency	Example
Associated Condition Inspection	JVD, October 23, 1994
Deficiency Description	Pistons Worn
Severity	Moderate
Extent of Deficiency	30%
Probable Cause of Deficiency	Normal Wear From Use
Location of Deficiency	Pistons
Urgency of Deficiency	Normal Overhaul Cycle

list of all documents reviewed by the project team, including information generated by the states, is included in Appendix C.

The preferred method for ascertaining data requirements is to determine the reporting needs, develop analysis capable of producing the required output, and determine the data required to support the analysis. An alternate approach is to examine available data and determine what can be done with it.

Define Additional Data to Be Collected—Data necessary for a PTMS that are not available from existing sources will need to be collected. As mentioned in Chapter 2, useful asset information can be divided into two categories: fixed data and variable data. Fixed data are the inventory attributes that do not change over time; variable data are attributes of the facility asset that change over time including, but not limited to, condition. Collection of fixed data can be a one-time activity to create a database that describes the current inventory and requires minimum updating as facility assets and elements are replaced, added, or retired. Collecting and maintaining relevant variable data requires the commitment of resources over time.

Establish a Data Collection System

Determine Inventory Level of Detail—The following issues should be considered when determining the level of detail to be recorded for the assets and inspection units:

- The ISTEA legislation mandates that the PTMS be a comprehensive base inventory of all transit assets. Coverage of all assets is more important than the level at which ratings are assigned.
- Because the PTMS is cyclical, there will always be opportunities to collect data at a more focused level in future cycles.
- There is no reason for all assets in a PTMS to be inspected at the same level of detail; the structure can accept many levels.
- The levels of detail used in current inspection programs should provide clues on the appropriate levels of detail for the PTMS. Current inspections should define the most focused level that might be appropriate; however, the PTMS may function with less detailed information.
- Assets not currently inventoried or inspected have not been recognized as worthy of detailed management—probably with good reason. Consider a very broad level of detail for these assets.
- Many PTMS reports will be rolled-up summaries for the asset categories, modes, or property totals. The level of detail for the underlying data will be viewed primarily in asset-level reporting.

Develop Inspection Standards—To remove the problem of inconsistent and misinterpreted transit asset inspection data, a "standard" methodology may be desired for the assessment of the current condition of all transit assets within a PTMS, whether statewide or regional in scope. Standardized inspections ensure that each agency will receive a fair analysis of its capital assets and their condition. In addition, consistent, reliable field-inspection data form convincing justification for fund requests. The transit operators would be the information providers. The following section summarizes the development of appropriate standards to address a broad range of transit assets.

For a detailed PTMS, the inspection standards could include the following for each portion of the PBS:

1. A description of the element to be inspected
2. An identification of associated assembly or standard components
3. An identification of probable failure points
4. A list of deficiencies that may affect the specific condition of the PBS
5. A list of objective measures that can be used to establish current condition or predict requirements
6. Illustrated examples of sample elements assigned to each condition rating on the scale

Some of the assets to be analyzed in the PTMS process will be covered by existing standards. Federal- and state-level standards should be included in the PTMS when possible. Standards developed at individual agencies should be compared to other agency standards; PTMS should promote the development of combined standards using the best approach from various agencies. Additional potential sources of standards data include manufacturers, industry groups, material-testing organizations, and trade groups. A list of potential sources for standards is included in Appendix D.

Develop Inspection Methods

Although there have been strides in technology that have had significant impact on physical asset inspections, the mainstay of these inspections continues to be visual examinations and review and evaluation of historical records of the various systems comprising the asset.[5] The inspection methods promoted in these guidelines rely on this foundation. Development of PTMS data collection methods built on visual assessments involves the following steps:

1. Defining inspection methods
2. Establishing condition-rating criteria
3. Determining inspection timing

Determining who will collect requisite condition data affects the data collection methods. Significant to developing a PTMS

[5] "Condition Assessment Survey (CAS) Program Inspection Methods Manual," U.S. Department of Energy, 1992.

methodology is the fact that states will seek most PTMS data from transit agencies. Close coordination among these entities is necessary to ensure that the data needs for the PTMS match the ability of the agencies to deliver them and that the methods and standards match the skills of the inventory or assessment staff.

