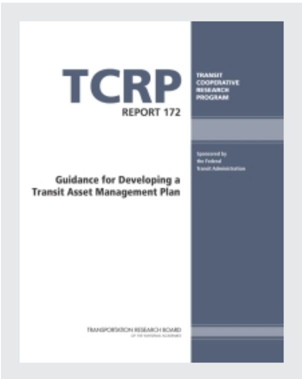


Guidance for Developing a Transit Asset Management Plan

DETAILS

118 pages | 8.5 x 11 | PAPERBACK
ISBN 978-0-309-30817-5 | DOI 10.17226/22306

AUTHORS

Robert William; Reeder, Virginia; Lawrence, Katherine; Cohen, Harry; and þÿKatherine O Neil

TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP REPORT 172

Guidance for Developing a Transit Asset Management Plan

William Robert
Virginia Reeder
Katherine Lawrence
SPY POND PARTNERS, LLC
Arlington, MA

Harry Cohen
Ellicott City, MD

Katherine O'Neil
KKO & ASSOCIATES, LLC
Andover, MA

Subject Areas
Public Transportation

Research sponsored by the Federal Transit Administration in cooperation with the Transit Development Corporation

TRANSPORTATION RESEARCH BOARD
WASHINGTON, D.C.
2014
www.TRB.org

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 Transportation 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 Academies, 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 end users 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.

TCRP REPORT 172

Project E-09A
ISSN 1073-4872
ISBN 978-0-309-30817-5

NOTICE

The project that is the subject of this report was a part of the Transit Cooperative Research Program, conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council.

The members of the technical panel selected to monitor this project and to review this report were chosen for their special competencies and with regard for appropriate balance. The report was reviewed by the technical panel and accepted for publication according to procedures established and overseen by the Transportation Research Board and approved by the Governing Board of the National Research Council.

The opinions and conclusions expressed or implied in this report are those of the researchers who performed the research and are not necessarily those of the Transportation Research Board, the National Research Council, or the program sponsors.

The Transportation Research Board of the National Academies, the National Research Council, and the sponsors of the Transit Cooperative Research Program do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of the report.

Published reports of the

TRANSIT COOPERATIVE RESEARCH PROGRAM

are available from:

Transportation Research Board
Business Office
500 Fifth Street, NW
Washington, DC 20001

and can be ordered through the Internet at

http://www.national-academies.org/trb/bookstore

Printed in the United States of America

COOPERATIVE RESEARCH PROGRAMS

CRP STAFF FOR TCRP REPORT 172

Christopher W. Jenks, *Director, Cooperative Research Programs*
Dianne S. Schwager, *Senior Program Officer*
Jeffrey Oser, *Senior Program Assistant*
Eileen P. Delaney, *Director of Publications*
Margaret B. Hagood, *Editor*

TCRP PROJECT E-09A PANEL
Field of Maintenance

Michael S. Tanner, *Bay Area Rapid Transit District, Danville, CA* (Chair)
Caroline Downing, *AECOM, Boston, MA*
Jeffrey D. Gonneville, *Massachusetts Bay Transportation Authority, Boston, MA*
Kim Johnson, *Michigan DOT, Lansing, MI*
James R. Plomin, *Oak Park, IL*
Jerry Rutledge, *King County (WA) Transit, Seattle, WA*
Winston Simmonds, *Simmonds Construction, LLC, Saxonburg, PA*
Joel Slavit, *San Mateo County (CA) Transit District, San Carlos, CA*
Waheed Uddin, *University of Mississippi, University, MS*
Alan M. Warde, *New York State DOT, Albany, NY*
John Giorgis, *FTA Liaison*
Chris Nutakor, *FTA Liaison*
Terrell Williams, *FTA Liaison*
Jeff Hiott, *APTA Liaison*
James W. Bryant, Jr., *TRB Liaison*

FOREWORD

By Dianne S. Schwager
Staff Officer
Transportation Research Board

TCRP Report 172: Guidance for Developing a Transit Asset Management Plan provides a process for developing a transit asset management plan used by transit agencies seeking to achieve a state of good repair (SGR). The report is accompanied by a Transit Asset Prioritization Tool (TAPT), which is composed of four spreadsheet models designed to assist transit agencies in predicting the future conditions of their assets, and in prioritizing asset rehabilitation and replacement.

TCRP Report 172 together with the TAPT models are valuable resources for transit agencies and will be of interest to regional, state, and federal agencies that oversee, plan, or finance public transportation. The report, TAPT models, and the contractor's final report summarizing the research conducted can be found at http://www.trb.org/Main/Blurbs/171285.aspx.

This research is the second phase of a two-part research project to develop tools for transit agencies to improve asset management and achieve SGR. Asset management is concerned with using quality data to support decisions that will maintain, rehabilitate, and replace existing assets in a cost-effective way and minimize asset lifecycle costs. By implementing best practices in transit asset management, a transit agency can make investment decisions that reduce the costs over time of maintaining its system, freeing up funds, where possible, to help improve service.

- Phase 1. The first phase of this research produced *TCRP Report 157,* which developed a preliminary framework and spreadsheet tools for transit agencies to use for prioritizing capital asset rehabilitation and replacement decisions. The research in this phase reviewed existing SGR practices in transit and other related industries. Based on the review, a framework was developed for evaluating the impacts and implications of different investment levels for rehabilitation and replacement of transit assets. The framework was built upon fundamental concepts involved in prioritizing asset rehabilitation and replacement decisions and provided a basic set of steps for transit agencies to analyze their SGR needs.
- Phase 2. The second phase produced three deliverables to improve transit asset management: *TCRP Report 172,* the TAPT spreadsheet, and a final research report. Additional research was undertaken to further develop the SGR framework and spreadsheet tools developed in Phase 1 and prepare guidance materials for transit agencies. Pilot tests and a workshop were conducted to solicit input from transit agencies and industry experts involved in transit asset management. These initiatives helped validate and refine the guidance document and the spreadsheet tools.

TCRP Report 172 and the accompanying TAPT spreadsheet are intended for use by transit agencies of all sizes and with all types of assets. The complexity of the process of developing an asset management plan as described in the report is dependent upon the total number of assets and the number of types of assets in a transit agency's inventory. *TCRP Report 172* provides a set of tutorials illustrating the use of TAPT and describes additional resources that may be relevant for transit agencies implementing an asset management approach for helping achieve SGR. The TAPT tutorials illustrate use of the process and tool with two transit agencies; the first describes a smaller agency modeling its bus assets, and the second describes an agency using the tool to analyze needs for buses, light rail, track, and facilities. The final research report, which is a separate electronic deliverable, documents the Phase 2 research and supplements *TCRP Report 172* and the TAPT spreadsheet.

CONTENTS

Note: Photographs, figures, and tables in this report may have been converted from color to grayscale for printing. The electronic version of the report (posted on the web at www.trb.org) retains the color versions.

CHAPTER 1

Introduction

Background

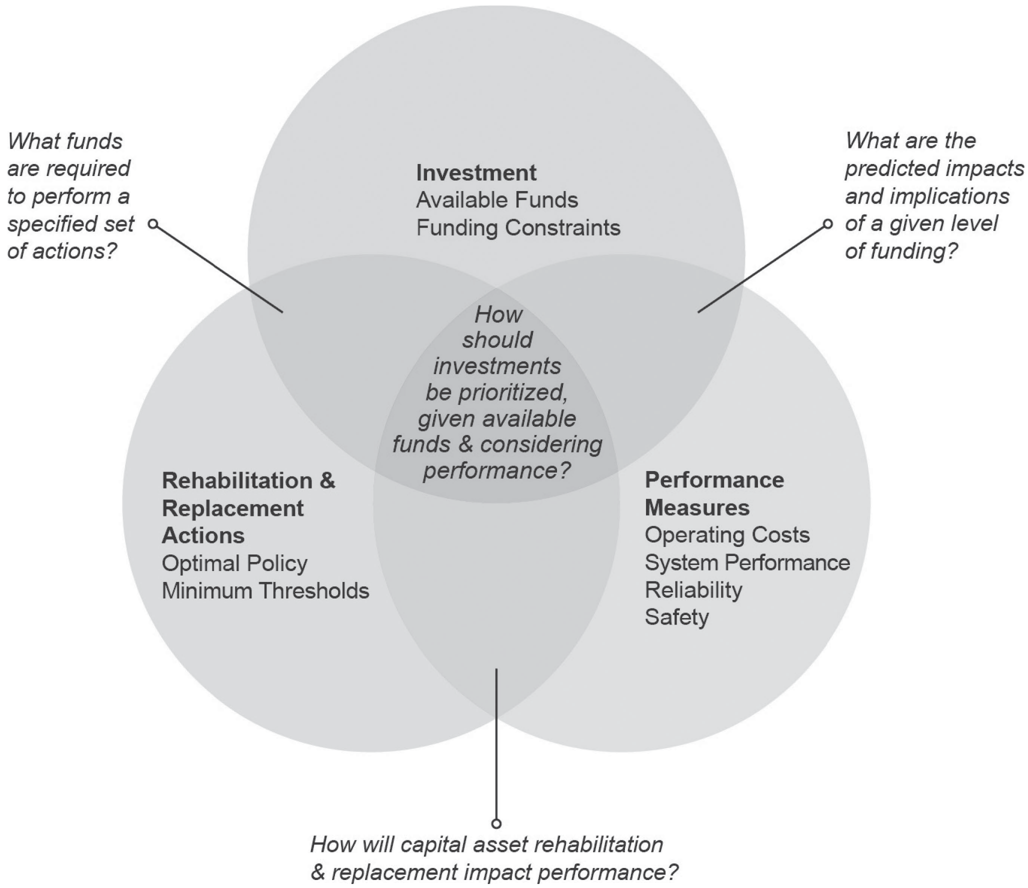
U.S. transit agencies have a wide variety of capital assets to maintain, including, but not limited to, buses, rail cars, guideway, stations, and other facilities and supporting systems. Transit agencies must rehabilitate and replace their existing physical assets to keep them in a state of good repair (SGR) and provide a consistent level of service to their passengers. Absent adequate investment in existing assets, a transit agency may find its equipment becoming increasingly unreliable and difficult to maintain, and in extreme cases may suffer reductions in system reliability resulting in degraded transit service. In recent years, transit ridership has increased, but funds for rehabilitating and replacing existing assets remain tightly constrained, further heightening the challenge that transit agencies face.

Transit asset management provides a set of tools and approaches for helping transit agencies manage their physical assets and achieve SGR. Specifically, asset management is concerned with using quality data to support decisions that will maintain, rehabilitate, and replace existing assets in a cost-effective way and minimize asset lifecycle costs. By implementing best practices in transit asset management, a transit agency can make investment decisions that reduce the costs over time of maintaining its system, freeing up funds where possible to help improve service.

Developing an asset management plan encompasses many of the basic steps in implementing an asset management approach. An asset management plan describes the physical assets that a transit agency owns and/or maintains, their existing condition, the strategy used for investing in those assets, the transit agency's plan for future asset rehabilitation and replacement, and how assets relate to levels and the quality of services that agencies provide. Preparing an asset management plan is not just good practice; with the passage of the transportation reauthorization bill MAP-21 in 2012, it is also the law for all recipients of federal transit funding.

TCRP Report 157 provides a framework for transit SGR, and describes a basic set of steps in applying the framework, including development of an investment plan. Figure 1.1 illustrates the components of the framework, and the questions the framework is meant to help answer. Fundamentally, the SGR framework is intended to help transit agencies prioritize investments to rehabilitate and replace existing transit capital assets.

In addition to providing the SGR framework, *TCRP Report 157* details a set of analytical tools and approaches for prioritizing asset investments. The framework and tools provide a starting point for transit agencies interested in using an asset management approach. However, transit agencies require more detailed guidance and tools to develop asset management plans and prioritize their investments. Thus, following completion of *TCRP Report 157*, additional research was performed to further develop the framework and tools described in the report, as well as



Source: *TCRP Report 157*

Figure 1.1. Elements of the transit SGR framework.

to incorporate additional considerations resulting from the transit asset management-related requirements of MAP-21. The results of this additional research are described in this guide and in the accompanying research report, *Guidance for Applying the State of Good Repair Prioritization Framework and Tools: Research Report*, which can be found at http://www.trb.org/Main/Blurbs/171285.aspx.

Purpose of the Guide

This guide describes the process of developing a transit asset management plan (TAMP) and is intended for use by transit agencies as they seek to achieve SGR and comply with the requirements of MAP-21. Also, it describes how to use the Transit Asset Prioritization Tool (TAPT), a spreadsheet tool designed to assist transit agencies in predicting the future conditions of their assets and in prioritizing asset rehabilitation and replacement. Further, this guide provides a set of tutorials illustrating the use of TAPT, and describes additional resources that may be relevant for transit agencies implementing an asset management approach.

This guide is intended for use by transit agencies of all sizes and with all types of assets. Note, the complexity of the process is dependent upon the total number of assets and the number of types of assets. The TAPT tutorials illustrate use of the process and tool with two agencies; the first describes a smaller agency modeling their bus assets, and the second describes an agency using the tool to analyze needs for buses, light rail, track, and facilities.

MAP-21 Requirements

MAP-21 includes several definitions and provisions related to using a performance-based approach to making transportation investment decisions, and to asset management, in particular. At the time of this writing, the FTA was developing the rules for implementing the requirements of MAP-21. This section describes the basic requirements of the law, pending further clarification and details from FTA's rulemaking.

MAP-21, for the first time, provides a federal definition of the term "asset management." Section 1103 of the bill defines the term as follows.

> ASSET MANAGEMENT.—The term 'asset management' means a strategic and systematic process of operating, maintaining, and improving physical assets, with a focus on both engineering and economic analysis based upon quality information, to identify a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions that will achieve and sustain a desired state of good repair over the lifecycle of the assets at minimum practicable cost.

The primary provisions related to transit asset management are in Section 20019 of the bill, which amends Section 5326 of Title 49 of United States Code (USC). This section begins with definitions of the terms "transit asset management system" and "transit asset management plan." MAP-21 defines "transit asset management system" as:

> TRANSIT ASSET MANAGEMENT SYSTEM.—The term 'transit asset management system' means a strategic and systematic process of operating, maintaining, and improving public transportation capital assets effectively throughout the lifecycle of such assets.

And the law includes the following definition of "transit asset management plan":

> TRANSIT ASSET MANAGEMENT PLAN.—The term 'transit asset management plan' means a plan developed by a recipient of funding under this chapter that—(A) includes, at a minimum, capital asset inventories and condition assessments, decision support tools, and investment prioritization; and (B) the recipient certifies complies with the rule issued under this section.

This section further directs the Secretary of Transportation to establish a "national transit management system" and lists the elements to be included in that system. These include:

(1) a definition of the term 'state of good repair' that includes objective standards for measuring the condition of capital assets of recipients, including equipment, rolling stock, infrastructure, and facilities;
(2) a requirement that the recipients and subrecipients of Federal financial assistance under this chapter develop a transit asset management plan;
(3) a requirement that each recipient of Federal financial assistance under this chapter report on the condition of the system of the recipient and provide a description of any change in condition since the last report;
(4) an analytical process or decision support tool for use by public transportation systems that—(A) allows for the estimation of capital investment needs of such systems over time; and (B) assists with asset investment prioritization by such systems; and
(5) technical assistance to recipients of Federal financial assistance under this chapter.

Section 20019 also requires the Secretary of Transportation, to "establish performance measures based on the state of good repair standards . . ." Finally, this section sets a timeline for the rulemaking and for recipients of federal funds to begin reporting performance and performance targets, and submitting annual transit asset management plans following completion of the rulemaking.

The net effect of these provisions is that following FTA's rulemaking, transit agencies will be required to prepare transit asset management plans that describe their inventory of capital assets and their conditions. Also, the plan will describe how they prioritize their SGR investments. Section 20028 of MAP-21, which amends USC Title 49, Section 5337, further stipulates that any projects funded through the SGR grants defined in this section should be listed in the transit agency's asset management plan.

Another requirement of the law is that transit agencies will need to report on their performance on an annual basis, and set performance targets using measures that incorporate consideration of SGR. Here we have assumed that a transit agency's asset management plan will include reporting of SGR-related performance measures, though transit agencies may be required to submit separate documents for performance reporting in addition to their TAMP. It's quite possible that performance measures other than what are presented in the guide may be required by FTA.

The guidance provided in this document is intended to aid in development of a TAMP consistent with best asset management practice and in compliance with MAP-21 requirements. However, developing a TAMP is beneficial regardless of federal requirements. Such a plan is valuable as a tool for communicating needs for investment in existing capital assets, for "making the case" for increased funding where needed to achieve SGR, and for establishing a transparent, repeatable, and effective process for making investment decisions. Likewise, the document describes the use of TAPT. This tool can assist a transit agency in developing its TAMP but the fundamental goal of the tool is to help transit agencies optimize their asset rehabilitation and replacement decisions.

Asset Management Guidance

Per MAP-21 requirements, transit agencies must develop a TAMP. However, there are many other aspects and elements to implementing an asset management approach. Two documents, in particular, have additional guidance pertinent to this broader topic: the FTA Transit Asset Management Guide and the ISO 55000 Standard Series. Chapter 5 of this report provides more information on these resources and the broader concepts, but the following is a summary of the guidance they provide relating to the development of a transit asset management plan.

The FTA Transit Asset Management Guide offers targeted guidance for transit agencies interested in advancing the practice and implementation of transit asset management. This document is largely focused on how to implement an asset management approach. It defines an asset management plan as a plan for implementing an asset management approach, focused primarily on investments needed for a set of assets, and less on process improvements. The FTA guide also describes the development of asset class-specific lifecycle management plans, which share several of the same sections that Chapter 2 of this document recommends for transit asset management plans. FTA's proposed sections for lifecycle management plans include:

- Roles and Responsibilities—Who is responsible for this asset's lifecycle management activities?
- Asset Inventory—What assets are included in this lifecycle management plan?
- Condition Assessment and Performance Monitoring—How will the asset class' performance be measured and monitored?
- Preventative Maintenance Plan—What activities can be proactively completed?
- Rehabilitation and Replacement Plan—What capital investments are needed?
- Asset Policy and Strategy—What are the asset management goals for this asset class?
- Asset Lifecycle Management—What are the investment activities necessary for maximizing the performance of this asset?
- Capital Programming and Operations and Maintenance Budgeting—How will asset management support capital programming and operations and maintenance budgeting?
- Performance Modeling—How will asset condition data support scenario evaluation?
- Continuous Improvement—How can we ensure we continue to get better at managing this asset?

The other key resource for implementing an asset management approach is the ISO 55000 standards series. This standard includes specific requirements for establishing asset management systems. Particularly relevant to the development of asset management plans are the planning requirements in the standard (more detail is provided on these in Chapter 5). These requirements are consistent with, but broader than, the TAMP outline presented in Chapter 2. They include important additional considerations such as criteria for decision making, responsibility for performing needed actions, the approach for reviewing the plan, and the risks associated with managing assets. Transit agencies implementing the ISO 55000 standards may wish to supplement their MAP-21 asset management plans accordingly by incorporating the additional considerations. As meeting the ISO 55000 standards will take more work, agencies may want to implement a model where they complete the broader plan, but then opt only to update the MAP-21 required sections annually. Another agency might plan to create an ISO 55000 asset management plan every five years, and pull from that the MAP-21 related elements for the annual update.

Important Concepts

This section discusses key concepts used throughout the document. The final section of the document includes a list of references with more information on each of these items.

Lifecycle cost is the sum of the costs of an asset over the course of its life. The calculation of lifecycle costs always includes **agency costs**, costs borne by the owner and operator of the asset (typically a transit agency in the context of transit assets). These costs may include, but are not limited to: the cost of the purchase or construction of an asset; costs from performing maintenance, repair, and rehabilitation work over the asset's life; and costs incurred in the event an asset fails prematurely. The calculation may include **user costs**, costs associated with use of the asset. The determination of exactly what costs are included in an analysis depends in large part upon what options the decision maker is weighing. Lifecycle costs are often presented on an average annual basis to facilitate comparison between assets with different lives. Lifecycle costs are always calculated considering a **discount rate**, which captures the time value of money.

Asset life (or service life) is the estimated useful economic life of an asset, specified in terms of time (years) or some other unit (e.g., accumulated mileage). The **remaining service life** (RSL) is the difference between this life and the age of the asset. Note one can continue to maintain an asset even once it has reached its service life, but it is unlikely to be cost effective to do so.

Asset failure occurs when an asset unexpectedly ceases to provide its intended service. For revenue vehicles, a failure (also called **road calls**, in the case of buses) is defined using the National Transit Database (NTD) definition of "major mechanical failure," which includes cases where the failure of a mechanical element of the vehicle prevents the vehicle from completing a scheduled revenue trip or starting the next scheduled revenue trip. For other assets, the term refers to the catastrophic failure of the asset requiring its replacement.

An **optimal policy** for an asset is a description of the set of actions to be taken to best achieve transit agency objectives. Typically the transit agency's objective, with respect to an asset, is to minimize the lifecycle cost of purchasing and maintaining the asset. Ideally, the level of maintenance should also maintain or improve service levels and meet the public's expectations. However, a transit agency may consider other factors that are difficult to incorporate in a lifecycle cost calculation, such as aesthetics, compliance with legal requirements, environmental concerns, and other factors. Strictly speaking, the policy for an asset should address when all maintenance, repair, rehabilitation, and replacement actions should be taken and how these will at least conceptually relate to the quality of the transit agency's services. However, this document focuses on rehabilitation and replacement actions which may be included in a transit agency's capital program.

Guide Organization

The remainder of this document is organized as follows:

- Chapter 2 describes a step-by-step process for developing a transit asset management plan.
- Chapter 3 details how to use TAPT to predict asset performance and prioritize rehabilitation and replacement actions.
- Chapter 4 provides a set of tutorials illustrating the use of TAPT to help prioritize asset investments and prepare an asset management plan.
- Chapter 5 describes additional references valuable for transit agencies implementing a transit asset management approach and/or developing an asset management plan.

CHAPTER 2

Steps in Developing a Transit Asset Management Plan

This chapter walks through the steps involved in development of a Transit Asset Management Plan (TAMP). It describes the way in which a tool [such as the Transit Asset Prioritization Tool (TAPT), described in Chapter 3] can be used by transit agencies to support this process. Upon completion, readers will understand the necessary steps and required data to develop a TAMP.

The process of developing and finalizing a TAMP is divided into 5 steps, as illustrated in Figure 2.1.