There are two approaches to assess who is best suited for the data collection task. Each approach has advocates, and both are appropriate for certain methodologies. The first assessment approach considers the data collection process as a standardized tool for more efficient recording of the subjective judgments of highly skilled assessors. Processes developed with this approach in mind lead the data collector through scripts or checklists and demand data in preestablishing formats. The underlying assumption, however, is that the qualitative ratings of skilled personnel are the best indication of component condition. Adherents to the other approach believe that minimally skilled inventory workers can be led through scripts prompting them to collect objective information that can be manipulated through algorithms.

Systematic inventory and assessment methods and data collection tools have been developed to accommodate both points of view. When making a determination of the most appropriate survey method, keep in mind the survey's purpose and the staffing resources. The skill level of the inventory assessment worker also affects the development of the data collection process because the lower the skill level of the inventory assessment worker, the easier the data collection process should be to learn and implement.

Define Field Collection Methods—Inspection methods can be considered in a four-level hierarchy progressing in level of detail:

- Standard inspection methods
- Nonstandard inspection methods
- Standard testing methods
- Nonstandard testing methods

These guidelines focus on the development of standard inspection methods because base-level PTMS data can be collected using only standard methods. These standard inspection methods identify typical inspection methods that enable field inspectors to identify the condition of an asset and the systems comprising the asset. Again, depending on the skill level of the inspector, standard inspection methods could include the following for each PBS:

- *List of Appropriate System Observations:* In addition to inspecting and analyzing the inspection units that comprise the asset, the inspector should perform the following actions as part of an overall system evaluation:

  - Evaluate the functional adequacy of the inspection unit
  - Evaluate the overall physical condition of the inspection unit
  - Evaluate and estimate the inspection unit's remaining useful life as observed
  - Recommend potential actions to address observed deficiencies
  - Evaluate and estimate the inspection unit's remaining useful life if the recommended potential actions are accomplished

- *Inspection Guide Sheets:* Guide sheets can be developed that provide appropriate inspection instructions for the inventory assessment worker and could include the following:

  - Special instructions
  - List of concurrent actions
  - Description of standard inspection actions
  - List of physical deficiencies related to the inspection standards

- *Inspection Forms:* The inspection form provides a standard format for collecting inventory and condition data.

Establish Condition-Rating Criteria—A standard condition-rating scale should be established for all PTMS inspections. The scale must have sufficient flexibility to address diverse assets and allow condition descriptions of individual elements and large groups of assets. Once significant deficiencies are recorded, the overall condition of the inspection unit will be characterized by two ratings—a physical condition rating and a functional rating. Separate scales allow differentiation of the potential actions. Suggested scales were presented in Chapter 2.

Determine Timing of Inspections—Inspection cycles for the different assets within a PTMS may vary and should be developed for each asset. Considerations in determining the inspection cycles should include the following:

- Role of the asset in the operation
- Coverage of the asset by other inspection programs
- Deterioration rate of the particular asset type
- Life cycle of the asset

Individual inspection units comprising an asset, such as individual subway cars or buses of the same model and year, can be inspected on differing cycles considering the following similar criteria:

- Criticality of the inspection unit to the asset
- Coverage by other inspection programs
- Deterioration rate of the inspection unit
- Life cycle of the inspection unit

To remain relevant, PTMS data should reflect the current condition of the transit asset. For assets and inspection units that are subject to existing inspection programs, the PTMS should take advantage of the available data on the existing systems.

Develop Methods of Analysis

The categories of PTMS analysis were presented in Chapter 2. They include the following:

- Unconstrained needs
- Life-cycle replacement requirements

TABLE 9 Attributes of potential actions

Attribute	Long Description	Example
Action	Category of potential action	Repair
Extent	Extent of action required	100 square feet
Purpose	Purpose of potential action	Safety
Remaining Life	Estimated remaining life assuming action	10 years
Consequence	Description of consequences for taking action	Arrest deterioration

- Prioritized needs
- Evaluated alternative strategies

In this section, the basic information needed to support these analyses—potential actions, standard costs, and standard remaining life estimate—are described first. A short description of how this information could be applied in a PTMS follows, and, finally, brief examples are given for each of the four categories of analysis. Because PTMSs will vary according to each state's situation, examples throughout this section are subdivided, whenever possible, into base-level, mid-level, and high-level categories.

Define Potential Actions—Potential actions to address observed deficiencies of forecasted requirements are key to each of the mentioned categories of analyses. Potential actions are most likely defined initially by the field inspection staff. These potential actions will be proposed to address one or many observed deficiencies, and each potential action should include the attributes given in Table 9.

The potential action given in Table 9 illustrates a repair activity that has been specifically scoped (i.e., repair 100 sq ft). Following are other methods that can be developed to estimate the extent of action required.

Base Level

Each condition rating could be assigned a repair cost on the basis of the percentage of replacement. For instance, excellent status would be less than 2 percent of replacement cost, good status would be less than 5 percent, fair status would be less than 25 percent, poor status less than 60 percent, or 100 percent replacement. For this approach, data needs are limited because costs for potential actions are generated automatically, and all budgets are generated from the total costs for inspection-unit replacement. There are limitations to this approach, because inspectors cannot fine-tune assessments, and the specific nature of the potential action is not described.

Mid Level

In this approach, inspectors assign a separate repair requirement as a percentage of replacement independent of the condition-rating summary. For instance, the condition of two separate but similar inspection units can both be rated fair on the basis of the actual inspection. However, one unit may be slightly more deteriorated than the other or require a different type of repair that is more costly. The inspector in the field would be allowed to enter different repair requirements as a percentage of the replacement cost as the situation warrants. For example, two inspection unit engines are both rated good. The first unit requires the replacement of all hoses, spark plugs, and fan belts while the second requires only the replacement of the hoses. The first unit would be assigned a repair cost of 2 percent of the replacement cost, while the less-deteriorated second unit would be assigned a repair cost of 1 percent of the replacement cost. For the inspectors, this method allows more flexibility than the base-level method, but it still only requires the total unit costs for replacement as a basis for each inspection unit. Like the base-level method, the process yields only budgetary requirements and not specific descriptions of proposed actions.

High Level

The high-level method has been described in Chapter 2. Potential action activities are defined and scoped. For each deficiency of an inspection unit, this approach defines alternative repair scenarios. The level of detail for the repair cost of each alternative is not based on a percentage of the inspection unit's replacement cost but is based on a quantity take-off cost estimate. This approach recognizes that there may be more than one way to address a given set of deficiencies and provides the raw high-level input data for an alternative analysis.

Determine Standard Cost—Regardless of the approach, each potential action has a cost, and cost tables can be used to store unit cost data efficiently for many potential actions. Unit costs can address actions ranging from minor crack repair to full replacement of inspection units. The key to leveraging cost data is to develop generic unit-cost data where appropriate. For example, a unit cost for concrete crack repair need only be developed once, and then this single cost can be referenced for concrete slabs, walls, and ceilings. The format used in Table 10 for unit-cost data promotes leveraging.

Sources of cost data include R.S. Means Company handbooks, Richardson Engineering Services handbooks, state historical records, property historical records, actual quotes, and current contract costs.

Standard Life—A standard life for each inspection unit is a necessary component of all life-cycle analyses. Like unit-cost data, a single standard life may apply for many inspection units. Accordingly, the standard life data are similar to unit-cost data (see Table 11).