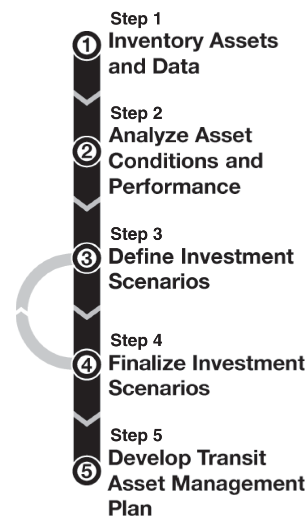


Figure 2.1. 5-Step TAMP development process.

For transit agencies with larger asset inventories it will likely be necessary to use software tools to support the process outlined above. TAPT, detailed in the next chapter, is designed to support prioritization of transit asset rehabilitation and replacement, and can be used to support development of the TAMP. Also, the FTA Transit Economic Requirements Model (TERM) Lite can be used in conjunction with TAPT or independently from TAPT to support analysis of investment scenarios. Further, many transit agencies have implemented asset management systems and decision support tools that can be used to support TAMP development.

The process described in this chapter is applicable whether a transit agency uses TAPT, TERM Lite, and/or other tools. However, where TAPT is used, the text notes steps where the reader should refer to Chapter 3 for more information. Further, many of the examples in this chapter are drawn from the transit agency pilots performed using TAPT with data from King County Metro, the Denver Regional Transportation District (RTD), and the Southeastern Pennsylvania Transportation Authority (SEPTA). Note the examples are used strictly for illustrative purposes, and do not reflect actual investments or plans.

Step One: Inventory Assets and Data

The process of evaluating and prioritizing rehabilitation and replacement work starts with collecting data on existing transit capital assets. **Described at the very basic level: first you need to know what you have (i.e., capital assets), and then you need to understand what you know about what you have (i.e., data).** Data are needed to describe the transit agency's asset inventory, and establish the condition of the inventory as an initial step in determining what replacement actions will be needed and when. While the scope of this guidance does not include detailed inventory and data collection methods, additional resources in Chapter 5 can be used to develop a more detailed data collection process.

Step 1 includes 5 sub-steps. Upon completion you will have:

- A comprehensive list of your transit agency's capital assets, organized by subsystem type to facilitate data collection

- A list, by asset, of the data your transit agency currently collects related to its assets
- An agency-approved definition of SGR
- A selected list of performance measures
- A plan or protocol for gathering, storing, and updating the necessary data

Note: If utilizing the TAPT you should refer to Chapter 3 for specific instructions on how to use the tool to help complete Steps 1 through 4. Return to this chapter for Step 5 (Develop Transit Asset Management Plan).

Step 1.1 Establish the Capital Asset Inventory

Creation of a TAMP starts with quantifying, describing, and categorizing a transit agency's existing capital assets. MAP-21 defines a capital asset as follows:

> (1) CAPITAL ASSETS—The term 'capital asset' includes equipment, rolling stock, infrastructure, and facilities for use in public transportation and owned or leased by a recipient or sub recipient of Federal Financial assistance under this chapter.

To create your capital asset inventory, you may choose to reference an existing asset classification system as a guide. TERM Lite, an FTA tool available to help transit agencies assess their SGR needs, provides a classification system for organizing an asset inventory. For more information on TERM Lite refer to Chapter 5. The high level classification from TERM Lite is provided in Table 2.1. This table also summarizes basic inventory data that should be collected for each asset to support development of the TAMP. Note that regarding collection of cost data, ideally you should be able to calculate the full cost of asset acquisition, replacement, etc., including "soft" or indirect costs such as administrative and design costs. However, what is most important

Table 2.1. TERM Lite inventory structure.

Asset Type	Sub-Category/Classification	Inventory Data
Vehicles	Revenue Vehicles	Quantity (unit), year built, unit cost, acquisition cost, replacement cost, cost year, useful life
	Non-Revenue Vehicles	
	Equipment/Parts	
Guideway Elements	Guideway	
	Trackwork	
	Speed Structures	
	Bus Guideway	
Stations	Rail	
	Motor Bus	
	Ferry	
Facilities	Buildings	
	Storage Yard	
	Equipment	
	Major Shops	
	Central Control	
Systems	Train Control	
	Roadway Traffic Signals	
	Electrification	
	Communications	
	Security	
	Revenue Collection	
	Utilities	
	ITS	

Table 2.2. NTD asset module structure.

Asset Type	Sub-Category/Classification	Inventory Data
Revenue Vehicle Inventory	Vehicles in Operation	Vehicle type, ownership, funding source, year of manufacture, year of rebuild, manufacturer, model number, fuel type, vehicle length, seating capacity, standing capacity
Transit Way Mileage	At-grade	Miles of track; crossings
	Elevated	Miles of track
	Open-cut	
	Subway	
Stations and Maintenance Facilities	Passenger Stations (Single and Multimodal)	Number of stations for fixed route or fixed guideway
	Maintenance Facilities	Type, ownership, and size

regarding tracking of data on costs is that you track costs in a consistent manner, which argues for tracking indirect costs only if you can do this consistently.

The guidelines for the NTD reporting also can serve as a foundation for these efforts, providing a de facto minimum set of standards for describing a transit asset inventory. NTD requirements are summarized in Table 2.2. Note that there are additional requirements pertaining to vehicles not summarized in the table, and different requirements for rural transit agencies. For more information on the NTD, refer to Chapter 5.

If you are using TAPT, you will have the flexibility to define the set of assets in your inventory, and the tool will list the data items required for quantifying the inventory. Table 2.3 provides an example of an inventory of buses. In TAPT these are detailed at the subfleet level, with data items defined consistently with the NTD reporting requirements.

When creating your asset groups, you may want to consider whether there are groups of assets that may fall within the same asset category (e.g., same model and age), but whose operational characteristics may impact asset management and condition (e.g., some buses may be run on suburban and rural routes while others are servicing urban areas, or the annual mileage varies significantly). In these cases it may be worth creating sub-asset groups for each type to ensure that the replacement and rehabilitation recommendations are as accurate as possible.

Table 2.3. Capital asset inventory example—buses.

Type	ID	Description	#	Age (yrs)	Avg. Accumulated Mileage
Articulated	Bus-Artic 1	2000 NABI	118	12	330,900
Mall	Bus-Mall 1	2000 Mall Shuttle	18	12	138,904
	Bus-Mall 2	2001 Mall Shuttle	15	11	141,193
	Bus-Mall 3	2002 Mall Shuttle	3	10	130,023
Intercity	Bus-IC 1	1998 MCI	67	14	1,024,371
	Bus-IC 2	2001 Neoplan	85	11	493,701
	Bus-IC 3	2009 Blue Bird	6	3	55,487
	Bus-IC 4	2010 MCI	6	2	84,036
40' Transit	Bus-Transit 1	2000 Orion V	199	12	482,740
	Bus-Transit 2	2005 Gillig Diesel	42	7	295,447
	Bus-Transit 3	2006 Gillig Hybrid	4	6	171,153
	Bus-Transit 4	2006 Gillig Diesel	7	6	249,523
	Bus-Transit 5	2008 Gillig Diesel	6	4	170,629
	Bus-Transit 6	2008 Gillig Hybrid	5	4	115,508

Step 1.2 Establish Available Data Resources

Once you have established the capital asset inventory, it is important to identify available sources of inventory and condition data for use in developing the TAMP. Specifying which data sources are used for each asset type will allow for consistent, future updates to the inventory. The specification of which data are required for the TAMP would ideally be determined considering both best practices and the story it is that you are trying to tell—i.e., which performance measures you are going to track, report, and use in your decision-making and prioritization processes. However, for a transit agency that has an established data collection process, it makes sense to utilize existing resources to determine the way your conditions will be described.

In performing this step, first determine what existing systems and tools are used in the transit agency to collect and store asset data. These systems may include:

- Enterprise asset management (EAM) systems with detailed data on the inventory and day-to-day maintenance work;
- Asset-specific management systems, such as vehicle, facility, and bridge management systems;
- Operations and service planning systems, which may detail relevant fleet operations data;
- Financial management systems with information on capital expenditures;
- Electronic and/or paper inspection reports;
- Analysis tools, such as TERM Lite;
- Other databases and spreadsheets with inventory and condition data; and/or
- Transit agency reports with asset details, such as capital plans or asset-specific analyses.

Note that a transit agency may have many systems that have valuable data for use in developing a TAMP outside of its asset management systems. For instance, in many cases systems used for supporting operations may have useful information on delays or slow orders attributed to asset maintenance or failures that are highly valuable in developing a TAMP. As another example, financial management systems with records of capital expenditures can be used to establish an inventory of capital assets and details on asset costs. However, it is important to assess data quality and currency when using data from other systems, or repurposing data collected for other purposes.

Once the set of data resources has been established, you will establish basic information on each resource, and the types of data stored in, listed in, and/or managed using the resource. Table 2.4 lists the information required on each data resource.

Table 2.4. Information required on data resources.

Item	Notes
Resource name	System or database name.
Owner	Should specify owner of the system if the system is licensed by the transit agency, as well as the transit agency business owner.
Asset types included	Should specify level of detail of the inventory. Are individual assets listed, or are assets grouped by subfleet, line, or using other approaches. Are complex assets such as structures and facilities specified by system or subsystem?
Update approach	Should detail major system uses, and how frequently the data in the system are updated and used.
Inventory data items	List of inventory items. These are typically entered upon purchase/construction of an asset
Condition data items	List of data items that are updated as the asset ages, such as mileage and/or physical condition.
Cost-related data items	May include purchase cost, replacement cost, cost of actual or planned maintenance or rehabilitation actions, energy consumption, transit agency soft costs, and/or other fields.
Operations-related data items	May include information on the service for which assets are used (e.g., ridership by vehicle), data on delays and asset failures.

As a result of this step you may find that you do not have sufficient data on all of your assets to complete a full prioritization analysis. If this is the case, you can focus on those assets for which you do have the data, and separately input budget data for other assets. For example, you may focus your TAMP development on your vehicle assets, and handle your facility assets separately (if you do not have complete data), or as an addition at the end. In future years, if you do have the data, you can add the additional asset types to the analysis.

Step 1.3 Define SGR

Nominally the goal of capital asset rehabilitation and replacement is to maintain a transit agency's assets in, or return them to, SGR. However, it is important to define what SGR means to the transit agency, and how the definition relates to transit agency goals and objectives. The process of defining the term "state of good repair" for your transit agency will allow you to set appropriate targets, benchmark progress over time, and provide direction and guidance in the prioritization of capital improvements and maintenance.

As discussed in Chapter 1, MAP-21 requires FTA to create a definition for SGR, and establish performance measures that will support this definition for use by transit agencies in their TAMPs. This document will be updated once FTA has established its definition of the term. However, even given FTA's definition, a transit agency should relate the definition to its goals and objectives, and may find that in so doing, it needs to clarify or extend the definition of SGR.

At the 2010 State of Good Repair Roundtable, FTA presented three possible approaches to defining SGR. Each one combines a mix of approaches from the following categories:

- Management activities and processes,
- Asset conditions (as defined by transit agency, owner's manual, industry standards),
- System performance (as defined by transit agency),
- Safety conditions (as defined by transit agency),
- Quality (as reported by customers).

FTA's example definitions include:

Option 1

A transit system is in a SGR when:

- The transit agency possesses and maintains a comprehensive list of its capital assets and rolling stock.
- The transit agency possesses an asset management plan, which is integrated into the management processes and practices of the transit agency.
- A set percentage of the transit agency's assets are within their particular useful life and remaining assets are performing at their designed function.

Option 2

A transit system is in a SGR when:

- System components are properly maintained or replaced in accordance with:
  - The owner's approved O&M procedures and schedules; or
  - The original equipment manufacturer's recommended criteria when owner's procedures do not exist; or
  - Industry standards when the above are not available.
- The system satisfactorily performs its intended design function.

Option 3

A transit system is in a SGR if it exhibits the following characteristics:

- Safety: Transit infrastructure and vehicles are well maintained and replaced before their condition deteriorates to the point of presenting a safety risk.
- Quality Transit: Infrastructure and vehicles meet customer expectations for comfort and reliability.

Source: Presentation by A. James at 2nd State of Good Repair Roundtable, 2010: "Addressing the Challenge: Formulating a Definition of SGR for a Federal Program."

Table 2.5 provides examples of SGR definitions used by six transit agencies. As reflected in the FTA approaches, the definitions in this set range from those based on a condition or performance assessment, to those based on maintenance or replacement activities.

Once your transit agency has defined SGR, it is important to link it to your transit agency's mission and goals. Table 2.6 shows how the MBTA has linked its mission and goals to SGR. The SGR program is specifically mentioned under the infrastructure goal. Also, certain SGR-related activities may relate to the service and financial goals. The ISO 55000 and IIMM asset management guidance documents cited in the Chapter 5 emphasize a top-down approach whereby desired service levels drive asset condition goals and objectives.

Step 1.4 Select Performance Measures and Targets for Asset Management

The performance measures and targets that you select for your TAMP will provide you with the baseline asset conditions, help you track your progress across program areas, predict how conditions are likely to change in the future, and provide a level to which you are striving. The measures should be quantifiable using the data that your transit agency is collecting (identified in Step 1.2) and help describe and track the state of the repair of your transit agency's assets, as well

Table 2.5. Example SGR definitions.

Transit Agency	Definition
Chicago Transit Authority (CTA) Illinois	CTA defines SGR primarily in terms of standards: • Rail lines should be free of slow zones and have reliable signals. • Buses should be rehabbed at 6 years and replaced at 12 years. • Rail cars should be rehabbed at quarter- and half-life intervals and replaced at 25 years. • Maintenance facilities should be replaced at 40 years (70 years if rehabbed).
Cleveland Regional Transit Authority (RTA) Ohio	State of good repair projects are those needed to bring the system to a consistent, high quality condition system-wide
Massachusetts Bay Transportation Authority (MBTA) Massachusetts	A state of good repair standard [is where] all capital assets are functioning at their ideal capacity within their design life.
New Jersey Transit (NJT) New Jersey	"State of Good Repair" is achieved when the infrastructure components are replaced on a schedule consistent with their life expectancy.
New York City Transit (NYCT) New York	Investments that address deteriorated conditions and make up for past disinvestment.
Southeastern Pennsylvania Transportation Authority (SEPTA) Pennsylvania	An asset or system is in a state of good repair when no backlog of needs exists and no component is beyond its useful life. State of good repair projects correct past deferred maintenance, or replace capital assets that have exceeded their useful life.

Source: *Transit State of Good Repair: Beginning the Dialogue.* FTA, 2008.

Table 2.6. MBTA mission.

Mission: Committed to excellence, the MBTA strives to provide safe, accessible, dependable, clean, and affordable transportation to our valued customers through the dedication of our diverse and talented workforce.		
Goals:	Service	To provide clean, safe, and reliable public transportation, accessible to everyone, and a clean and safe environment for employees.
	Infrastructure	To modernize the system through an aggressive SGR program while investing in cost-effective expansion projects to increase our customer base.
	Financial Condition	To provide affordable transit for the public toward reducing the burden to taxpayers through efficient operations, innovative fare policies, and the generation of non-fare revenues, while simultaneously supporting a balanced capital program of modernization and expansion through strong project and grant management.
	Employee Development	To recruit, train, and retain a highly professional, diverse, and committed workforce capable of improving the system in an efficient and cost-effective manner.
	Communication	To develop direct, effective communication techniques that inform our customers, obtain valuable feedback, and develop goodwill for the organization.

Source: *The MBTA FY2009 Budget.* MBTA, 2008.

as the impacts and implications of operating at a given state of repair. Most (if not all) of the measures you will use for your TAMP are likely among those that your transit agency is already collecting.

FTA is currently developing guidance on performance measures and targets for transit asset management. Once adopted, these measures will be used by all transit agencies in their TAMP. However, transit agencies may choose to report additional measures beyond the minimum set required by FTA. This document provides some general guidance on the selection of measures, and offers suggestions for other resources that may be useful.

Appendix A of FTA's *Asset Management Guide* provides guidance on performance metrics by asset type. *TCRP Report 88: A Guidebook for Developing a Transit Performance-Measurement System* provides background information on the use of performance measures by transit agencies across all areas. It includes a list of possible measures, including detail about data requirements, appropriate use, and other related information. The NTD *Annual Reporting Manual* provides additional guidance. Though many of the metrics required for NTD reporting are not performance measures, it does include a few relevant measures (e.g., total miles on active vehicles during period). These resources are discussed further in Chapter 5.

Selecting Performance Measures for Asset Management

Performance measurement is a complex topic, and extends beyond the area of capital asset rehabilitation and replacement that is the focus of this report. Important considerations in identifying performance measures for supporting transit asset rehabilitation and replacement decisions adapted from *NCHRP Report 551* are as follows:

- **Feasibility:** a performance measure is useful only if the transit agency can capture the data needed to support its calculation. In considering whether to use a given measure, the transit agency must consider the cost of quantifying the measure, and weigh this against the marginal value of having the information that the measure would provide.
- **Policy sensitivity:** performance measures used to support resource allocation decisions should ideally relate to transit agency policy objectives, and should provide a measure of whether

the expected outcomes of policy objectives are occurring. This tends to emphasize measures correlated with transit service from the transit customer's viewpoint. For instance, on-time performance is more meaningful for a typical passenger than a condition score.

- **Long-term view:** to support rehabilitation and replacement decisions it is important to leverage information on trends in performance and predictions of future performance given a set of budget assumptions. Also, it should be possible to predict performance of the selected measures over the entire lifecycle of an asset. If a measure cannot be predicted in the future, then it may be of value for reporting or tracking purposes, but it will not be an effective measure for supporting asset replacement decisions.
- **Useful for decision support:** the ideal measure would provide information on when rehabilitation or replacement is needed, would be impacted as a result of rehabilitation/replacement actions, would not be unduly impacted by factors outside of the transit agency's control, and would be useful for testing different budget scenarios. Asset age, remaining service life, and condition ratings are commonly-used measures that meet these criteria for many assets.
- **Useful across the transit agency:** ideally the performance measures adopted for supporting asset management decisions are measures that are used broadly across the transit agency, such as for reporting across modes or units and to the public.

Your TAMP should include a core set of measures, which together will capture the condition of your agency's assets. This set in Table 2.7 includes the minimum recommended set of measures, the data for which should be readily available at any transit agency.

For those transit agencies interested in moving beyond the minimum recommended measures, Table 2.8 provides additional measures recommended for comprehensive reporting of asset management. Combined with the core measures, this set should offer your transit agency a complete picture of the state of your assets, and effectively support your prioritization and decision-making processes.

Once you have selected your measures, you will select targets corresponding to each one. These should be realistically achievable, and related to the transit agency's definition of SGR. After you

Table 2.7. Core TAMP measures.

Measure	Use for	How to Measure	Notes
Backlog of investment needs	All assets	Sum of costs for unmet needs for achieving SGR	Calculate using TERM Lite, TAPT, or an alternative, documented approach
Average asset age	Guideway, stations, facilities, systems	Year of manufacture for vehicles; year of construction or installation for other assets. Weight by asset value when combining assets.	Use age of initial construction or last major rehabilitation when reporting for stations and facilities. May report age by station/facility, or group by type.
Mean distance between failures (MDBF)	Vehicles	Vehicle-miles traveled/number of road calls or failures	Should include major mechanical failures reported to NTD at a minimum
Average accumulated mileage	Vehicles	Total lifetime mileage averaged among all vehicles in the subfleet	Measure by subfleet

Table 2.8. Comprehensive TAMP measures.

Measure	Use For	How to Measure	Notes
Percent of assets in good/fair/poor condition	Guideway, stations, facilities, systems	Measure using TERM condition ratings (or a documented alternative rating) with a rating of 5 or 4 as good, 3 as fair, and 2 or 1 as poor. Weight by asset value when combining assets.	A good/fair/poor classification is recommended for combining different rating scales used (e.g., 5-point TERM ratings and 10-point National Bridge Inventory ratings used for structures).
Asset availability	Elevators and escalators	Percent of total operating time that elevator or escalator is available.	Ideally repair time should be included as down time even when scheduled
Hours of delay	Vehicles, guideway	Passenger hours of delay caused by mechanical failures of vehicles or fixed assets	Typically requires assumptions concerning variables such as passenger loads. An alternative for guideways is to report extent of slow orders.
Greenhouse gas (GHG) emissions	Vehicles	Tons of CO_2 emitted by the vehicle fleet per year	May also report per vehicle mile, extent to include emissions from vehicle manufacture and/or report for fixed assets.

have completed Step 2.1 (calculation of your agency's current conditions and performance), you may need to revisit your targets to ensure that they are appropriate.

Step 1.5 Define Data Collection Protocols and Reporting Schedule

A successful TAMP is dependent upon accurate, consistent data to support the monitoring and performance measurement activities. Therefore, having the methods used to collect the data are as critical as what data you are collecting and what you are measuring.

Once your performance measures and targets have been selected, it is important to conduct an analysis of the data you have to support them. Depending upon the measures that you have selected, or the frequency with which you plan to report, the following actions may be necessary:

- Aggregation of data for calculating measures (e.g., vehicle level to subfleet or fleet);
- Integration of data for analysis;
- Update of data collection schedule; and
- Establishment of new data sharing pathways within a transit agency.

Since some data collection can be time and resource intensive, this analysis may raise legitimate questions regarding the value of the measures compared with the resources needed to report them. Therefore, this may be an iterative process, requiring the shifting of how you are calculating your measures, as you match up your data and reporting techniques with your performance measurement reporting.