TABLE 10 Format for unit-cost data

Description	Long Description
PBS	Physical breakdown structure
Reference	Specific asset or agency reference for nongeneric costs
By	Source of the unit cost information
Cost Unit of Measure	$/sq ft, the units of the unit costs
Labor	Labor cost
Material	Material cost
Equipment	Equipment cost
Total Cost	Total of labor, material, and equipment costs
Percentage Multiplier	Markup to account for contractor overhead and profit, and for engineering and construction management

TABLE 11 Format for standard life data

Description	Long Description
PBS	Physical breakdown structure
Reference	Specific asset or agency reference for non-generic life spans
By Agency	Source of the unit life information
Standard Life	Numerical measure of standard life; may be years or other measure such as miles
Life After Rehabilitation	Expected life after major rehabilitation; may be years or other measure such as miles

Engineering Data Hierarchy—Both life-cycle and unit-cost data can be applied to an asset or inspection unit using standards determined and used at the industry level, national level, statewide level, or within a given transit agency. The following example shows how a hierarchy of this information can be used.

Given: The hierarchy of the PTMS for cost and life-expectancy data is as follows:

1. Specific asset (e.g., urban bus shelter, rural bus shelter)
2. Property type (e.g., urban, rural)
3. State level
4. National level

For example, a state has three transit agencies operating within the state. Two serve rural areas and the other serves an urban area. Each of the agencies has established an inventory of bus shelters, which are of all common age. The shelters at the three agencies were installed in the 1970s and are reaching the end of their projected life expectancy.

Life Expectancy

The engineering data in the PTMS regarding life expectancy only include the information given in Table 12.

TABLE 12 Example of engineering data

Asset (PBS)	Reference	Life
buildings.shelters.all	national	25 years

To determine the standard life of the bus shelters for the two rural agencies by using the hierarchy previously mentioned, the PTMS would perform the following tasks:

1. Search for data on an asset-specific level ("rural bus shelters") under the reference column. No data would be found.
2. Search for data on a transit agency level ("rural property") under the reference column. No data would be found.
3. Search for data on a state level under the reference column. Again, no data would be found.
4. Search for data on a national level. Here, the data would indicate a 25-year life expectancy.

In the example of the urban agency, a standard life expectancy of 25 years would also be identified.

Unit Cost

The background data in the PTMS regarding unit cost include the information given in Table 13.

To determine the unit cost of the bus shelters for the two rural agencies by using the hierarchy previously mentioned, the PTMS would perform the following tasks:

1. Search for data on an asset-specific level ("rural bus shelters") under the reference column. No data would be found.
2. Search for data on a property level ("rural property") under the reference column. No data would be found. (Although there is a price for an urban property, no price

TABLE 13 Example of unit-cost data

Asset (PBS)	Reference	Potential Action	Total Unit Cost	Unit of Measure
buildings.shelters.all	national	replacement	$3,500	$/unit
buildings.shelters all	urban property	replacement	$4,500	$/unit

is found for a rural area and the system would look for data on a state level.)

3. Search for data on a state level. Again, no data would be found.
4. Search for data on a national level. Here, the data would indicate a replacement cost of $3,500 per unit.

To determine the unit cost of the bus shelters for the urban transit property by using the hierarchy previously mentioned, the PTMS would perform the following tasks:

1. Search for data on an asset-specific level ("urban bus shelters") under the reference column. No data would be found. (Although there is a price for an "urban property," there are no data for the asset level, and the system would continue to search.)
2. Search for data on a property level ("urban property") under the reference column. Here it finds a replacement cost of $4,500 per unit.

This type of hierarchical system allows a PTMS to start with a small amount of generic engineering data. Over time, as data become available and agencies wish to contribute detailed property- and asset-level data, the resulting analysis will be fine-tuned. This approach also offers the potential benefit for a PTMS to serve as a national clearinghouse of PTMS engineering data, further leveraging the analyses of each of the states.

Evaluate and Analyze

Using the basic information from the categories previously described, the following are summaries of their applications in the four types of analysis.