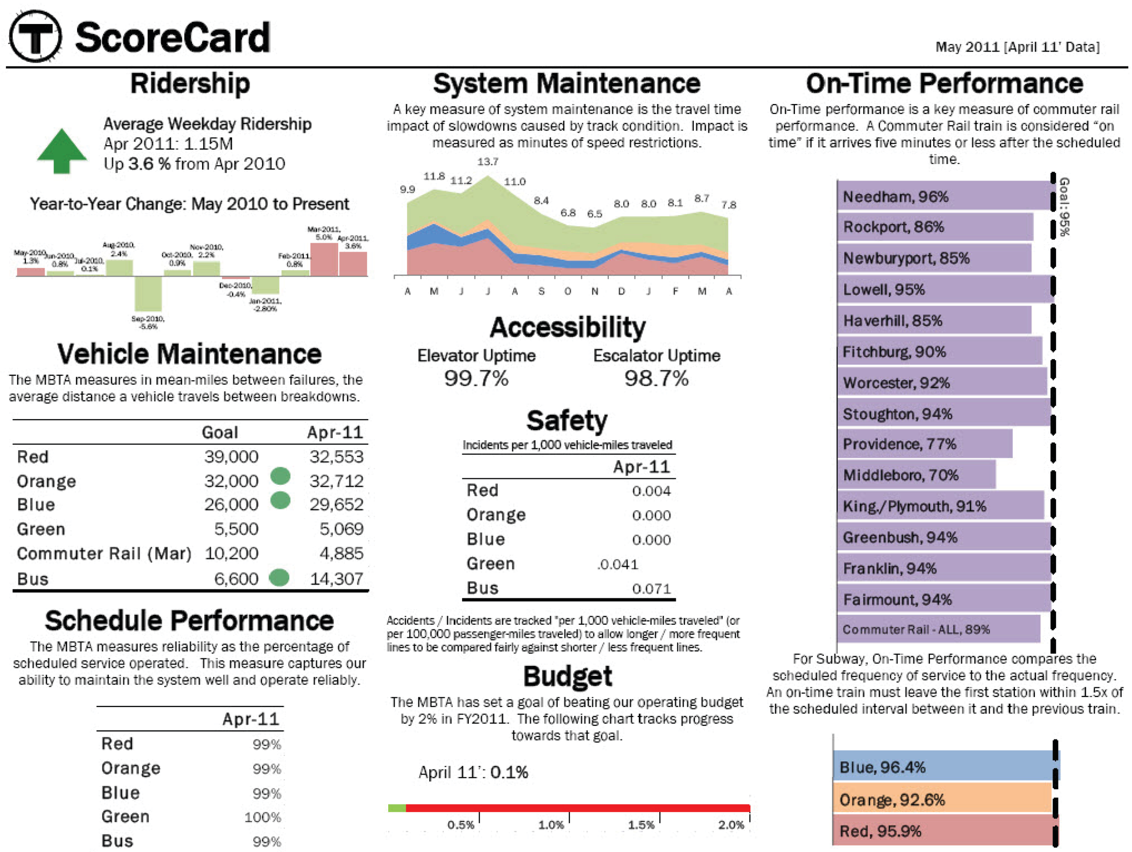
Table 2.9 recommends the level of aggregation, performance measures, and calculation frequency organized by TERM asset type.

Once you have established your measures, targets, and data collection practices, you may find value in using them to communicate progress and trends outside of the TAMP. Figure 2.2 provides an example of a monthly scorecard established for performance reporting.

Table 2.9. Recommended aggregation level, performance measures, and reporting frequency by asset types.

Asset Type	Aggregation Level for Calculations	Performance Measure	Measure Category	Calculation Frequency
Guideway	At a minimum, aggregate by line. Ideally, calculations should be performed for track, other guideway elements, and major systems using the TERM asset hierarchy or equivalent	Backlog of investment needs	Core	Annual
		Average age	Core	Annual
		Percent of assets in good/fair/ poor condition	Comprehensive	Annual
		Hours of delay	Comprehensive	Monthly
Facilities	At a minimum aggregate by facility. Ideally calculations should be performed by building and major system (e.g., roof, electrical, HVAC).	Backlog of investment needs	Core	Annual
		Average age	Core	Annual
		Percent of assets in good/fair/poor condition	Comprehensive	Quarterly
Systems	Aggregate by system using TERM asset hierarchy. Note this category excludes systems within stations and facilities.	Backlog of investment needs	Core	Annual
		Percent of assets in good/fair/poor condition	Comprehensive	Quarterly
Stations	At a minimum aggregate by mode or line. Ideally calculations should be performed by station and major system.	Backlog of investment needs	Core	Annual
		Average age	Core	Annual
		Percent of assets in good/fair/poor condition	Comprehensive	Quarterly
		Asset availability (for escalators and elevators)	Comprehensive	Monthly
Vehicles	Aggregate by subfleet.	Backlog of investment needs	Core	Annual
		Mean distance between failure	Core	Monthly
		Average accumulated mileage	Core	Monthly
		Hours of delay	Comprehensive	Monthly
		Percent of assets in good/fair/poor condition	Comprehensive	Quarterly
		Average tons of $C0_2$ (per vehicle/fleet/ per mile	Comprehensive	Quarterly

EXAMPLE: MBTA PERFORMANCE MEASURE REPORTING



The MBTA has established a one-page scorecard for use in reporting asset conditions. The scorecard includes summary measures of: ridership; mean distance between failures (MDBF), service reliability; minutes of speed restrictions; elevator and escalator uptime; safety adherence to budget; and on-time performance. The scorecard is accompanied by additional details by mode, and is updated on the MBTA web site on a monthly basis.

Source: MBTA

Figure 2.2. MBTA scorecard.

Step Two: Analyze Asset Conditions and Performance

With data, performance measures, and targets in order, you are ready to put that information to work. **In this step you will first determine where you are today, and establish the assumptions needed to determine where you are headed.** This will provide the foundation required to understand the implications of your prioritization and funding decisions that will be the meat of your TAMP.

Step 2 is completed in 4 sub-steps. Upon completion you will have:

- A snapshot of where your transit agency stands today, with respect to your chosen performance measures for asset management
- The point in time at which each of your asset types will need replacement, as described by your deterioration model
- A lifecycle policy, for each asset type, which will guide your investment scenarios and inform your prioritization decisions

Note: If utilizing TAPT you should refer to Chapter 3 for specific instructions on how to use the tool to help complete Step 1 through Step 4. Return to this chapter for Step 5 (Develop Transit Asset Management Plan).

Step 2.1 Calculate Current Asset Conditions and Performance

In this step, you will establish your baseline conditions. You will use this snapshot as you compare (and finally select) your alternatives (in Step 4), as well as in your ongoing performance monitoring to track your actual progress.

The basis for your current conditions assessment should be your performance measures (selected in Step 1.4), and it should include all of your transit agency's measures. If your agency has historical data on these measures, you may decide to present the trends leading to today's conditions. Table 2.10 illustrates an example of data for the example buses listed previously in Table 2.3. Table 2.10 shows the recommended measures of backlog, accumulated miles, failures, MDBF, and CO_2 emissions for each of four types of buses, as well as additional cost data. In this example, intercity buses are shown as being at the end of their useful life as a result of their high mileage, though they are highly reliable compared to other bus types in the fleet.

Step 2.2 Develop Asset Deterioration Models

A deterioration model predicts how the condition of an asset will change over time. Deterioration models are needed to help predict the impacts on costs and performance as

Table 2.10. Current asset conditions and performance pilot example—buses.

Measure	Value by Bus Type			
	Artic	Mall	Intercity	40 foot
Backlog of Needs ($ 000)	0	0	37,654	76,416
Average Accumulated Mileage (000)	331	135	679	428
Mechanical Failures (roadcalls)	88	65	87	317
MDBF (miles)	35,649	20,407	33,033	39,791
CO_2 Emissions (tons)	10,843	1,778	18,454	28,942

an asset ages and help determine when to rehabilitate or replace an asset. Asset deterioration models can be established through analysis of historic data, using models from TERM Lite or other systems, through expert judgment, based on industry standards, or using a variety of other approaches.

Establish Useful Life. The most straightforward way to model deterioration is to establish a useful life for the asset and determine the remaining useful life of the asset based on the asset age. This approach will support calculating an investment backlog. However, for complex assets such as maintenance facilities or guideway, a single asset age may not provide a reliable indicator of when rehabilitation or replacement is required. Also, this approach provides little indication of what the impacts may be of allowing the asset to continue to deteriorate once it has reached its assumed useful life.

Vehicles. For vehicles, tracking MDBF as the vehicles ages provides a better indication of asset deterioration than age alone. Although it can be difficult to compare MDBF between different fleets and systems, for a given fleet one would expect this measure to decrease as the fleet ages. Also, MDBF is well correlated with both the maintenance cost incurred by the transit agency, and mechanical failure–induced delays experienced by passengers. Figure 2.3 shows an example of MDBF predicted by TAPT for the example bus fleet described in Table 2.3. When analyzing historic MDBF data to predict future performance, it is important to use data where failures have been reported in a consistent manner over time. Also, it is important to note that a transit agency can impact MDBF through increased or decreased preventive maintenance.

Non-vehicle Assets. For assets besides vehicles, a common approach to characterizing conditions is to use the TERM condition ratings, which range from 5 (excellent) to 1 (poor). TERM Lite includes default deterioration curves for all asset types that predict the change in condition over time, and these are incorporated in TAPT. Figure 2.4 shows an example TERM deterioration curve, in this case for stations.

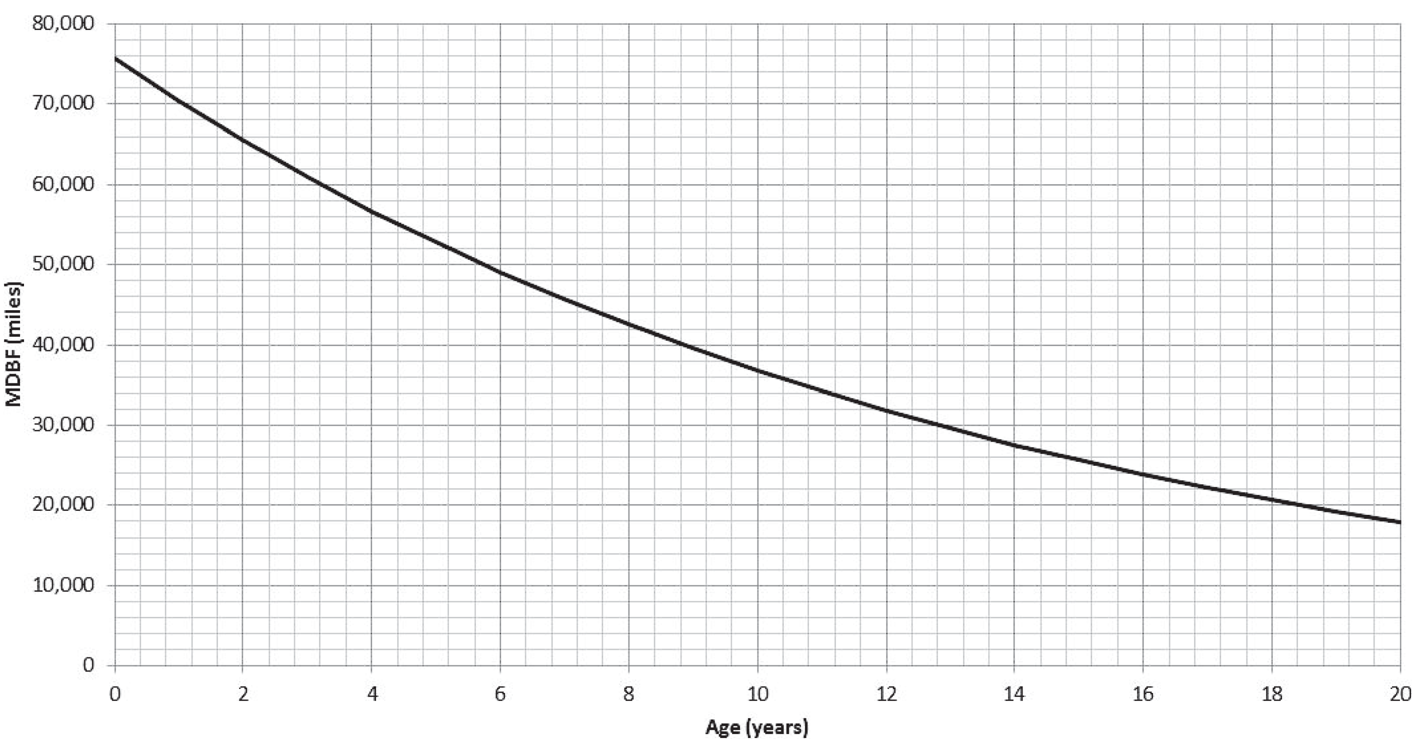


Figure 2.3. Example asset deterioration curve—MDBF versus age.

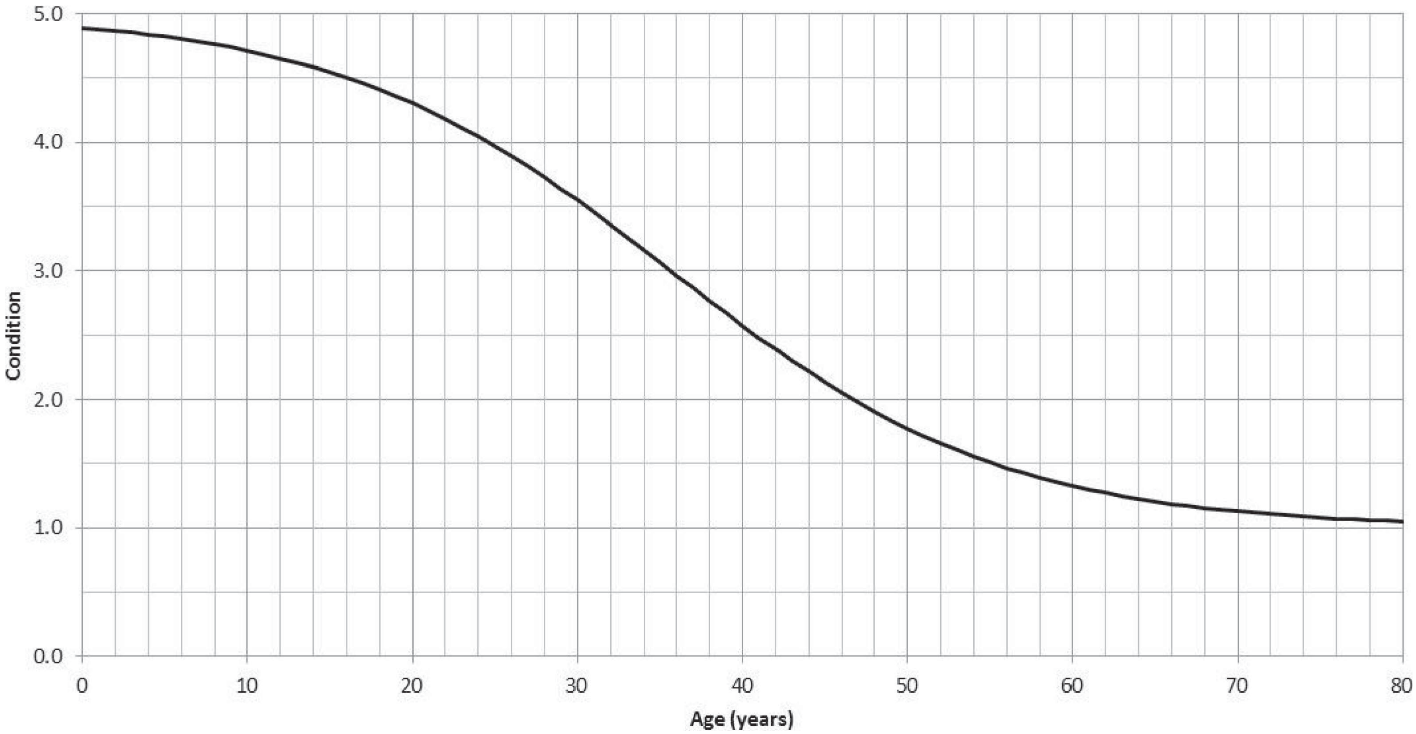


Figure 2.4. Example asset deterioration curve—TERM condition rating versus age.

Asset Deterioration. To develop a TAMP with predictions of future conditions it is necessary to make some assumption about asset deterioration. The most straightforward way to accomplish this step is to either: a) use a tool such as TAPT or TERM Lite with default deterioration curves; or b) model deterioration using asset age or MDBF based on transit agency experience. For transit agencies with large inventories and sufficient data, the recommended approach is to develop deterioration curves specific to the deterioration of the transit agency's assets using historic data and existing TAPT and TERM Lite models as a starting point. Chapter 3 has additional information on how to model deterioration using TAPT.

Step 2.3 Project Replacement Impacts

In this step you will consider your current assets and model the impacts of replacement. In other words, how (and how much) will things improve if you replace your assets, and what will replacement cost? How will a new asset perform, and what will that do to the overall performance level of all of your assets? Performing this step amounts to predicting the lifecycle costs resulting from replacing an asset, and the performance that will result from asset replacement in terms of each of the performance measures established in Step 1.

Generally speaking this step is performed manually only for very straightforward cases with minimal measures to predict. TAPT and other tools simplify this step and combine it with Step 2.4 to determine when to replace an asset to maximize performance and minimize lifecycle costs.

Step 2.4 Develop an Asset Lifecycle Policy

Your transit agency's asset lifecycle policy will guide you in determining how to structure your asset management plan. The policy specifies what maintenance, repair, rehabilitation, and/or replacement actions should be performed on each asset over the asset's lifecycle, viewing each asset type separately. For the purpose of developing the TAMP, the most critical aspect of the lifecycle policy is that it specifies at what point an asset should be rehabilitated or replaced consistent

Table 2.11. Example asset replacement policy—buses.

Vehicle Type		Optimal Replacement Mileage (000)	Optimal Replacement Age (years)	Average Annual Cost (000)
Bus	Artic	569	16	191
	Mall	219	15	128
	Intercity	1,085	18	177
	40-ft	665	15	142

with transit agency goals, absent specific budget, or other constraints. The policy is developed using the results of Steps 2.3 and 2.4 to determine the point at which different actions should be performed to yield the best performance of the agency's service and lowest overall lifecycle cost.

Tools such as TAPT automate the specification of the lifecycle policy. In the case of TAPT, the tool attempts to quantify the full set of agency and user costs that change as an asset deteriorates, and recommend an "optimal policy" with the objective of minimizing lifecycle costs. However, as discussed in Chapter 1, a transit agency may consider additional objectives that are difficult to monetize in forming its lifecycle policy.

The end result of this step is a specification of when different actions should be performed, at a minimum including capital asset rehabilitation and replacement actions. This can be specified in terms of the asset age, mileage, condition, impact on the quality and level of the agency's services, or other measures. Table 2.11 shows an example of a policy for the example set of buses listed in Table 2.3. In this example the policy specifies when to replace different types of buses considering the lifecycle costs of asset maintenance, rehabilitation, replacement, fuel, emissions, and road calls.

Step Three: Define Asset Investment Scenarios

Now that you have catalogued your asset inventory and conditions and have established an approach for predicting replacement needs, it is time to look into the future. **In this step, you will define a number of possible asset funding scenarios and get a view of how those look with respect to your performance measures.** Each scenario will "tell a story" about what will happen to the transit agency's assets, its level and quality of services, and to your system as a whole based on your funding and prioritization decisions.

Comparing alternative scenarios is a powerful tool for supporting investment decisions, particularly when a decision maker must contend with significant uncertainty and investment objectives that are difficult to weigh against each other. The process of evaluating asset investment scenarios requires developing funding and prioritization assumptions, defining the scenarios, and simulating future conditions. The description focuses on asset replacement scenarios, but in practice the approach can be extended to compare these investments to other transit agency investments, such as investments in new capacity.

Step 3 is completed in 4 sub-steps. Upon completion you will have:

- A prioritization approach and some basic funding assumptions to guide you in project selection
- Three or more defined investment scenarios that provide an accurate picture of how key funding and policy decisions will impact your transit agency's operations on the ground

Note: If utilizing the TAPT you should refer to Chapter 3 for specific instructions on how to complete Step 1 through Step 4. Return to this chapter for Step 5 (Develop Transit Asset Management Plan).

Step 3.1 Specify Prioritization Approach

The prioritization approach, informed by the lifecycle policy (Step 2.4) and project replacement impacts (Step 2.3), provides a methodology for designating the order (and timing) that assets will be replaced. While this step does not include funding assumptions (that comes in Step 3.2), it is developed based on the assumption that there may not be sufficient funds to conduct all asset replacement activities at the optimal point in time.

Most structured approaches to prioritizing capital projects assume investments should be prioritized based on an objective of minimizing lifecycle costs. However, many additional considerations may need to be factored into the prioritization process. A transit agency's particular prioritization process is, to a degree, subjective; it should rely on measures and inputs that reflect the agency's customers' desires and expectations.

The prioritization approach can be structured to consider a wide range of factors, depending on your transit agency's goals and objectives. Example factors include:

- Agency lifecycle costs
- User benefits, including travel time and reliability
- Risk of service interruption
- Accessibility
- Environmental impacts
- Projected ridership
- Impact on disadvantaged communities

Safety is not listed above, as operating transit service safely is a fundamental requirement of a transit agency and not a factor which may be varied at different funding levels. Rather than operate in an unsafe manner, it is generally assumed that a transit agency will remove assets from service, or operate them in a manner that provides the required level of safety. For instance, when a section of track is badly deteriorated, a transit agency will place a slow order on the section, increasing delay, rather than operating with a reduced margin of safety. The above factors, including travel time, reliability, and risk of service interruption, quantify impacts caused by reducing the level of service as a result to maintain safe operations.

There are different quantitative approaches for combining the various factors a transit agency may wish to consider when prioritizing. There is no one right approach; the best approach is one that results in a set of priorities that best reflects a transit agency's goals and objectives. Following are three basic approaches for prioritizing projects:

1. **Monetize the different prioritization factors**, and then use this information to select projects based on incremental benefits (cost savings) of performing a recommended rehabilitation or replacement action relative to deferring the action. This is the approach used by TAPT.
2. **Develop a priority rating or score** combining different prioritization factors using a set of weights established through an elicitation process. Various software tools have been developed to assist in this process.
3. **Develop a basic strategy for prioritizing** that reflects agency goals and objectives. For instance, for a transit agency with a limited number of asset types and different funding sources for vehicles and facilities, the prioritization approach may be to use grant funds for vehicle replacements, prioritizing these based on vehicle accumulated mileage. Other transit agency funds are used for facility rehabilitation/replacement, prioritizing these based on remaining service life.

Regardless of the specific approach used for prioritizing, it is important that the approach for establishing initial priorities be documented and repeatable. In cases where a transit agency has a large number of asset types, this implies the use of a software tool to support the prioritization process.

Table 2.12. Example asset project prioritization.

ID	Description	Cost ($ 000)	Rank	
			2014	2023
Guideway-XC 1	Guideway–Grade Crossings–Central	306	1	1
Guideway-Embedded 1	Guideway–Embedded–Central	37,797	2	2
Guideway-Embedded 2	Guideway–Embedded–SW	2,700	3	3
Track-XC Int 1	Track–Grade Crossing–Intensive Use–Central	160	4	6
Track-Embedded Int 1	Track–Embedded–Intensive Use–Central	631	5	7
Track-Special Int 1	Track–Special Trackwork–Intensive Use–Central	5,928	6	9
Guideway-XC 2	Guideway–Grade Crossing–CPV	600	7	4
Guideway-Embedded 3	Guideway–Embedded–CPV	5,267	8	5
Track-Curved Ballasted Int 1	Track–Curved Ballasted–Intensive Use–Central	6,656	9	10
Bus-IC 1	1998 MCI	37,654	10	12
Track-Embedded 1	Track–Embedded–Central	19,104	11	16
Guideway-Embedded 4	Guideway–Embedded–SE	2,371	N/A	8
Bus-Mall 2	2001 Mall Shuttle	5,760	N/A	11
Bus-Transit 1	2000 ORION V	76,416	N/A	13
Bus-Mall 1	2000 Mall Shuttle	6,912	N/A	14
Bus-Mall 3	2002 Mall Shuttle	1,152	N/A	15
Bus-Artic 1	2000 NABI	74,812	N/A	17
Track-Tangent Ballasted Int 1	Track–Ballasted–Intensive Use–Central	990	N/A	18
Bus-Transit 2	2005 Gillig Diesel	16,128	N/A	19
Track-Special 1	Track–Special Trackwork–Central	2,175	N/A	20
Bus-Transit 4	2006 Gillig Diesel	2,688	N/A	21
Track-Curved Ballasted 1	Track–Curved Ballasted–Central	7,176	N/A	22
Track-Embedded 2	Track–Embedded–SW	1,410	N/A	23
Track-Yard 1	Track–Yard–Central	1,097	N/A	24
Bus-IC 2	2001 Neoplan	47,770	N/A	25
Bus-Transit 3	2006 Gillig Hybrid	1,536	N/A	26
Bus-Transit 5	2008 Gillig	2,304	N/A	27
Track-XC 1	Track–Grade Crossing–Central	313	N/A	28
Track-Embedded 3	Track–Embedded–CPV	2,750	N/A	29
Fac-Stations 1	Boulder Transit	2,569	N/A	30
Fac-Stations 2	Civic Center	53,937	N/A	31
Track-Special 2	Track–Special Trackwork–SW	10,429	N/A	32
Bus-Transit 6	2008 Gillig Hybrid	1,920	N/A	33

Table 2.12 shows an example of the results of a project prioritization exercise. In this case the priorities generated by TAPT are shown using pilot data, with a project ID, description, prioritization index (PI), and rank indicated. Here projects are ranked according to PI, which represents the cost savings resulting from performing the project (relative to deferring it) divided by the project cost. Thus, a PI greater than 0 represents a project that, if performed, is expected to reduce lifecycle costs.

Step 3.2 Develop Funding Assumptions for Asset Investments

In order to apply your prioritization approach to a set of actual projects and generate a number of investment scenarios, you must have a working assumption about available funding. At this stage in the process this number need not be final, but it should be realistic given constraints. This funding level will likely be key in distinguishing the investment scenarios you define in Step 3.3. Therefore, it is typical to identify the following:

- Current annual funding amount; and
- An amount that represents a realistic, but meaningful, increase in funding.

You will revisit this funding level in Step 4.2 once you have worked through the investment scenarios.

Step 3.3 Develop Asset Investment Scenarios

The next step is to determine the exact scenarios that will be evaluated as well as the timeframe for analysis. This can result in an iterative process based on the results of the initial set of scenarios. At least four scenarios are recommended for analysis:

- **Current Funding Levels:** this scenario assumes that your funding levels will stay the same as they are (on a constant dollar basis), indefinitely. As the needs and costs continue to rise and assets continue to deteriorate, this will most likely mean that your conditions and performance will decline.
- **Maintaining Current Asset Conditions and Performance:** this scenario describes the funding required to maintain the status quo. As most transit agencies have a backlog of investment needs, maintaining current asset conditions is generally a less ambitious goal than achieving a state of good repair. However, if the system is new, the status quo may actually be better than the long-term condition would project if maintained in state of good repair. In such cases, assets should be assumed to be replaced according to transit agency policy rather than kept in new condition.
- **Projected Future Funding for Assets:** this scenario is where you will test your funding assumptions established in Step 3.2. It will allow you to illustrate the outcomes based on your selected preferred funding level. Typically this amount will lead to conditions and performance that fall above current conditions, and below SGR (although that may not be the case).
- **Achieving a SGR:** this scenario involves those replacement actions consistent with your transit agency's policy to achieve a SGR. This scenario is most meaningful if your asset lifecycle policy has been established to minimize lifecycle costs. In this case, you will be able to show that over time, costs will be minimized if a state of good repair is achieved.

Additional scenarios may be defined to support relevant key factors, such as asset deterioration, ridership, or external events that may impact the system. Scenarios should extend at least 10 years and preferably 20 years into the future.

Step 3.4 Describe Future Decisions, Conditions, and Performance for Each Investment Scenario

In this step, you will use the funding and prioritization assumptions as inputs into an analysis of the investment scenarios that you have selected. This will require the identification of actual projects, and the inclusion or exclusion of each within each of your chosen scenarios. You will then look at how your projects perform within each of the investment scenarios. The analysis for this step should be performed using the same basic approach as that in Step 2.1 (Calculate Current Asset Conditions and Performance), but with the analysis repeated for each year of the analysis period. From one year to the next the approaches used for calculating deterioration (Step 2.2) should be applied to determine how conditions and performance will vary, and the impacts of replacement (Step 2.3) should be considered for any projects assumed to occur given projected funding. The results of this step will be a set of predicted conditions and costs that will enable you to compare the scenarios against the current environment.

Table 2.13. Example scenario summary.

Scenario	Initial Value (2014)	Value in 2023		
		1-Do Nothing	2-$25M Annually	3-Unconstrained
Unmet Needs ($ 000)	116,803	439,419	233,004	0
Cumulative Spent ($ 000)	N/A	0	209,415	439,419
MDBF (miles)	35,649	20,407	33,033	39,791
Average TERM Condition (non-vehicle assets)	4.68	4.39	4.54	4.62
Passenger Delay (hrs)	113,682	170,399	150,781	146,801
CO_2 Emissions (tons)	248,160	294,722	278,009	271,134
Other Agency Costs ($ 000)	196,292	278,332	219,534	197,762
Total Agency and User and External Costs ($ 000)	207,750	293,654	233,504	211,374

Table 2.13 shows example results from this step, in this case the results projected for three scenarios for the transit agency pilots using TAPT. These scenarios include: 1) do nothing, 2) invest $25 million annually, and 3) unconstrained (achieve SGR).

Step Four: Finalize Asset Investment Scenarios

With projected results for your chosen investment scenarios, you now have the opportunity to review the results, and revise them to arrive at the best possible final scenario considering available funding. **In this step you will revisit your asset lifecycle policy, prioritization approach, and funding assumptions; and select a preferred scenario.** Your preferred scenario will be the one that you will take to your decision makers, and, if approved, will be the version that is reflected in your TAMP.

Step 4 is completed in 2 sub-steps. Upon completion you will have:

- A final (and perhaps revised) asset lifecycle policy
- A final (and perhaps revised) asset prioritization approach
- A preferred asset investment scenario

Note: If utilizing the TAPT you should refer to Chapter 3 for specific instructions on how to complete Step 1 through Step 4. Return to this chapter for Step 5 (Develop Transit Asset Management Plan).

Step 4.1 Revisit and Revise Asset Lifecycle Policy, Funding, and Prioritization Assumptions

Now that you have your scenarios developed, it is time to revisit some of the assumptions that you had to make initially to get to this point. Upon looking at the outputs, you may decide that your asset lifecycle policy is too aggressive for some asset types, or not aggressive enough for others. You may realize that your funding or prioritization assumptions are leading to outcomes within one or more scenarios that are not feasible, or leading you far from the targets you have established. Or, you may realize that replacement of some assets is dependent upon replacement of others (e.g., new low floor vehicles may require station upgrades which received a lower priority). This relationship should be noted in the lifecycle policy to ensure that your final plan does not present a set of investments that do not functionally support each other.

The following questions may assist you in this analysis:

- Are the investment priorities consistent with the scenarios defined previously? That is, if the priorities are used to select what work to perform, is the predicted distribution of funds consistent with that modeled in the scenarios? If not, then the scenario evaluation or prioritization approach should be revised so that its results better match.
- Do the resulting priorities match decision makers' expectations concerning how funds should be allocated across modes, asset types, types of investments, etc.?
- Do the conditions and performance predicted, given the expected budget allocation (or a range of possible budgets), meet transit agency performance measure targets? If they do not, this may suggest that changes to the prioritization approach are warranted. Alternatively, the transit agency may need to reconsider its goals or performance measure targets if available funds are insufficient for achieving them.
- Are there groups of investments with essentially identical priorities? This is a common outcome when an objective function is used to capture a number of different objectives. Where this occurs may suggest the need to fine-tune how projects are prioritized to better distinguish between projects, or establish a separate funding category for handling like projects.
- Are certain assets or activities systematically given low priority? Though some investments are clearly more vital than others, one would expect that as an asset nears the end of its useful life the benefits of replacing the asset would be manifest. Consistently low priorities may suggest the need for revising the prioritization approach, or may suggest that the lifecycle policy is overly conservative, generating recommendations for replacement before an asset is truly at the end of its useful life. If this issue occurs but cannot be easily addressed then a separate funding category or minimum funding level can be established for the affected assets or activities.
- Where are assets within the "window of opportunity" with respect to rehabilitation solutions? Generally, rehabilitation investments can be maximized when they are applied nearer the threshold of when replacement is required.

This is an iterative process, and may take you back through Steps 3.1 and 3.2.

Step 4.2 Finalize and Select the Preferred Scenario

Once you have completed Step 4.1 you will have a revised set of scenario results to review. The next step is to select a scenario that is preferred considering transit agency goals and objectives, as well as available funding. Ideally you will have one scenario that offers an acceptable set of future conditions, and that depends upon a level of funding that is reasonable and attainable. If not, it may be sensible to consolidate or develop a compromised version of two or more scenarios to arrive at the one that will be the best fit. Your final preferred scenario should include a projection of future values for all of the performance measures selected in Step 1.4 for a period of 10 to 20 years. Also, it should include details on the funding assumptions and work assumed to be performed given the projected funding. The scenario should be presented to the transit agency's executives for approval for inclusion in the TAMP. If it is helpful, you may want to include an overview of the other investment scenarios in presenting the preferred scenario for contextual purposes and to illustrate the impacts of different funding levels.

Step Five: Develop the Asset Management Plan

The final step will result in the development of your TAMP. If you are using a tool (e.g., TAPT), this is the step where you integrate those outputs into a plan that your transit agency can implement. **In Step Five you will make all final adjustments and decisions, and prepare your TAMP for official adoption by your agency.**

Step 5 is completed in 3 sub-steps. Upon completion you will have:

- A final version of your TAMP

Note: If utilizing TAPT, this is where you should start for guidance on putting together your TAMP once you have prioritized replacement needs in TAPT.

Step 5.1 Finalize Funding Levels and Constraints

At this stage in the process, your executives will have provided you with a final set of funding assumptions for your use in the TAMP. Your plan should include planned asset investments by year for a period of at least 10 years. For transit agencies with a small number of capital projects, the plan may simply be the transit agency's capital plan supplemented with additional information and analysis of its existing assets. For transit agencies with a large number of projects, the TAMP will likely stand as a companion document to the capital plan.

The determination of overall funding level may be influenced by perceptions of the transit agency's SGR needs, but in the short term the overall funding level is often a given based on available federal, state, and local funding, as well as projected farebox revenue. The distribution of assets between investment categories may also be a given, but as much as possible transit agency decision makers should rely on the analyses described in previous steps. This work enables them to consider funding levels based on an assessment of how well a given distribution of funds will achieve transit agency goals, perform, and meet the established targets.

Also in this step, it is necessary to specify any funding and other constraints that may impact project selection. For instance:

- Are certain funds specified for use for certain assets or actions (e.g., bus replacements)?
- Are there certain investments that will need to be "pipelined" either because the transit agency committed to these projects in the previous plan, or because a decision on the project has been made externally?
- What capacity constraints need to be considered, such as limits on the amount of work performed at once on a given line, or the number of projects that can be designed simultaneously?
- Are there minimum amounts of funding that should be invested by asset, mode, or administrative or geographic distribution, such as to best utilize existing staff and resources?
- Where is coordination with other stakeholders required, such as state and local agencies or other transit agencies, which may impact project timing?
- Do funding constraints systematically exclude certain types of work from consideration because they are ranked low on the list of priorities?
- Are there other political or institutional factors such as legal or environmental mandates that are influencing the distribution of funds or the selection of projects?

Step 5.2 Select Specific Projects

Before the plan can be prepared, the projects to be included in the plan need to be fully defined. This includes characterizing the scope, timing, and budget of each of those projects, and verifying that they can be scheduled as assumed (e.g., all design, permitting, etc. is or will likely be in place as programmed). The detail to which the projects are specified should match your transit agency's standards for capital plan development.

Next, a set of decision makers entrusted with finalizing the investment plan must select the set of rehabilitation and replacement projects to include in the plan, considering the funding levels that have been established and any constraints on how those funds may be used. If there are few complicating constraints, the project prioritization approach is fully specified, and funding levels are generally adequate, then selecting the set of projects may be as simple as working through the list of alternative projects in decreasing order of rank and selecting projects until the budget is expended. In practice, though, it is likely that there will be complicating factors that need to be considered when selecting the final set of projects.

For these reasons the decision makers who must finalize the investment plan generally have their work cut out for them as they balance competing objectives and constraints and attempt to find a plan that is both feasible and that best meets the transit agency's goals and objectives. The priorities suggested through the previous steps and the results of any models used to recommend specific projects provide valuable input, but the final decision of what projects to include in the plan is made weighing this information with additional factors not captured in the prioritization formula and models.

Step 5.3 Prepare the Plan

Once the set of projects to include in the plan has been specified, the TAMP itself can be finalized. The plan documents the results of the analysis in terms of what specific actions are recommended or planned, as well as to detail *why* funds are needed for asset replacement, *how* available funds should be distributed, and *what* the planned investments will accomplish. It thus forms an action plan and serves as a tool to support needed investments. There are many ways to structure a plan that will accomplish these goals. Here is a suggested format.

Sample Transit Asset Management Plan Table of Contents

1. Executive Summary
2. Introduction and Background
   The introduction should include an overview of what is included in the report, a quick overview of the process (including who was involved, how the investment scenarios were vetted, etc.), the dates to which it applies, and how it will be implemented within the agency.
3. Transit Agency Context and Policies
   a. Asset Inventory
      The asset inventory can be done on a sub-class level (e.g., by fleet, not individual vehicle). (Step 1.1)
   b. Definition of State of Good Repair
      Beyond stating the transit agency's adopted definition of SGR, this section may discuss any relationships or connections to the agency's mission or goals. (Step 1.3)
   c. Performance Measures and Targets
      This section should clearly list the adopted performance measures and targets. It may also include details on reporting practices, data collection, etc. (Step 1.4)
   d. Asset Lifecycle Policy
      This section should describe the agency's asset lifecycle policy, focusing on thresholds for performing rehabilitation and replacement actions included in the plan. It may also discuss how the deterioration model and other analysis impacted this policy. (Step 2.4)
   e. Prioritization Approach
      This section should describe the transit agency's prioritization approach, including all factors that are considered and the way in which those factors are considered. (Step 3.1)

4. Current Conditions
   a. Asset Conditions and Performance (Step 2.1)
      This section should be a list of the existing assets and how they are doing with respect to the selected performance measures and targets.
5. Investment Scenario
   a. Funding (Step 5.1)
      This section should detail the finalized funding amounts, by funding category if applicable.
   b. Projects (Step 5.2)
      This section should include a high level description of the projects that were selected for inclusion in the preferred investment scenario.
   c. Projected Performance Measures and Targets (Step 3.4 and Step 4.2)
      This section will mirror section 4.1, but include the projected future performance measures and targets based on the preferred funding scenario.
6. Capital Investment Plan (Step 5.2)
   This final section can be a stand alone Capital Investment Plan (CIP) for your agency. It will include the standard CIP detail for all of the projects included in the selected investment scenario.

CHAPTER 3

Using the Transit Asset Prioritization Tool

Introduction

This section provides step-by-step instructions for using TAPT. After reading this chapter, you should understand how to input the required data, how to run scenarios, and how to interpret the outputs. Additional guidance is provided in the tool, indicated by a ⓘ symbol. Information on the modeling approach and defaults used in the model is provided in the accompanying research report, *Guidance for Applying the State of Good Repair Prioritization Framework and Tools: Research Report.*

TAPT is used to model rehabilitation and replacement needs for transit capital assets. The tool supports definition of a range of different asset types. For a transit agency's asset inventory, the tool predicts future conditions and performance, and helps prioritize asset rehabilitation and replacement.

The tool includes three basic models:

- A model for vehicle assets;
- A model for non-vehicle assets that can be modeled based on age; and
- A model for non-vehicle assets that can be modeled based on condition.

For each of these models, describe its existing asset inventory, and the model predicts how the condition and performance of the inventory will vary over time, as well as when to rehabilitate or replace assets. To use the tool one first creates models for each asset type, specifying which model to use for each type.

Once you have created a set of asset models, you can specify additional parameters, such as the budget available for asset rehabilitation and replacement, and then perform an analysis. The results of an analysis include a projection of future conditions, performance and costs by year, and a prioritized list of projects. By default, assets are prioritized with an objective of minimizing lifecycle transit agency and user costs using a metric called the PI. However, the system user can adjust the prioritization calculation to set weights on different types of cost, and/or incorporate other factors.

It is possible to perform multiple runs by changing either the parameters or the asset inputs (for example, deleting some assets from the analysis or adjusting the budget) to illustrate how those factors impact the recommended program. The results from the runs can be displayed as a table, or using a charting tool that allows up to two runs to be compared.

System Requirements

Running TAPT requires Microsoft Excel 2007 or higher. TAPT has been tested in Microsoft Excel 2007, 2010, and 2013 for Windows computers, and Microsoft Excel 2011 for Macintosh computers.

In order for the buttons and the models to function, macros must be enabled. To enable macros (in Excel 2007 or 2010):

1. If the computer security setting is set to Low, macros will automatically be enabled.
2. If the computer security setting is set to Medium, a window will appear when the tool is opened, prompting the user to enable macros. The user must click the **Enable macros** button to successfully enable the tool.
3. If the computer security setting is set to High, a 'Security Warning' window will open. Check the **Always trust macros from this source** option and click the **Enable macros** button to enable the tool.
4. If the **Always trust macros from this source** box cannot be checked, use the following steps:
   a. Click **Details** or **Detail Signature Details**.
   b. Click **View Certificate**.
   c. Click **Install Certificate**. This will initiate the Certificate Import Wizard.
   d. Click **Next**, **Next**, and **Finish**. This will initiate a security-warning window.
   e. Review the warning and click **Yes** at the bottom of the window.
   f. Click **OK** on all remaining windows.
   g. The **Always trust macros from this source** checkbox should now be available to edit. Check the box and click **Enable macros** to complete the process and enable the tool.
5. If the computer is running Microsoft Excel 2007, it is likely that macros will automatically be disabled. In order to enable macros, use the following steps:
   a. Click the **Office** icon and click **Excel Options** from the dropdown menu.
   b. Check the box for **Show Developer Tab in Ribbon**.
   c. Click on the **Developer** tab.
   d. Click on **Macro security** to open the 'Trust Center' window.
   e. Select **Disable all macros except digitally signed macros** and click **OK**. This will open the 'Security Warning' dialog box.
   f. Click **Options** on the 'Security Warning' dialog box.
   g. Click **Details** or **Detail Signature Details**.
   h. Click **View Certificate**.
   i. Click **Install Certificate**. This will initiate the Certificate Import Wizard.
   j. Click **Next**, **Next**, and **Finish**. This will initiate a security-warning window.
   k. A window will open to say the import was successful. Click **OK**.

Tool Components

TAPT is a Microsoft Excel spreadsheet with multiple models on different worksheet tabs. Figure 3.1 depicts the Start Screen of the tool, which provides access to all models, parameters, and results.

Using the Tool

All data is input in the asset model worksheets and in the **Budgets and Economic Analysis Parameters** worksheet. Concerning the asset model worksheets, each asset type utilizes one of three basic model templates: the **Vehicle Model**, the **Age-Based Model**, or the **Condition-Based Model**. It is important to review the required inputs for these three models to ensure that the model selected for each asset group best reflects the available data. Buttons on the **Start Screen** and model worksheets can be used to navigate through the tool. Note that certain fields in TAPT are hidden and/or locked to streamline use of the tool.

In addition to the instructions provided here, information on the data inputs is provided in the tool. For more information on any of the fields in TAPT, scroll over the ⓘ icon in the tool for a more detailed description.