Unconstrained Needs—An unconstrained needs analysis summarizes the total requirements of all observed deficiencies of an asset. The analysis involves totaling the cost of all potential actions. To aid in statewide and regional planning, it is possible to sort unconstrained needs reports by the following purposes of the potential actions:

- Maintenance and operations
- Operations efficiency
- Functional
- Code
- Safety

The data necessary to develop an unconstrained needs analysis shall include the following:

- Potential actions to address the deficiencies, including life-cycle replacement analysis
- Cost for each potential action
- Purpose of the potential action

Life-cycle Replacement Analysis—There are numerous forecasting methods to identify future life-cycle replacement requirements over a multiyear planning horizon.

Base Level

The base-level forecast for remaining useful life compares the age of the asset or inspection unit to standard life expectations. An example of this would be sorting all buses that are older than 12 years of age. This approach minimizes data requirements but it has limitations. Without an inspector's judgment regarding the effects of recommended repairs on the estimated remaining useful life of the inspection unit, alternatives analysis cannot be performed.

Mid Level

The mid-level forecast combines standard life expectancy with an inspector's judgment by asking the inspector to characterize the component as being in a quartile of the standard life (i.e., new = 90 percent of standard life remaining, good = 75 percent, fair = 50 percent, poor = 25 percent, bad = 0 percent). Inspectors could provide two assessments of the estimated remaining life on the basis of (1) the condition of the asset as observed and (2) the assumption that a recommended potential action is taken. The difference in these two assessments can be used to calculate the long-term costs of various action strategies. A variation of this approach asks inspectors to assign estimated remaining lives not in a percentage of the standard life but in actual years. This variation was illustrated in Figures 9 and 10.

High Level

For certain inspection units, deterioration algorithms have been developed to estimate the remaining life given objective input related to current condition, usage, and age. These algorithms are normally part of engineered management systems. The advantage of this approach is that the estimated remaining life and life-cycle consequences for given actions are based on statistical analysis of empirical data. There are two drawbacks:

the data needs are intensive, and the deterioration models exist for only a small number of inspection units.

In summary, for all three levels, the data needs for a life-cycle replacement analysis are the estimated remaining life for an inspection unit and the total cost to replace the inspection unit.

Prioritized Needs Analysis—There are numerous ways to prioritize the overall needs; the following focuses on two approaches.

Base Level

The classification approach provides decision makers a variety of ways to classify potential actions. This approach was illustrated in Chapter 2 and provides three separate levels of classification: function of the asset in delivering the service, criticality of the inspection unit to the asset, and purpose of the potential action. Variations of this approach involve more or fewer categories; for instance, urgency of the required action is often included. A potential shortcoming of this approach is that it does not rank the potential actions.

High Level

If the high-level approach is used for the evaluation of life cycles, mathematical techniques can be employed in an attempt to optimize investments, capital improvements, or other desired goals. Optimization is sometimes part of an engineered management system or may be a separate software package. Optimization allows decision makers to define optimization criteria and input various levels of constraints. The results are potentially very useful, but the data needs for the life-cycle analysis are extensive.

Data requirements for prioritization include the function of the asset in the delivery of service, the criticality of the inspection unit to the asset, and the purpose of the potential action.

Alternative Strategies Analysis—The basic requirement for any alternatives analysis is an estimate of the consequences of pursuing combinations of actions. The sophistication of the alternatives analysis methods is driven, to a large degree, by the methods chosen in the previous analyses. Alternatives analysis is often an iterative process with each successive round of analysis suggesting alternative approaches. Time constraints and the consequences of constrained approaches on the long-term cost of owning transit assets must also be considered. This type of approach was illustrated in Chapter 2 and requires the following data:

- Potential actions with consequences
- Life-cycle forecasts based on potential actions
- Escalation models to account for inflation
- Discount models to account for discount rates

IMPLEMENTING THE PTMS PLANNING CYCLE

As a management system providing information and input into planning processes, resource allocation decisions, and needs statements on the state of public transit assets, the PTMS is not a static document. To be valuable and useful, it must reflect up-to-date information on the assets, their condition, and the strategies to maintain them. Listed below are the ongoing activities that should be addressed to ensure a credible, useful system:

- Adjust master inventory list to reflect new and retired assets and inspection units
- Perform field inspection for new assets and inspection units
- Perform periodic reinspections to update inspection-unit condition data
- Generate potential actions to address newly observed deficiencies
- Generate new unit-cost and standard life data to address new assets and inspection units
- Update existing standard life data
- Adjust existing unit costs to reflect inflation or deflation
- Generate unconstrained needs, forecasted requirements, and prioritized needs reports
- Evaluate various strategies for addressing the requirements of the subject transit assets
- Update plans and reports
- Distribute the results to stakeholders for their use
- Solicit feedback from participants and stakeholders
- Fine-tune the PTMS as necessary

POTENTIAL ENHANCEMENTS

Develop PTMS Database System

An automated PTMS has many advantages. With a lower level PTMS, storage and manipulation of PTMS data can be made more efficient by using a spreadsheet. A PTMS of midlevel sophistication could apply standard database management systems to assist the stakeholders in sorting and retrieving appropriate information from the databases. A high-level application would be a PTMS with input, analysis, and reporting modules.

Develop Automated Data Collection Tool

A potential enhancement to a PTMS is to develop an automated data collection tool that can be easily integrated into the PTMS process. A PTMS is a powerful tool for maintenance, operations, and planning; however, the first-time inventory, periodical condition assessment, and entry of information is a significant job for even a modest transportation system. Use of an automated data collection tool, such as hand-held computers, by field inspectors can greatly increase the efficiency of data collection and yield such other positive results:

- Validation—Development of automated data collection programs forces early decisions about what information is required.

- Consistency—Automated inventories or assessments use preestablished classifications and definitions.
- Repeatability—Scripted inventories or assessments can be used by multiple inspectors over the years and yield consistent results.
- Quality—Inventories or assessments are designed to require proper formatted answers to all appropriate questions.
- Usability—Digitized data are uploaded by wire into computers for use in standard database programs.
- Efficiency—Inspectors record results directly in digital format, alleviating time-consuming and error-prone transcription of handwritten field notes.

Key issues to consider when designing a PTMS include the long-term usefulness of collected information, number and amount of items to be inventoried, type of data to be collected, data format, subject and data uniformity, and implementation budget and schedule.[8]

Coordinate with Engineering and Maintenance Management Systems

The concept of a pyramid was used in the Summary to illustrate that raw data are needed to support development of a PTMS. These data can be gathered through such means as a short questionnaire; frequently transit systems already use an engineering management system (EMS) or a maintenance management system (MMS). It is therefore advantageous that the PTMS system components be made compatible with existing EMSs or MMSs. Given the various data formats, rating methods, and other software issues, it should be understood that a PTMS is not an isolated system and should be coordinated with other systems. Existing programs that have methods and procedures useful for the PTMS should be incorporated, thus saving research and development effort. From the start, the PTMS should be developed as a multiuser system. It is initially easier to communicate with other EMSs or MMSs on that level; subsequent enhancements to the PTMS should include projectlevel features or other low-level EMS or MMS components.

Existing EMSs such as PAVER, ROOFER, and PONTIS hold in their databases a wealth of information on their respective assets. Whether it is the physical description data, work history, or condition data, all information is stored in an electronic form. It is advisable to collect as much information as possible from these sources when initially populating the PTMS database. The policy should be "import what you can, inspect what you must." Ideally, all the data are shared in common storage on a network. Realistically, collected inspection data for the PTMS should be made available for all other concerned EMSs or MMSs, if applicable.

The EMSs or MMSs focus a great degree of detail on selected elements and groups of elements. They offer rigorous analytical tools to optimize investment in the maintenance, repair, and replacement (MR&R) of asset elements. It is conceivable that potential actions fed into the PTMS from various EMSs or MMSs will have to be reconciled. There may be discrepancies in timing, local workforce, material availability, overall funding, or environmental load. The PTMS should contain a mechanism to deal with these conflicting scenarios as well as a mechanism to communicate its "opinions" to all concerned.

[8] Neil G. Jacobson, "Automating Assessment of Transit Infrastructure," APTA Computran, 1992.