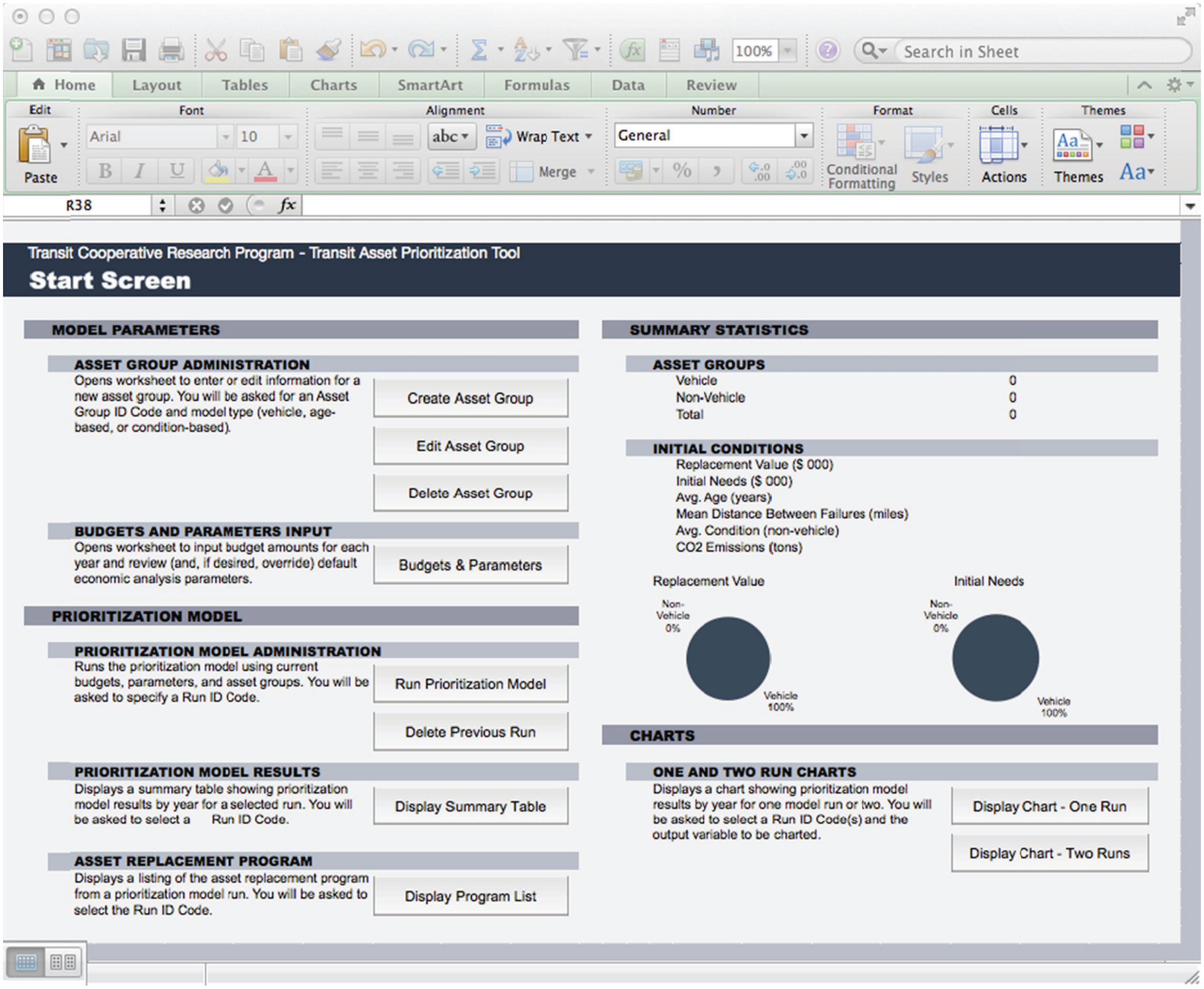


Figure 3.1. TAPT Start Screen.

The Start Screen

The Start Screen contains buttons for accessing all of the major components of TAPT. The screen contains four sections (Figure 3.2).

1. The **Model Parameters** section allows the users to provide inputs, including managing assets in the tool and setting parameters for all assets.
   - **Asset Group Administration:** Defines asset groups to be included in the analysis. Asset groups can be created, edited, and deleted from the Start Screen.
   - **Budgets and Parameters Input:** Includes a button to define the budgets and parameters that will be applied to all of the assets in the analysis.
2. The **Prioritization Model** section allows the user to run the prioritization model and display the results.
   - **Prioritization Model Administration:** Runs the prioritization model based on the included assets and allows the user to delete previous runs.

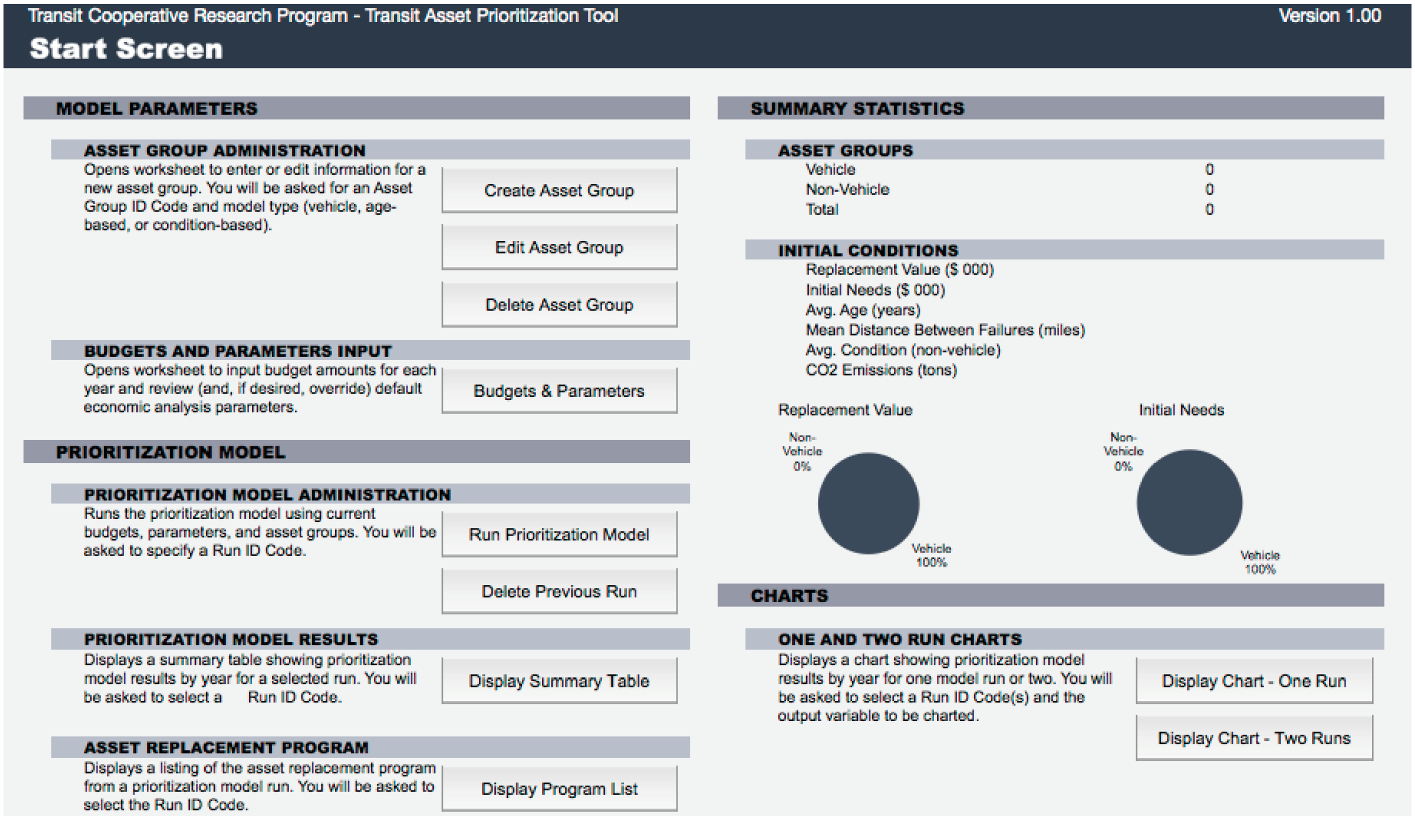


Figure 3.2. Start Screen.

- **Prioritization Model Results:** Displays a summary table that shows the data that has been included in the prioritization analysis.
- **Asset Replacement Program:** Displays a program list that shows how projects used in the prioritization run should be programmed over the analysis period. Includes information on program year, asset descriptions, and cost.

3. The **Summary Statistics** displays data from the most recent prioritization model run.
4. The **Charts** section allows the user to create charts using prioritization model runs. The tool provides a number of default calculations that can be graphed, either using a single prioritization run or comparing two prioritization runs.

Parameters

Inputting Budgets and Parameters

The following steps describe the process of entering budgets and parameters into TAPT. The parameters will be used to define the defaults for assets in the tool and determine constraints for the analysis. The budget is used during the analysis phase to simulate rehabilitation and replacement work. Note that budgets are specified in constant dollars.

1. From the Start Screen, click on the **Budgets and Parameters** button (Figure 3.3).
2. Define the budget using the first set of **Parameters** (Figure 3.4).
   - Choose the **First Budget Year**, which will be the first year of the analysis. The default for this value is 2015, meaning that the first projects will be programmed for 2015. The suggested value for the first budget year is the year after the most recent inspection.

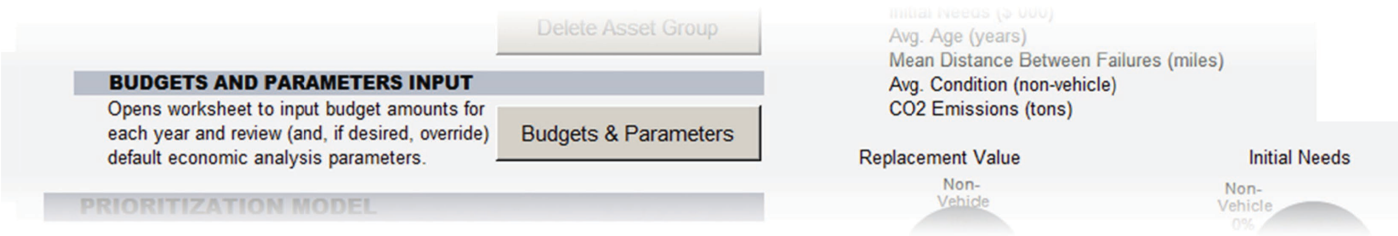


Figure 3.3. Budgets and Parameters Input.

- Determine if the analysis should **Allow budget to carry over**? This will determine if excess funds at the end of the program year can be used in subsequent years. Valid inputs for this field are either "TRUE" or "FALSE." The default for this value is "TRUE," meaning the budget will be allowed to carry over. Only provide an override value if the budget should be reevaluated annually and excess funds from previous years will not be allowed to carry over.
- Define the **PI Threshold for Asset Replacement**. The PI is the net present value (i.e., benefits minus costs) of replacing or rehabilitating an asset in the current year relative to deferring action for one year divided by the rehabilitation or replacement cost. If the PI is greater than zero, then the lifecycle cost of maintaining the asset will be lower if the asset is rehabilitated or replaced in the current year rather than later. If the PI is less than zero, then asset rehabilitation/replacement in the current year cannot be justified strictly based on economic grounds, though it may be justified based on consideration of other factors. TAPT will attempt to perform all rehabilitation/replacement actions with a PI value greater than or equal to the specified threshold value. The default for this threshold is zero, meaning that any project that is not considered economically justifiable will not be included in the analysis. Pipeline projects will be considered regardless of the PI. Adjusting this value allows the user to program projects that have additional value to the transit agency or to determine a program for allocating excess funding.

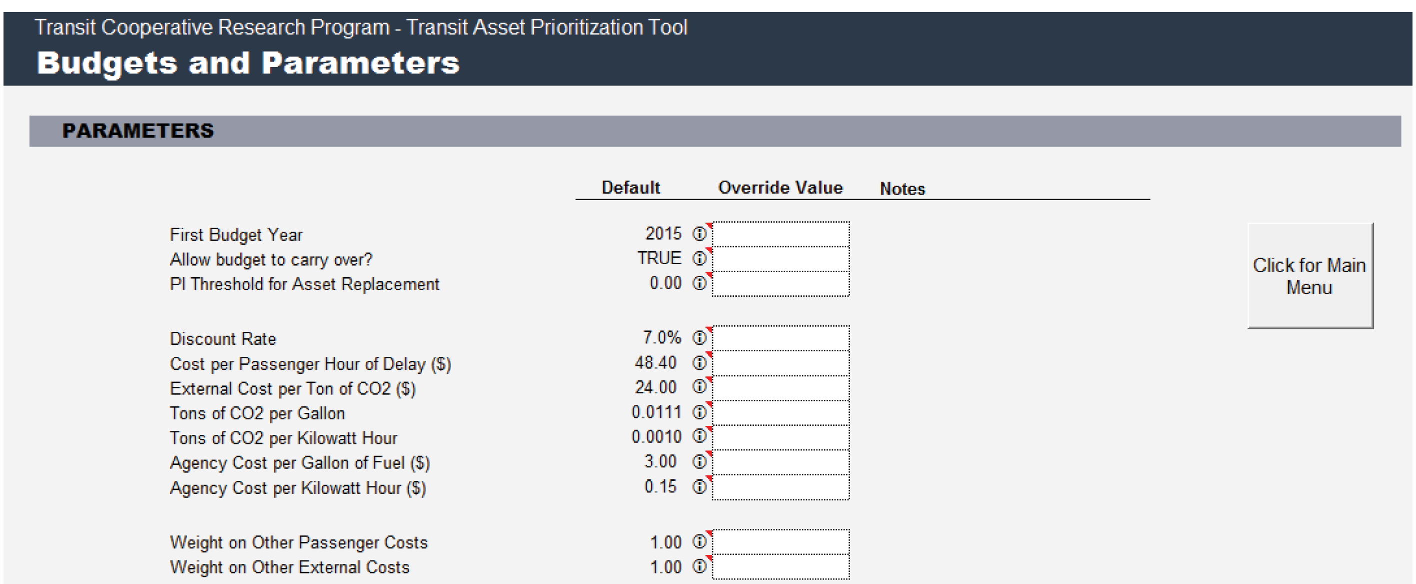


Figure 3.4. Parameters.

What Is the PI Threshold and When Should It Be Adjusted?

The PI is used to rank projects in TAPT. By default it represents the savings in lifecycle transit agency and user and external costs from performing a project in a given year relative to deferring the project for one year divided by the project cost. Thus, a project with a PI greater than 0 is projected to reduce costs over the long term relative to deferral. However, one can adjust the PI values for a given asset group in TAPT and/or adjust the weights on different types of costs, which may raise or lower PI. The PI threshold is the minimum value for PI for a project to be considered as a need and included in the prioritization. By default this threshold is 0, but you may wish to adjust this value through editing the **PI Threshold for Asset Replacement** field. Some examples of when it might be appropriate to adjust the threshold for replacement include:

- If there are additional benefits to asset rehabilitation or replacement that are not reflected in the models, such as improved quality or service from implementation of new technologies.
- If the transit agency has adjusted weights on user or external costs, or entered a supplemental replacement benefit for any of the asset groups to better reflect transit agency priorities.
- If the **Allow budget to carry over**? field is set to "FALSE," meaning that funds may not be carried over from one year to the next, a lower threshold may be justified to reduce the extent of unspent funds.

3. Define the Economic Analysis Parameters for the analysis. Note these parameters all are populated with default values, but the user can override these defaults if desired (Figure 3.5).
   - Define the **Discount Rate**. This value is used to quantify the time value of money and should be set according to transit agency policy. If no transit agency value has been defined, the default value of 7.0% should be used.

Defining the Discount Rate

The discount rate is the annual percentage by which future costs should be reduced (discounted) to compare with present costs. The discount rate is used to quantify the time value of money. That is, provided the opportunity to receive a given benefit either in the present or in the future, you would generally prefer to receive the benefit in the present. Likewise, if you must incur a given cost in the present or future, you would generally rather incur the cost in the future. The discount rate quantifies these preferences. Note the discount rate is not a measure of inflation: all costs and benefits in TAPT are expressed in constant dollars and exclude consideration of inflation.

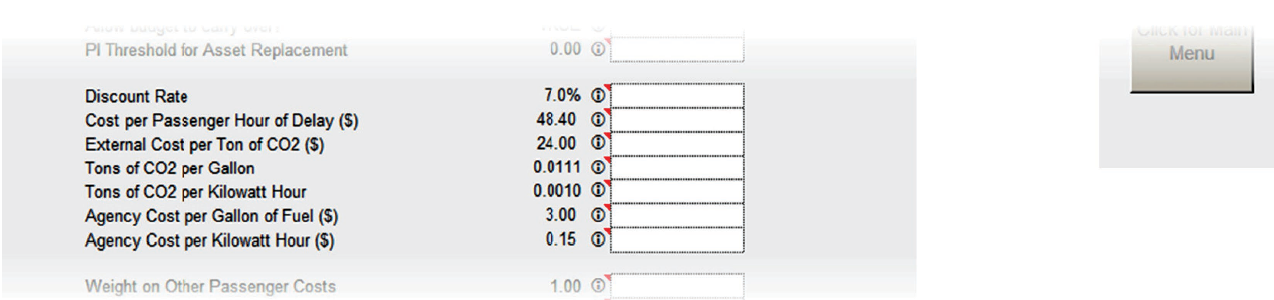


Figure 3.5. Parameters cont.

The discount rate is an important parameter in any calculation of future economic costs and benefits. Many organizations establish a discount rate for use in analyzing potential investments. If your transit agency has developed guidance on the rate to use for economic analyses, you should enter that in TAPT. The default value in TAPT is set at 7%, which is the value used by the federal government for benefit-cost analyses of public investments, as stipulated in Office of Management and Budget (OMB) Circular A-94. For internal investments, OMB recommends using the U.S. Treasury borrowing rate. For 2013, the real borrowing rate (with inflation removed) was 1.1% for a 30-year bond. Thus, pending specific guidance on the rate to use, and depending on the nature of the analysis being performed in TAPT, a rate between 1% and 7% is recommended.

- Define the **Cost per Passenger Hour of Delay**. This value defines the delay cost per hour for a transit passenger. This value will be used to calculate defaults for all assets included in the tool.
- Define the **External Cost per Ton of CO_2**. This value defines the external cost of a ton of CO_2. This value will be used as the default for assets in the tool. This value will also be used to calculate energy and environmental costs. Override values for specific assets can be input using the models.
- Define the **Tons of CO_2 per Gallon**. This value defines the tons of CO_2 produced per gallon of fuel. This value will be used as the default for assets in the tool that use fuel. This value will also be used to calculate energy and environmental costs. Override values for specific assets can be input using the models.
- Define the **Tons of CO_2 per Kilowatt Hour**. This value defines the tons of CO_2 produced per kilowatt hour. This value will be used as the default for assets in the tool that utilize electric power. This value will also be used to calculate energy and environmental costs. Override values for specific assets can be input using the models.
- Define the **Agency Cost per Gallon of Fuel**. This value defines the cost to the transit agency of purchasing a gallon of fuel. This value will be used as the default for assets in the tool that use fuel and will be used to calculate transit agency costs.
- Define the **Agency Cost per Kilowatt Hour**. This value defines the cost to the transit agency of purchasing or producing a kilowatt hour of energy. This value will be used as the default for assets in the tool that utilize electric power and will be used to calculate transit agency costs.

4. If desired, define weights for other passenger costs and external costs (Figure 3.6). These costs are used to define the relative importance of passenger costs and other external costs relative to transit agency costs in selecting assets for replacement. These are set to 1 by default, meaning these costs are weighted the same priority as other costs in the analysis. The user can override these values based on transit agency priorities, such as if defining a custom priority function.

   Note: This does not include the costs for personal value of time or CO_2, as those costs are defined elsewhere in the spreadsheet.
   - Define the weight for **Other Passenger Costs**.
   - Define the weight for **Other External Costs**.

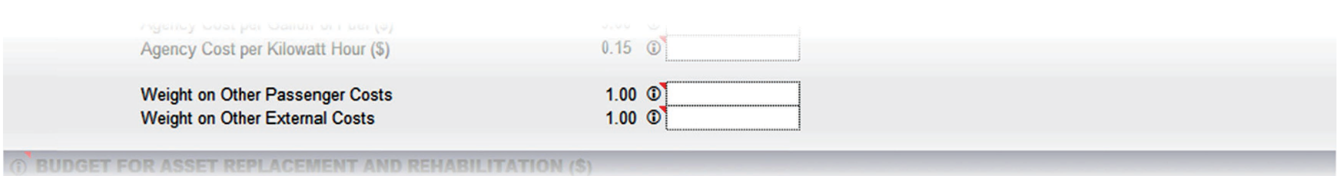


Figure 3.6. Parameters cont.

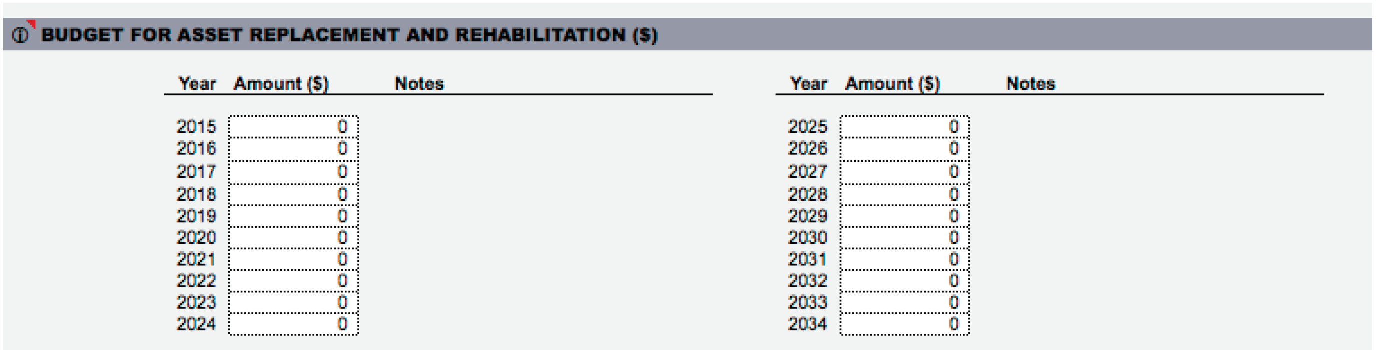


Figure 3.7. Budget for Asset Replacement and Rehabilitation.

Weighting Costs

TAPT considers three types of costs in prioritizing asset rehabilitation and replacement activities:

- Agency costs, including costs of maintenance, asset replacement, and asset failure, as well as energy costs.
- Passenger costs, including delay costs (and delay from asset failure), as well as other unspecified passenger costs.
- External costs, including costs of CO_2 emissions and other unspecified external costs, which may include costs of noise and air pollution, for instance.

The system user has the ability to adjust the priority on all of these costs either by explicitly entering unit costs, or entering weights as described above. There are numerous transit agency cost parameters, so to change the priority on transit agency costs it is easiest to leave these unchanged, and adjust the priority of other costs accordingly. To change the priority on passenger delay costs, edit the value of the Cost per Hour of Passenger Delay. To change the priority on CO_2 emissions, change the External Cost per Ton of CO_2. To change the priority on other passenger and external costs, edit the weights on these. Together these parameters can be used to specify a transit agency-specific prioritization function in TAPT.

5. Define the **Budget for Asset Replacement and Rehabilitation** (Figure 3.7). **This field is required**. The **Budget for Asset Replacement and Rehabilitation** should be defined annually. The analysis period, which covers 20 years beginning with the **First Budget Year**, is automatically populated in the **Year** field. For each **Year** the budget **Amount** should be specified. No default values are provided for this field.
6. When all of the required values have been defined and any additional fields for which the transit agency has data have been completed, use the **Click for Main Menu** button to return to the Start Screen.

Asset Group Administration

The following pages describe how to create a new asset group in TAPT (Figure 3.8). Note that when creating an asset group, you must decide whether to use the vehicle, age-based, or condition-based model. The vehicle model should be used for all revenue vehicles. The other models are used for assets beside vehicles, with the condition-based model reserved for cases

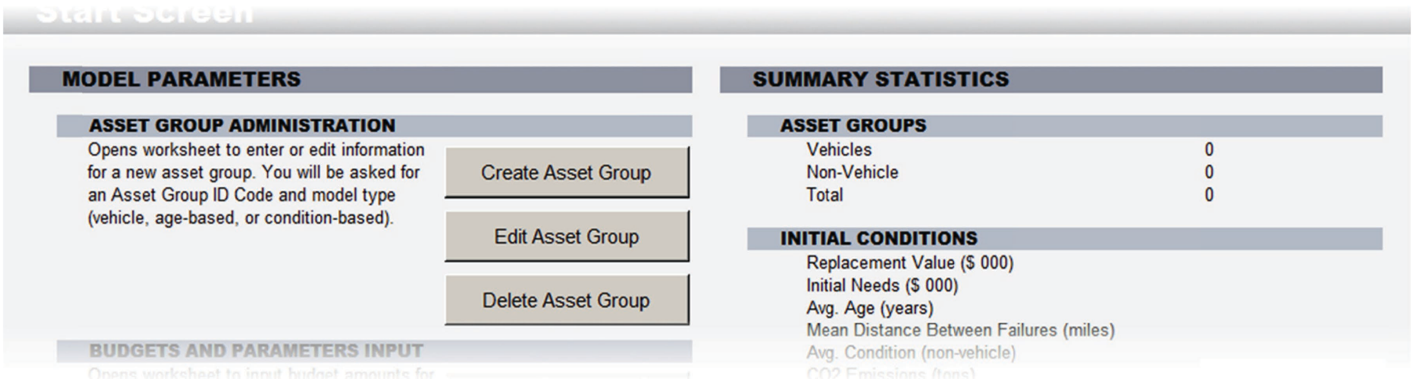


Figure 3.8. Asset Group Administration.

where a transit agency has condition data available. Separate instructions are provided for each model type.

Creating an Asset Group: Vehicle Assets

The vehicle model is used for all vehicle assets in TAPT. The model is designed to take input data that are readily available for revenue data, such as items reported to the NTD. The model contains defaults for multiple vehicle types including: bus, light rail, heavy rail, commuter rail locomotive, commuter rail coach, vans, and small buses.

1. From the Start Screen, click on the **Create Asset Group** button.
2. On this screen, define an **Asset Group ID Code** for the asset group (Figure 3.9).

   Note: It is mandatory to define an asset group ID code and codes cannot be repeated. It is recommended that the ID code contain a basic description of the asset being modeled, as the code will appear throughout the results.
3. Select the **Asset Group Model Type** as **Vehicle Model** to create an asset group for vehicle assets.
4. Click the **Create New Group** button to create a new sheet and input data for the asset group.
5. Use the drop down menu to select the **Vehicle Type** (Figure 3.10). The vehicle type can be defined as Bus, Heavy Rail, Light Rail, Commuter Rail Locomotive, Commuter Rail Coach, Vans, or Small Buses. The default values used in the model will automatically adjust based

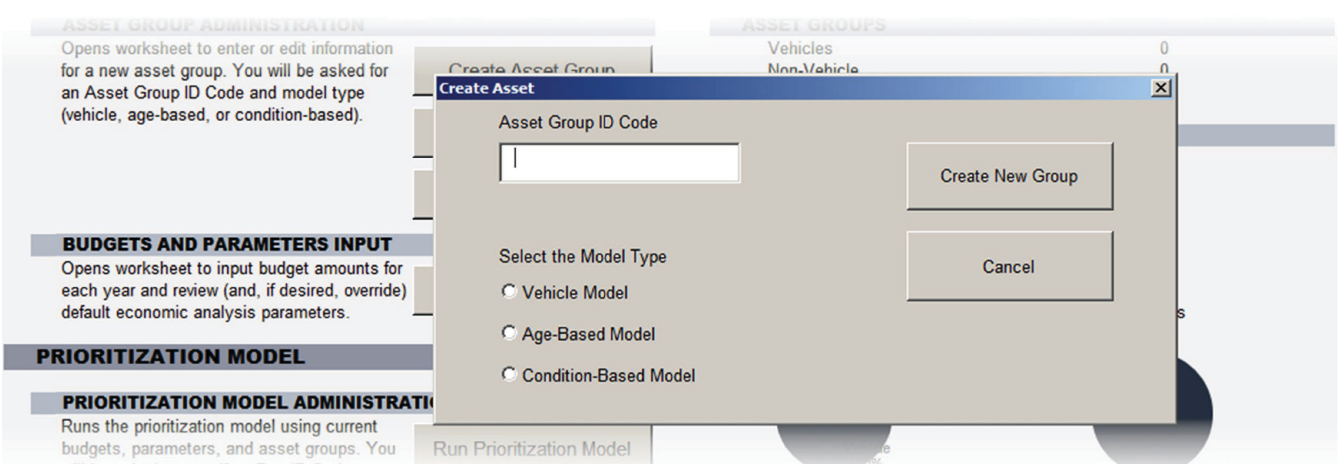


Figure 3.9. Create Asset.

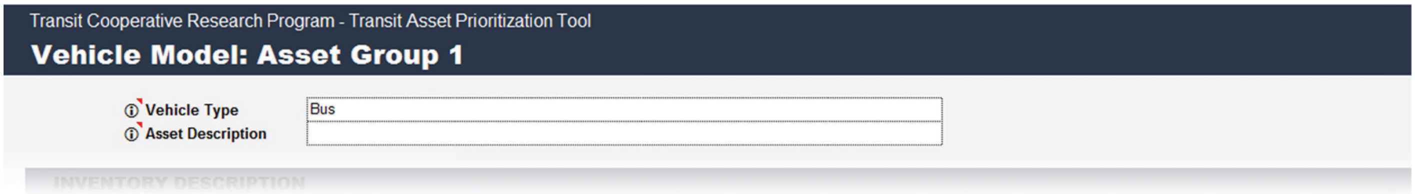


Figure 3.10. Vehicle Model.

on the vehicle type that is selected. If the desired vehicle type is not available, choose the vehicle type that best describes the asset to be modeled and provide override values to adjust the model as necessary.

6. Use the **Asset Description** field to input a detailed text description of the assets included in the worksheet. This description will be used later in the tool to describe projects that appear in the Program List.

Handling Different Operational Environments

If your transit agency operates assets differently within the same asset group, you may want to consider creating additional asset groups. For example, you may have a fleet of buses, some of which you operate in urban service areas and others you run on suburban routes. While they may fall within the same NTD group, these sets of vehicles are going to have different average annual miles and maintenance costs and needs. Therefore, creating separate asset groups for such can offer more accuracy in the model, and result in more reasonable prioritization recommendations in the output.

7. **These fields are required.** Input **Inventory Description** data (Figure 3.11). For this section, vehicles are typically grouped together based on where they are of similar type and age.
   - The **Accumulated Mileage** is the average total mileage for each of the vehicles in the sub-group. It is the total mileage from when the vehicle was new until the end of the year before the first budget year. For each asset sub-group, input the accumulated mileage.

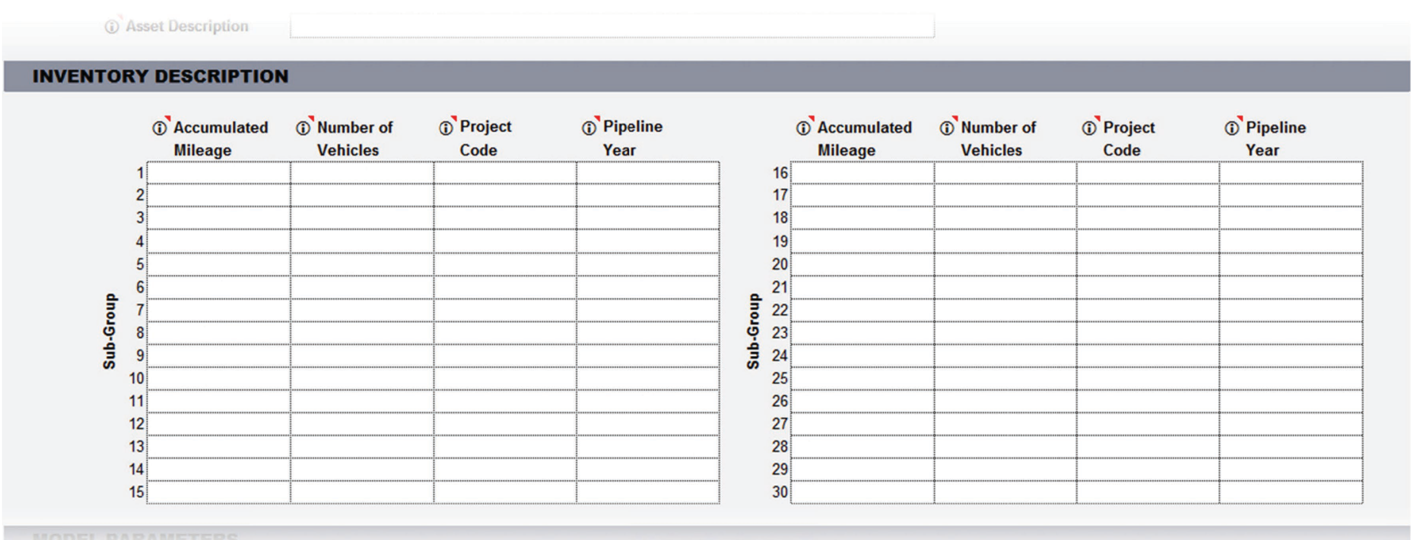


Figure 3.11. Vehicle Model: Inventory Description.

- Input the **Number of Vehicles** in the asset sub-group.
- The **Project Code** is used to specify when the replacement of two or more groups of assets is to be treated as a single project. Entering the same project code for two or more sub-groups of assets means they are to be analyzed together. This means that either all sub-groups with the same project code will be replaced in a given year, or none of the sub-groups will be replaced. A project can include different types of assets, provided they have the same project code. Input a project code if multiple asset sub-groups should be analyzed together. If the asset sub-group should be analyzed on its own, the project code can be left blank or given a unique value to help describe the asset subgroup in the model results.
- The **Pipeline Year** is entered when the replacement of a group of vehicles has already been scheduled for a given year. If the project has already been scheduled during the analysis period, input the year the project is programmed. If the project has not been scheduled, the pipeline year should be left blank.

8. Input **Vehicle Data from the National Transit Database** (Figure 3.12). The vehicle data from the NTD is used to establish a number of model parameters for the vehicles being modeled. If these items are left blank, then the system user will have the option to either use national defaults for the model parameters described in the next section, or can enter these directly. While these fields are not required, they are strongly suggested. If the assets being modeled correspond to the assets reported for a single mode in the NTD, then NTD-reported values can be used directly, as described below.
   - Define **Passenger Miles (000)**. This value is the cumulative sum of the distances ridden by each passenger, measured in thousands of miles. This value can be found in Service form S-10.
   - Define **Unlinked Trips (000)**. This value is the annual number of passengers who board public transportation, measured in thousands of trips. This value can be fund in Identification form B-10, Operating Expenses form F-30, Service form S-10, and Federal Funding Allocation Statistics form FFA-10.
   - Define **Vehicle Miles (000)**. The value is the total number of miles traveled by a vehicle, measured in thousands of miles. This value can be found in Service form S-10.
   - Define **Revenue Vehicle Miles (000)**. This value is the number of miles traveled by a vehicle while in revenue service, measured in thousands of miles. This value can be found in Source of Funds form F-10.
   - Define **Revenue Vehicle Hours (000)**. This value is the number of hours that vehicles are scheduled to or actually travel while in revenue service, measured in thousands of hours. This value can be found in Service form S-10.

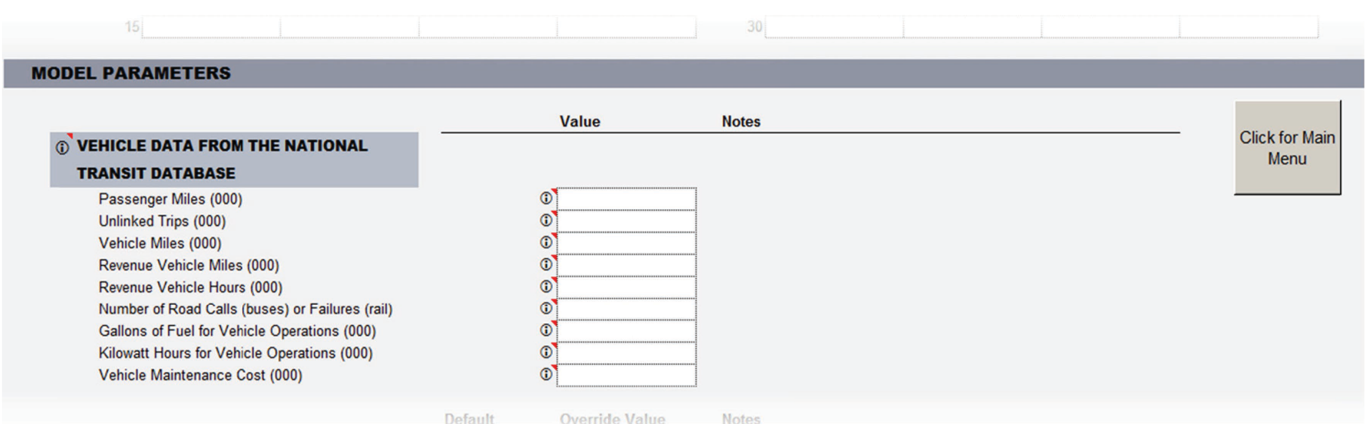


Figure 3.12. Vehicle Model: Model Parameters.

- Define **Number of Road Calls (buses) or Failures (rail)**. This value is the annual number of road calls (for buses) or failures (for rail). This value can be found in Maintenance Performance form R-20.
- Define **Gallons of Fuel for Vehicle Operations (000)**. This value is the gallons of fuel required for annual vehicle operations, measured in thousands of gallons. This value can be found in Energy Consumption form R-30.
- Define **Kilowatt Hours for Vehicle Operations (000)**. This value quantifies the electricity consumption for annual vehicle operations, measured in thousands of kilowatt hours. This value can be found in Energy Consumption form R-30.
- Define **Vehicle Maintenance Cost (000)**. This value is the transit agency maintenance cost for all vehicle groups in the worksheet, measured in thousands of dollars. This value can be found in Uses of Capital form F-20, Operating Expenses form F-30, and Employees form R-10.

NTD Inputs

All of the **Vehicle Data from NTD** fields are marked as required. These fields are used to calculate defaults for the **Additional Vehicle Data** fields, which will be used in the analysis. In instances where the transit agency does not have access to all of the required NTD fields, the user should attempt to provide override values for all of the **Additional Vehicle Data** fields.

The vehicle model does include default NTD values for the selected asset type, which will be included in the analysis if no other input values have been provided, but these values are based on national averages and are unlikely to accurately reflect the current status of transit agency assets.

9. Input **Additional Vehicle Data** (Figure 3.13). Defaults for the following fields are calculated based on the **Inventory Description** and **Vehicle Data** inputs. Where data are missing, model defaults will be used in the calculations. Override values can also be input. Values for **Other Passenger Cost** and **Other External Cost** field defaults are set to zero and the fields will not be included in the analysis unless specified by the user.
    - Define the **New Vehicle Cost ($ per vehicle)**. This value describes the cost to the transit agency of purchasing a new vehicle, measured in dollars.
    - Define the **Total Fleet (number of vehicles)**. If inventory data have been entered, this number will be calculated automatically as the default value.
    - Define the **Annual Miles per Vehicle**. If values have been input for **Vehicle Miles** and **Total Fleet**, the default value will be recalculated to reflect the transit agency data and no additional input is required.

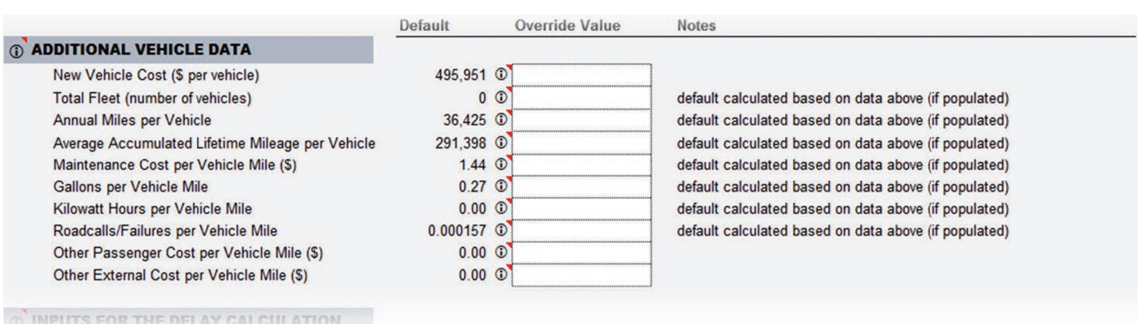


Figure 3.13. Vehicle Model: Additional Vehicle Data.

- Define the **Average Accumulated Lifetime Mileage per Vehicle**. If values have been input for **Number of Vehicles** and **Accumulated Mileage**, the default value will be recalculated to reflect the transit agency data and no additional input is required.
- Define the **Maintenance Cost per Vehicle Mile ($)**. If values have been input for the **Vehicle Maintenance Cost** and **Vehicle Miles**, the default value will be recalculated to reflect the transit agency data and no additional input is required.
- Define the **Gallons per Vehicle Mile**. If values have been input for **Gallons of Fuel for Vehicle Operations** and **Vehicle Miles**, the default value will be recalculated to reflect the transit agency data and no additional input is required.
- Define the **Kilowatt Hours per Vehicle Mile**. If values have been input for **Kilowatt Hours of Vehicle Operations** and **Vehicle Miles**, the default value will be recalculated to reflect the transit agency data and no additional input is required.
- Define the **Roadcalls/Failures per Vehicle Mile**. This value defines the number of road calls (bus) or failures (rail) per vehicle mile. If values have been input for **Number of Road Calls or Failures** and **Vehicle Miles**, the default value will be recalculated to reflect the transit agency data and no additional input is required.
- Define the **Other Passenger Cost per Vehicle Mile ($)**. This value defines other passenger costs, divided by vehicle miles, measured in dollars per vehicle mile. No default is provided for this value and it should only be input if it is relevant to the transit agency.
- Define the **Other External Cost per Vehicle Mile ($)**. This value defines other external costs, divided by vehicle miles, measured in dollars per vehicle mile. No default is provided for this value and it should only be input if it is relevant to the transit agency.

How Should I Account for Indirect Costs?

Procuring a vehicle costs significantly more than the price tag on the vehicle. Likewise, the cost of rehabilitating a facility is greater than the sum of the labor and materials required for the work. In these and other cases, there are additional "soft" or indirect costs, such as administrative and design costs. Ideally, the asset models you develop will include all relevant costs. Since approaches for tracking and allocating indirect costs vary considerably from one transit agency to another, it is up to you to determine what indirect costs to include in your models, and how these relate to your capital budget. The critical factor to consider is that whatever approach is used should be applied consistently across all asset groups. Also, you may need to adjust the budgets used when running TAPT to account for differences between the costs that are modeled and the actual costs incurred by the transit agency, to the extent these are different.

10. The **Inputs for Delay Calculation** are used to define the **Passenger Hours of Delay per Roadcall/Failure** (Figure 3.14). For best results in this section, provide an override value for

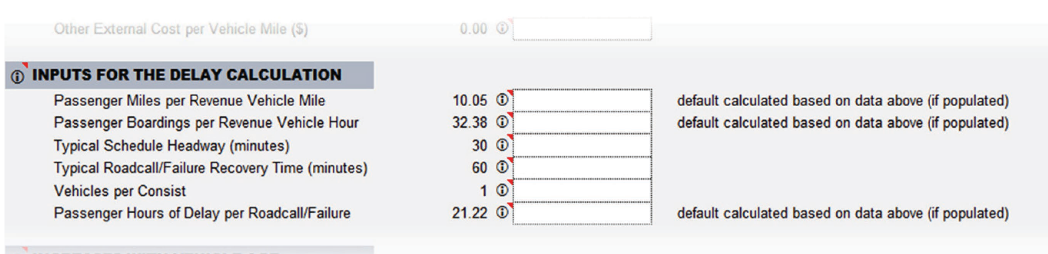


Figure 3.14. Vehicle Model: Inputs for the Delay Calculation.

Passenger Hours of Delay per Roadcall/Failure. If this field has been completed, continue to **Step 11**.

If the **Passenger Hours of Delay per Roadcall/Failure** is unknown or you wish to override the default calculations, complete the following fields to calculate the delay.

- Define **Passenger Miles per Revenue Vehicle Mile**. If values have been defined for **Passenger Miles** and **Revenue Vehicle Miles**, the default value will be recalculated to reflect the transit agency data and no additional input is required.
- Define **Passenger Boardings per Revenue Vehicle Hour**. This value is calculated from NTD data by default. If values have ben defined for **Unlinked Trips** and **Revenue Vehicle Hours**, the default value will be recalculated to reflect the transit agency data and no additional input is required.
- Define **Typical Schedule Headway (minutes)**. This value should be provided by the transit agency, when available, and describes the average number of minutes between vehicles dispatched along a given route.
- Define **Typical Roadcall/Failure Recovery Time (minutes)**. This value should be provided by the transit agency, when available, and defines the extent of service interruption resulting from a roadcall or failure. This is used to approximate network effects caused by vehicle failures, particularly in the case of rail.
- Define **Vehicles per Consist**. This value should only be updated for rail vehicles.

11. Define the **Increases with Vehicle Age (% per 100,000 miles)** (Figure 3.15). These inputs reflect the effects of vehicle age on costs, energy use, and roadcalls/failures per vehicle mile. The input will define the percentage increase per 100,000 miles for each cost type. Defaults for these values are populated based on the previously defined vehicle type.
    - Define the annual percent increase in **Maintenance Cost per Vehicle Mile**. This value will define the increase in maintenance costs over time.
    - Define the annual percent increase in **Energy Use per Vehicle Mile**. This value will define the increase in energy use over time.
    - Define the annual percent increase in **Roadcalls/Failures per Vehicle Mile**. This value will define the percent increase in roadcalls or failures over time.
    - Define the annual percent increase in **Other Passenger Cost per Vehicle Mile**. This value will define the increase in other passenger costs over time.
    - Define the annual percent increase in **Other External Cost per Vehicle Mile**. This value will define the increase in other external costs over time.
12. Define **Other Parameters** (Figure 3.16).
    - Define the **Energy Savings for a New Vehicle (%)**. This value describes the energy savings for a new replacement vehicle, such as that resulting from improved technology. Inputting a positive percentage means energy use for a replacement vehicle is less than that of an existing vehicle, even accounting for the difference in mileage. For example, entering +10% means a replacement vehicle will use 10% less energy per vehicle mile than a vehicle currently in use if both are the same age. The default value of 0.00% for all vehicle assets assumes that new vehicles will not provide any additional energy saving benefits besides that resulting from reducing vehicle mileage or age.

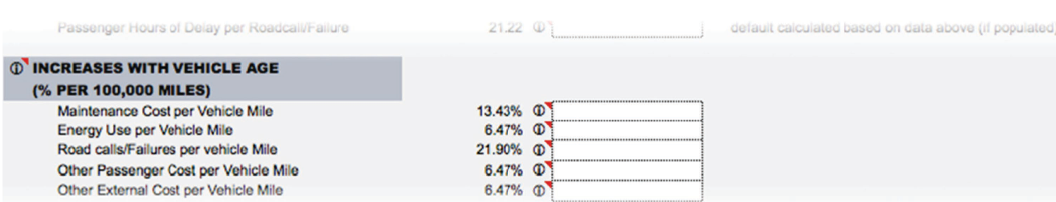


Figure 3.15. Vehicle Model: Increases with Vehicle Age.

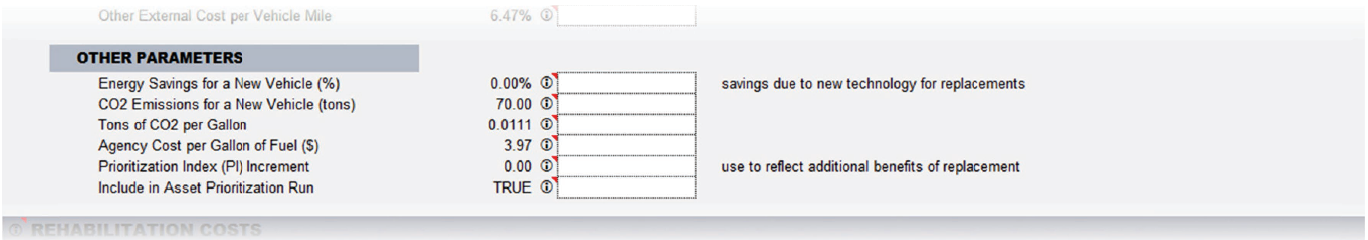


Figure 3.16. Vehicle Model: Other Parameters.

- Define the **CO_2 Emissions for a New Vehicle (tons)**. This value defines the CO_2 emissions resulting from vehicle replacement.
- Define **Tons of CO_2 per Gallon**. This value defines the tons of CO_2 produced per gallon of fuel and was defined on the **Budgets and Parameters** worksheet. This value should be adjusted only if the assets in the model differ from other transit agency assets.
- Define the **Agency Cost per Gallon of Fuel ($)**. This value defines the transit agency cost per a gallon of fuel, in dollars, and was defined on the **Budgets and Parameters** worksheet. This value should be adjusted only if the assets in the model differ from other transit agency assets.
- Define the **Supplemental Replacement Benefit (% of replacement cost)**. This parameter is used to specify the additional benefit of vehicle replacement, besides the types of benefits captured in the model. Entering a value here has the effect of increasing the PI for each vehicle replacement, and changing the priority of replacement for the asset group. The default for all asset types is set to 0.00.
- Define if the prioritization model should **Include in Asset Prioritization Run**. This value should be expressed as "TRUE" or "FALSE" and determines if the assets group defined in this model should be included in the prioritization model. Setting this variable to "FALSE" will exclude the asset group from prioritization runs and exclude the results for the vehicles from summary output tables and charts. The default for all vehicle types is "TRUE," meaning the assets will be included if a prioritization model is run.

13. Define the **Rehabilitation Costs** for the vehicle model (Figure 3.17). You can define **Periodic Rehabilitation Costs**, **Per Mile Rehabilitation Costs**, or both. If defining **Periodic Rehabilitation Costs**, you can specify that rehabilitation costs should be incurred at a specific mileage, or averaged out over time (by getting added to the **Per Mileage Rehabilitation Costs**. If you do not wish to define **Periodic Rehabilitation Costs** skip to **Step 14**. Otherwise complete the following steps:
    - Define the **Percent of Vehicle Replacement Cost**. This value describes the cost of rehabilitating a vehicle. This value is measured as a percentage of the previously defined **New Vehicle Cost**.
    - Define the **Rehab Interval (miles)**. This value determines at what point a vehicle should be rehabilitated, measured in lifetime accumulated mileage.

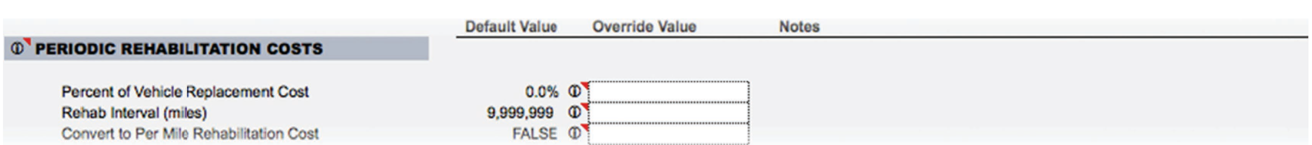


Figure 3.17. Vehicle Model: Periodic Rehabilitation Costs.

- Determine if the model should **Convert to Per Mile Rehabilitation Cost**. If periodic rehabilitation occurs at a set mileage, set this field to "FALSE" and continue to **Step 15**. If costs should be averaged out over time as per mileage costs, set this field to "TRUE" and continue to **Step 14**. Note that setting this field to "TRUE" forces recalculation of the default per mile costs described below.

What Type of Rehabilitation Cost Should I Use?

You can represent rehabilitation costs in the model using either **Periodic Rehabilitation Costs** and/or **Per Mile Rehabilitation Costs**. Periodic rehabilitation costs are costs that are automatically programmed when the asset reaches the specified mileage at the **Rehab Interval**. In this scenario, all assets in the group are programmed for rehabilitation in a single year and the cost is paid in full. One should use this option if rehabilitation is known to occur at a specific point, and if the transit agency would like to weigh rehabilitation against replacement. Alternatively, per mile rehabilitation costs should be used if rehabilitation costs are paid over time, or if there is no formal rehabilitation action for the asset group.

14. Define the **Per Mile Rehabilitation Costs** [**Rehab Cost ($/vehicle mile)**] (Figure 3.18). Default values are provided for buses. For other vehicle types no default is defined. However, defaults are overridden based on the **Replacement Cost** and **Rehab Interval** if **Convert to Per Mile Rehabilitation Cost** is set to "TRUE." The units for the **Rehab Cost** are measured in dollars per vehicle mile.
15. To exclude rehabilitation costs from the analysis, ensure that the **Rehab Interval (miles)** is a large number that would exceed the expected lifetime mileage of assets in the model (i.e., 9,999,999) and set the **Per Mile Rehabilitation Costs** to 0.
16. Review the Summary Statistics (Figure 3.19).
    - The **Average Annual Cost (dollars)** is the average cost per year of a vehicle, including the purchase cost of the vehicle and all transit agency, user, and external costs.
    - The **Cost-Minimizing Replacement Mileage (miles)** is the mileage at which the vehicle should be replaced to minimize the lifecycle costs.

Convert to Per Mile Rehabilitation Cost FALSE

PER MILE REHABILITATION COSTS

Lifetime Mileage		Rehab Cost ($/vehicle mile)	
From	To	Default	Override
0	35,000	0.1590	
35,000	70,000	0.3733	
70,000	105,000	0.5211	
105,000	140,000	0.5948	
140,000	175,000	0.6275	
175,000	210,000	0.6416	
210,000	245,000	0.6484	
245,000	280,000	0.6526	
280,000	315,000	0.6562	
315,000	350,000	0.6595	
350,000	385,000	0.6628	
385,000	420,000	0.6664	
420,000	455,000	0.6707	
455,000	490,000	0.6762	
490,000	525,000	0.6833	

Lifetime Mileage		Rehab Cost ($/vehicle mile)	
From	To	Default	Override
525,000	560,000	0.6926	
560,000	595,000	0.7042	
595,000	630,000	0.7182	
630,000	665,000	0.7344	
665,000	700,000	0.7527	
700,000	735,000	0.7721	
735,000	770,000	0.7919	
770,000	805,000	0.8106	
805,000	840,000	0.8267	
840,000	875,000	0.8385	
875,000	910,000	0.8385	
910,000	945,000	0.8385	
945,000	980,000	0.8385	
980,000	1,015,000	0.8385	
1,015,000		0.8385	

SUMMARY RESULTS

Figure 3.18. Vehicle Model: Per Mile Rehabilitation Costs.

Figure 3.19. Vehicle Model: Summary Results.

- The **Cost-Minimizing Replacement Age (years)** is the age at which the vehicle is projected to reach the replacement mileage value specified.

17. Use the **Click for Main Menu** button to navigate back to the Start Screen. From this menu it is possible to add additional assets or begin the analysis.

Creating an Asset Group: Age-Based Assets

The age-based model is used for non-vehicle assets for which accurate condition data are not available. Note that the asset types listed, as well as many of the defaults, including cost and deterioration data, are based on TERM Lite definitions. For additional information on the model defaults, refer to the accompanying research report. To create a model, follow these steps:

1. From the Start Screen, click **Create Asset Group**. On the screen, define an Asset Group ID Code for the asset group.

   Note: It is mandatory to define an Asset Group ID code and codes cannot be repeated. It is recommended that the ID code contain a basic description of the asset being modeled, as the code will appear throughout the results.
2. Select the **Asset Group Model Type** as **Age-Based Model** to create an asset group for assets using age data.
3. Click the **Create New Group** button to create a new sheet and input data for the asset group.

   Use the dropdown menu to select the **Asset Type** (Figure 3.20). Default values used in the model are automatically populated based on the asset type that is chosen. If the desired asset type is not available, choose the asset type that best describes the asset to be modeled and provide override values to adjust the model as necessary.
4. Use the **Asset Description** field to input a detailed text description of the assets included in the worksheet. This description will be used later in the tool to describe projects that appear in the Program List.
5. Enter the **Asset Units of Measure**. This field is used for documentation purposes.
6. Input **Inventory Description** data (Figure 3.21). For this section, you may list assets individually or group assets by age.
   - The **Age** is the age from when the asset was new until the end of the year before the first budget year. For each asset sub-group input the age.

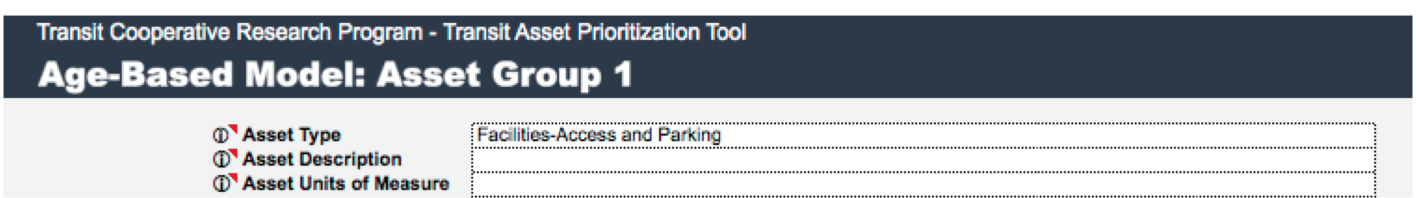


Figure 3.20. Age-Based Model.

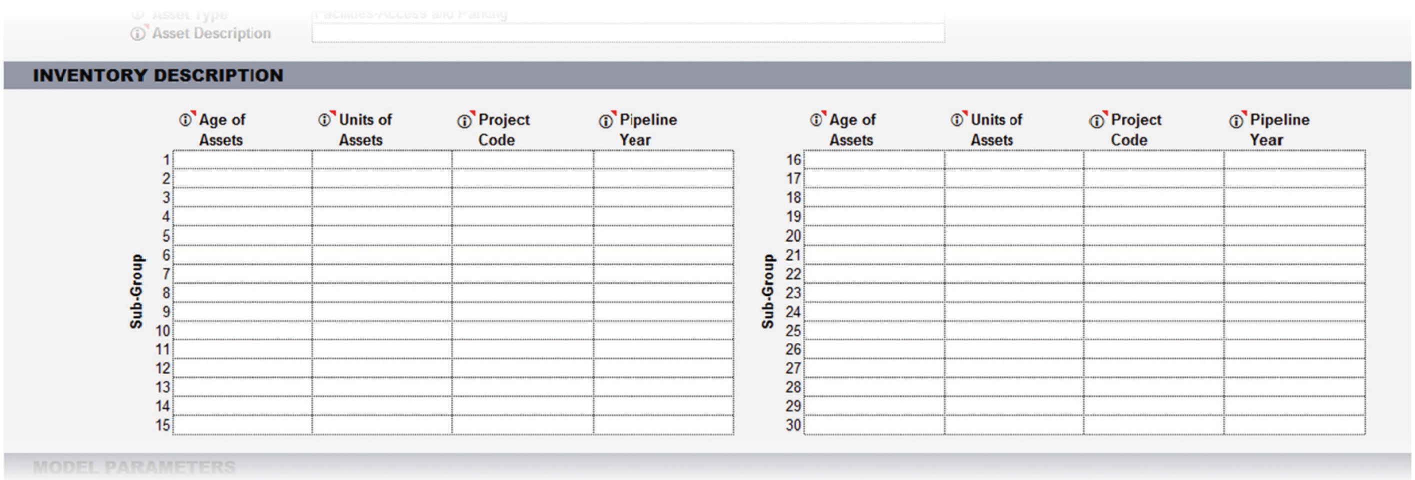


Figure 3.21. Age-Based Model: Inventory Description.

- Input the asset quantity for the sub-group in the **Units of Assets** field. The units chosen for this section should be used consistently throughout the worksheet.
- The **Project Code** is used to specify when the replacement of two or more sub-groups of assets is to be treated as a single project. Entering the same project code for two or more sub-groups of assets means they are to be analyzed together. This means that either all sub-groups with the same project code will be replaced in a given year, or none of the sub-groups will be replaced. A project can include different types of assets, provided they have the same project code. Input a project code if multiple asset sub-groups should be analyzed together. If the asset group should be analyzed on its own, the project code can be left blank, or can be given a unique value to help identify the asset sub-group when reviewing prioritization results.
- The **Pipeline Year** is entered when the replacement of a sub-group of assets has already been scheduled for a given year. If the project has already been scheduled during the analysis period, input the year the project is programmed. If the project has not been scheduled, the pipeline year should be left blank.

7. Define the **Asset Replacement Costs** (Figure 3.22). These are costs that are not incurred directly by the transit agency but have other impacts, such as to passengers, the environment, or other external parties.
   - Define the **Agency Replacement Cost ($)**. This is the cost, in dollars, of replacing an asset.

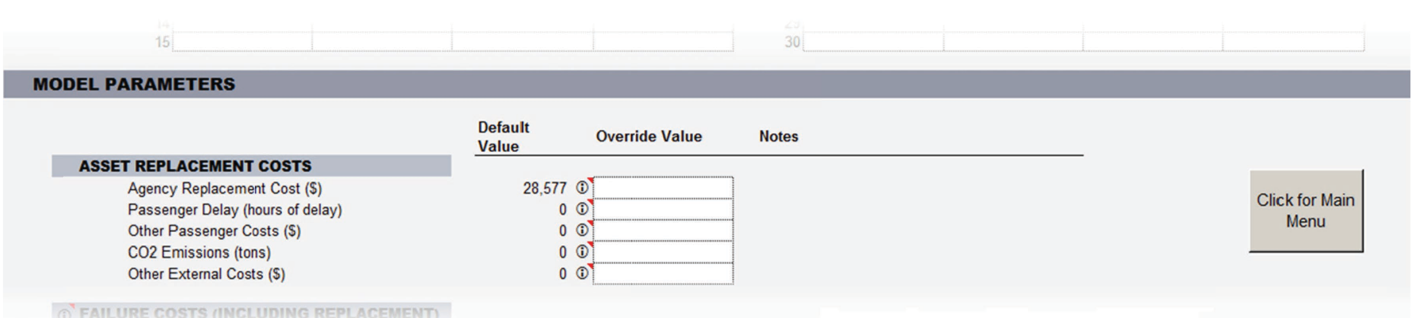


Figure 3.22. Age-Based Model: Asset Replacement Costs.

- Define the **Passenger Delay (hours of delay)**. This value defines the hours of delay incurred by passengers due to replacement, measured in hours. No default value is provided for this value, and it will be excluded from the analysis unless an override value is provided.
- Define the **Other Passenger Costs ($)**. This value quantifies other passenger costs besides delay due to asset replacement. No default value is provided for this value, and it will be excluded from the analysis unless an override value is provided.
- Define the **CO_2 Emissions (tons)**. This is the tons of emissions resulting from manufacture or construction of a new unit of the asset. No default value is provided for this value, and it will be excluded from the analysis unless an override value is provided.
- Define the **Other External Costs ($)**. This value quantifies other external costs due to replacement besides CO_2 emissions. This field is measured in dollars. No default value is provided for this value, and it will be excluded from the analysis unless an override value is provided.

8. Define the **Failure Costs (including replacement)** (Figure 3.23). These costs included the cost of replacing the asset, so that if failure occurs, it is assumed that the asset is replaced and this replacement is paid for as a part of the failure cost.
   - Define the **Agency Costs ($)**. This value defines the transit agency cost, measured in dollars, of a failed asset, including replacement. The default for this value is twice the **Asset Replacement Cost**.
   - Define the **Passenger Delay (hours of delay)**. This value defines the passenger delay caused by asset failure and replacement. No default is provided for this value, and it will be excluded from the analysis unless an override value is provided.
   - Define the **Other Passenger Costs ($)**. This value quantifies the other passenger costs besides delay, measured in dollars, of asset failure. No default is provided for this value, and it will be excluded from the analysis unless an override value is provided.
   - Define the **CO_2 Emissions (tons)**. This value quantifies the CO_2 emissions resulting from asset failure, in tons. No default is provided for this value, and it will be excluded from the analysis unless an override value is provided.
   - Define the **Other External Costs ($)**. This value quantifies the other external costs besides CO_2 emissions, measured in dollars, of asset failure. No default is provided for this value, and it will be excluded from the analysis unless an override value is provided.
9. If desired, define the **Annual Costs** (Figure 3.24). Annual costs describe the costs that are incurred every year, regardless of asset condition. It does not factor in the additional costs of replacing or rehabilitating assets in a given year.
   - Define the **Maintenance ($/year)**. This value defines the average annual maintenance costs incurred by the transit agency, measured in dollars per year. The default is set as a percentage of the **Replacement Cost**.
   - Define the **Energy Costs ($/year)**. This value defines the annual energy cost, measured in dollars per year. No default is provided for this value, and it will be excluded from the analysis unless an override value is provided.

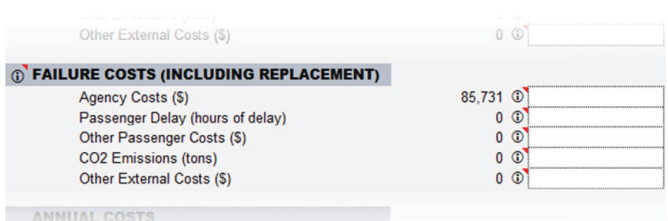


Figure 3.23. Age-Based Model: Failure Costs.

Figure 3.24. Age-Based Model: Annual Costs.

- Define the **Passenger Delay (hours of delay per year)**. This value defines the average annual passenger delay, measured in hours of delay per year. No default is provided for this value, and it will be excluded from the analysis unless an override value is provided.
- Define the **Other Passenger Costs (dollars per year)**. This value quantifies the average annual other passenger costs besides delay, measured in dollars per year. No default is provided for this value, and it will be excluded from the analysis unless an override value is provided.
- Define the **CO_2 Emissions (tons per year)**. This value quantifies the annual CO_2 emissions, measured in tons per year. No default is provided for this value, and it will be excluded from the analysis unless an override value is provided.
- Define the **Other External Costs**. This value quantifies the average annual other external costs besides CO_2 emissions, measured in dollars per year. No default is provided for this value, and it will be excluded from the analysis unless an override value is provided.

10. If desired, define the cost **Increases with Asset Age (% per year)** (Figure 3.25). These inputs reflect the effects of asset age on maintenance costs, passenger delay, and other costs. The inputs will define the percentage increase per year for each cost type. By default these are set to be double the corresponding replacement cost to account for the increased cost of emergency replacement of an asset.
    - Define the increase in **Maintenance Cost**. This value will determine the annual growth rate for the **Annual Maintenance Cost**.
    - Define the increase in **Energy Costs**. This value will determine the annual growth rate for the **Annual Energy Cost**.
    - Define the increase in **Passenger Delay**. This value will determine the annual growth rate for the **Annual Passenger Delay**.
    - Define the increase in **Other Passenger Costs**. This value will determine the annual growth rate for the **Annual Other Passenger Costs**.
    - Define the increase in **CO_2 Emissions**. This value will determine the annual growth rate for the **Annual CO_2 Emissions**.

Figure 3.25. Age-Based Model: Increases in Annual Costs with Asset Age.

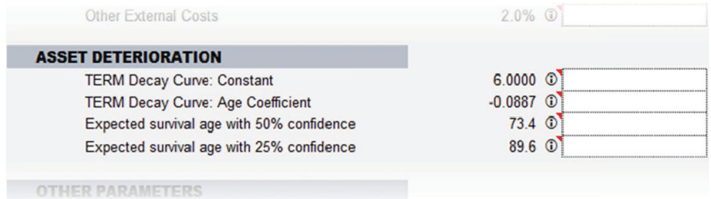


Figure 3.26. Age-Based Model: Asset Deterioration.

- Define the increase in **Other External Costs**. This value will determine the annual growth rate for the **Annual Other External Costs**.

11. If desired specify the parameters for **Asset Deterioration** (Figure 3.26). These parameters are populated by default based on asset type.
    - Define the **TERM Decay Curve: Constant**.
    - Define the **TERM Decay Curve: Age Coefficient**.
    - Define the **Expected Survival Age with 50% confidence**. This value defines the number of years this type of asset is expected to continue performing its function without experiencing a failure that requires replacement (assuming that the transit agency does not choose to replace the asset before it fails). This means that there is a 50% chance the asset will fail before reaching the input age. The default for this value is based on the defined asset type. The default is recalculated if the decay curve is changed.
    - Define the **Expected Survival Age with 25% confidence**. This value defines the number of years this type of asset is expected to continue performing its function without experiencing a failure that requires replacement (assuming that the transit agency does not choose to replace the asset before it fails). This means that there is a 75% chance the asset will fail before reaching the input age. The default for this value is based on the defined asset type. The default is recalculated if the decay curve is changed.
12. Use the following inputs to determine the **Other Parameters** (Figure 3.27) for the analysis.
    - Define the **Average Age of Assets**. This field is calculated based on the inventory data by default.
    - Define the **Supplemental Replacement Benefit (% of replacement cost)**. This parameter is used to specify the additional benefit of replacement, besides that quantified using the types of benefits captured in the model. Entering a value here has the effect of increasing the PI for each replacement, and changing the priority of replacement for the asset group. The default for all asset types is set to 0.00.
    - Define if the prioritization model should **Include in Asset Prioritization Run**. This value should be expressed as "TRUE" or "FALSE" and determines if the assets group defined in this model should be included in the prioritization model. Setting this variable to "FALSE" will exclude the asset group from prioritization runs and exclude the results for the asset group from summary output tables and charts. The default for

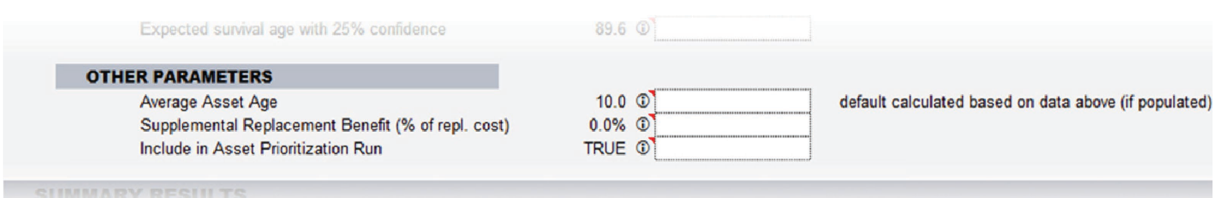


Figure 3.27. Age-Based Model: Other Parameters.

Figure 3.28. Age-Based Model: Summary Results.

all asset types is "TRUE," meaning the assets will be included if a prioritization model is run.

13. Review the Summary Statistics (Figure 3.28).
    - The **Average Annual Cost (dollars)** is the average cost per year of an asset, including the purchase/construction cost of the asset and all transit agency, user, and external costs.
    - The **Cost-Minimizing Replacement Age** is the age at which the asset should be replaced to minimize the average annual cost and lifecycle cost.
14. Use the **Click for Main Menu** button to navigate back to the Start Screen. From this menu it is possible to add additional assets or begin the analysis.

Creating an Asset Group: Condition-Based Assets

The condition-based model is used for non-vehicle assets for which accurate condition data is available. For additional information on the model defaults refer to the accompanying research report, go to http://www.trb.org/Main/Blurbs/171285.aspx. To create a model, follow these steps:

1. From the Start Screen, click on the **Create Asset Group** button.
2. On this screen, define an **Asset Group ID Code** for the asset group.

   Note: It is mandatory to define an asset group ID code and codes cannot be repeated. It is recommended that the ID code contain a basic description of the asset being modeled, as the code will appear throughout the results.
3. Select the **Asset Group Model Type** as **Condition-Based Model** to create an asset group for assets using condition data.
4. Click the **Create New Group** button to create a new sheet and input data for the asset group.
5. Use the drop down menu to select the **Asset Type** (Figure 3.29). Default values used in the model are automatically populated based on the asset type that is chosen.
6. Use the **Asset Description** field to input a detailed text description of the assets included in the worksheet. This description will be used later in the tool to describe projects that appear in the Program List.
7. Enter the **Asset Units of Measure**. This field is used for documentation purposes.

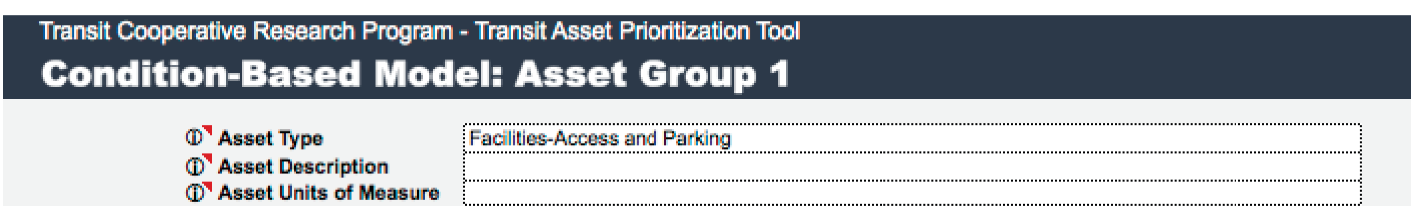


Figure 3.29. Condition-Based Model.

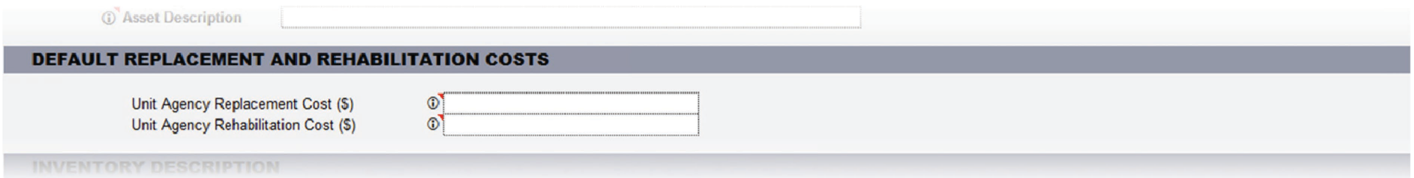


Figure 3.30. Condition-Based Model: Default Replacement and Rehabilitation Costs.

8. Input the **Default Replacement and Rehabilitation Costs** (Figure 3.30).
   - **This value is required.** Define the **Unit Agency Replacement Cost ($)**. This is the value, in dollars, of a scheduled replacement.
   - Define the **Unit Agency Rehabilitation Cost ($)**. This is the value, in dollars, of rehabilitating an asset. If rehabilitation is infeasible, set the rehabilitation cost greater than the replacement cost. No default value is provided.
9. Input **Inventory Description** data (Figure 3.31). For this section one may list assets individually or group by condition.
   - The **Asset Condition** is the current average condition of the asset group, based on a TERM Lite 1–5 scale. For each asset sub-group, input the condition.
   - Input the asset quantity for the sub-group in the **Units of Assets** field. The units chosen for this section should be used consistently throughout the worksheet.
   - The **Project Code** is used to specify when the replacement of two or more sub-groups of assets is to be treated as a single project. Entering the same project code for two or more sub-groups of assets means they are to be analyzed together. This means that either all sub-groups with the same project code will be replaced in a given year, or none of the sub-groups will be replaced. A project can include different types of assets, provided they have the same project code. Input a project code if multiple asset sub-groups should be analyzed together. If the asset sub-group should be analyzed on its own, the project code should be left blank, or can be given a unique value to help identify the asset sub-group when reviewing prioritization results.
   - The **Pipeline Year** is entered when the replacement of a sub-group of assets has already been scheduled for a given year. If the project has already been scheduled during the analysis period, input the year the project is programmed. If the project has not been scheduled, the pipeline year should be left blank.

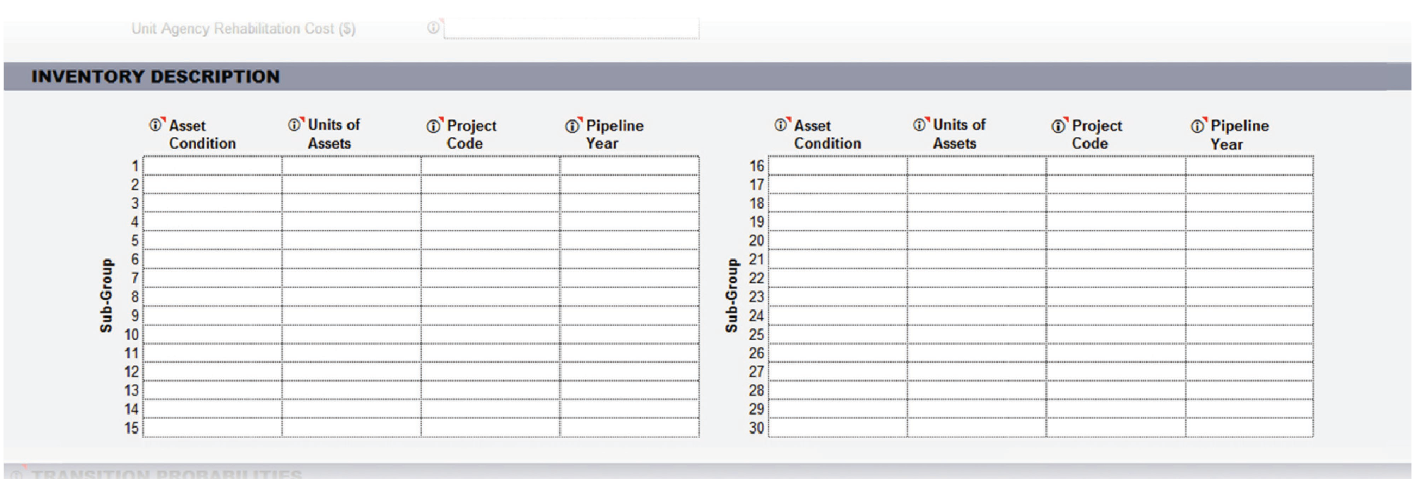


Figure 3.31. Condition-Based Model: Inventory Description.

TRANSITION PROBABILITIES

State	Action	5-Excellent Default	5-Excellent Override	4-Good Default	4-Good Override	3-Adequate Default	3-Adequate Override	2-Marginal Default	2-Marginal Override	1-Poor Default	1-Poor Override	0-Failed Default
5-Excellent	Do Minimum	98.1%		1.9%		0.0%		0.0%		0.0%		0.0%
	Rehab	0.0%		100.0%		0.0%		0.0%		0.0%		0.0%
	Replace	100.0%		0.0%		0.0%		0.0%		0.0%		0.0%
4-Good	Do Minimum	0.0%		95.9%		4.1%		0.0%		0.0%		0.0%
	Rehab	0.0%		100.0%		0.0%		0.0%		0.0%		0.0%
	Replace	100.0%		0.0%		0.0%		0.0%		0.0%		0.0%
3-Adequate	Do Minimum	0.0%		0.0%		92.9%		7.1%		0.0%		0.0%
	Rehab	0.0%		100.0%		0.0%		0.0%		0.0%		0.0%
	Replace	100.0%		0.0%		0.0%		0.0%		0.0%		0.0%
2-Marginal	Do Minimum	0.0%		0.0%		0.0%		88.5%		5.8%		5.8%
	Rehab	0.0%		100.0%		0.0%		0.0%		0.0%		0.0%
	Replace	100.0%		0.0%		0.0%		0.0%		0.0%		0.0%
1-Poor	Do Minimum	0.0%		0.0%		0.0%		0.0%		88.5%		11.5%
	Rehab	0.0%		100.0%		0.0%		0.0%		0.0%		0.0%
	Replace	100.0%		0.0%		0.0%		0.0%		0.0%		0.0%
0-Failed	Replace	100.0%		0.0%		0.0%		0.0%		0.0%		0.0%

Click for Main Menu

Figure 3.32. Condition-Based Model: Transition Probabilities.

10. If desired, define the **Probability of Transitioning to State** (Figure 3.32). The table defines the probability of transitioning between condition states given a specified action is taken. For each condition, three actions are defined: Do Minimum, Rehab, or Replace. These probabilities are populated with default values based on the **Asset Type**.

    Note: When populating the transition probability fields, each of the rows should add up to 100%. If the rows do not add up to 100%, the remainder will automatically be added to the **Failed** column.
11. If desired, define the **Unit Costs, Delay, and CO_2 Emissions** (Figure 3.33). The table defines the cost of performing actions in each condition state. These values that are input in this table are **Agency Costs ($)**, **Energy Cost ($)**, **Delay (hours)**, **Other Passenger Costs ($)**, **$CO_2$ (tons)**, and **Other External Costs ($)**. These values are defined for each of three actions: Do Minimum, Rehab, and Replace when the asset is in any of five condition states: 5-Excellent, 4-Good, 3-Adequate, 2-Marginal, 1-Poor, or has failed.
12. Define the **Other Model Parameters** (Figure 3.34).
    - Define the **Supplemental Replacement Benefit (% of replacement cost)**. This parameter is used to specify the additional benefit of replacement, besides that quantified through the types of benefits captured in the model. Entering a value here has the effect of increasing

UNIT COSTS, DELAY, and CO2 EMISSIONS

State	Action	Agency Cost Default	Agency Cost Override	Energy Cost Default	Energy Cost Override	Delay (hours) Default	Delay (hours) Override	Other Pass. Cost Default	Other Pass. Cost Override	CO2 (tons) Default	CO2 (tons) Override	Other Ext. Cost Default	Other Ext. Cost Override
5-Excellent	Do Minimum	0		0		0		0		0		0	
	Rehab	28,577		0		0		0		0		0	
	Replace	28,577		0		0		0		0		0	
4-Good	Do Minimum	0		0		0		0		0		0	
	Rehab	28,577		0		0		0		0		0	
	Replace	28,577		0		0		0		0		0	
3-Adequate	Do Minimum	0		0		0		0		0		0	
	Rehab	28,577		0		0		0		0		0	
	Replace	28,577		0		0		0		0		0	
2-Marginal	Do Minimum	1,429		0		0		0		0		0	
	Rehab	28,577		0		0		0		0		0	
	Replace	28,577		0		0		0		0		0	
1-Poor	Do Minimum	2,858		0		0		0		0		0	
	Rehab	28,577		0		0		0		0		0	
	Replace	28,577		0		0		0		0		0	
0-Failed	Replace	85,731		0		0		0		0		0	

Click for Main Menu

Figure 3.33. Condition-Based Model: Unit Costs, Delay, and CO_2 Emissions.

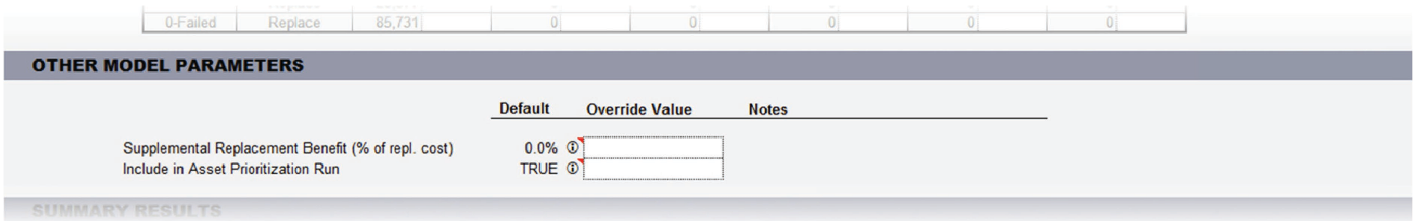


Figure 3.34. Condition-Based Model: Other Model Parameters.

the PI for each replacement, and changing the priority of replacement for the asset group. The default for all asset types is set to 0.00.

- Define if the prioritization model should **Include in Asset Prioritization Run**. This value should be expressed as "TRUE" or "FALSE" and determines if the asset group defined in this model should be included in the prioritization model. Setting this variable to "FALSE" will exclude the asset group from prioritization runs and exclude the results for the asset group from summary output tables and charts. The default for all asset types is "TRUE," meaning the assets will be included if a prioritization model is run.

13. Review the Summary Statistics (Figure 3.35).
    - The **Average Annual Cost (dollars)** is the average cost of the asset per year, including the purchase/construction cost of the asset and all transit agency and external costs.
    - Also shown is the optimal (cost-minimizing) action to perform in each condition state, and the PI corresponding to the action. The possible actions are Do Nothing, Rehab, or Replace. Projects are prioritized in decreasing order of PI in TAPT.
14. Use the **Click for Main Menu** button to navigate back to the Start Screen. From this menu it is possible to add additional assets or begin the analysis.

Editing an Asset Group

1. From the start screen, click on the **Edit Asset Group** button (Figure 3.36).
2. Select the Asset Group to Edit (Figure 3.37).
3. Click on the Edit Selected Asset Group button.
   Note: If no asset group has been selected, an error message will appear.
4. Edit data using the model inputs.
5. When finished, use the **Click for Main Menu** button to navigate back to the Start Screen.

Deleting an Asset Group

1. From the start screen, click on the **Delete Asset Group** button (Figure 3.38).
2. Select the Asset Group to Delete (Figure 3.39).

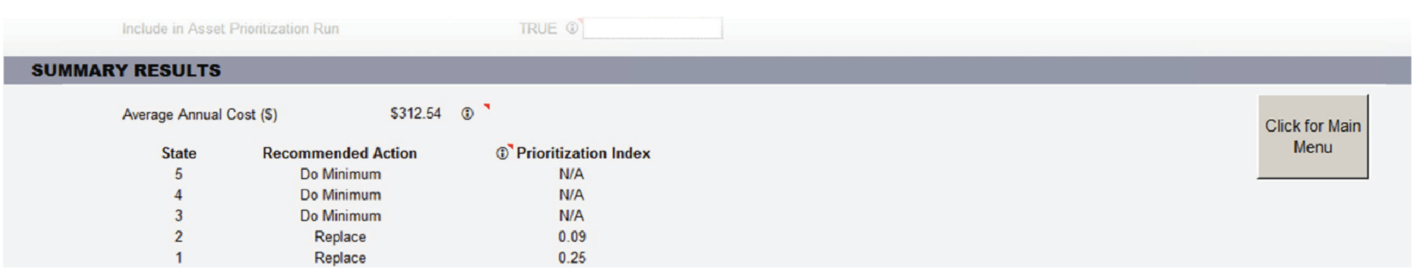


Figure 3.35. Condition-Based Model: Summary Results.

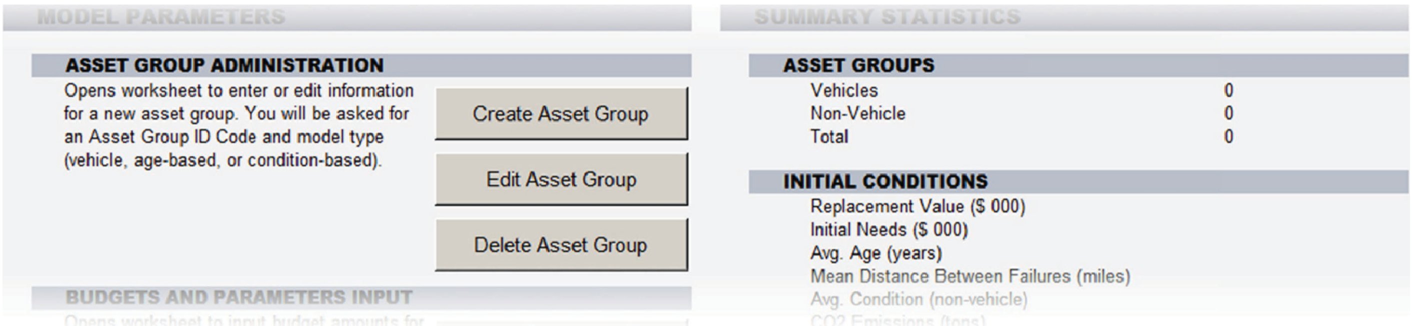


Figure 3.36. Start Screen Asset Group Administration.

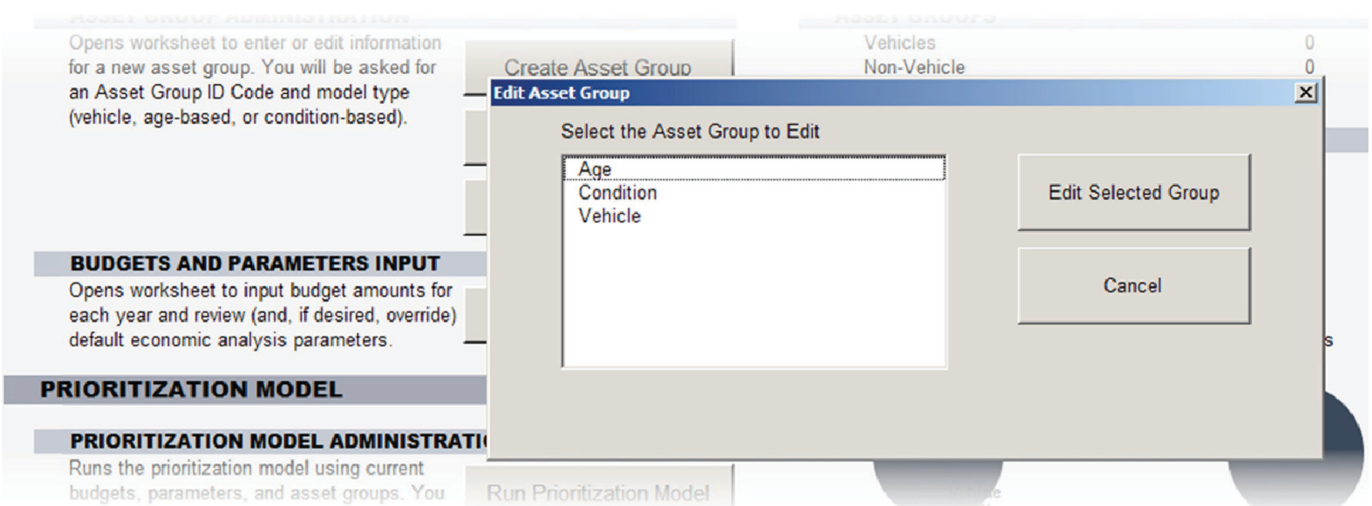


Figure 3.37. Edit Asset Group.

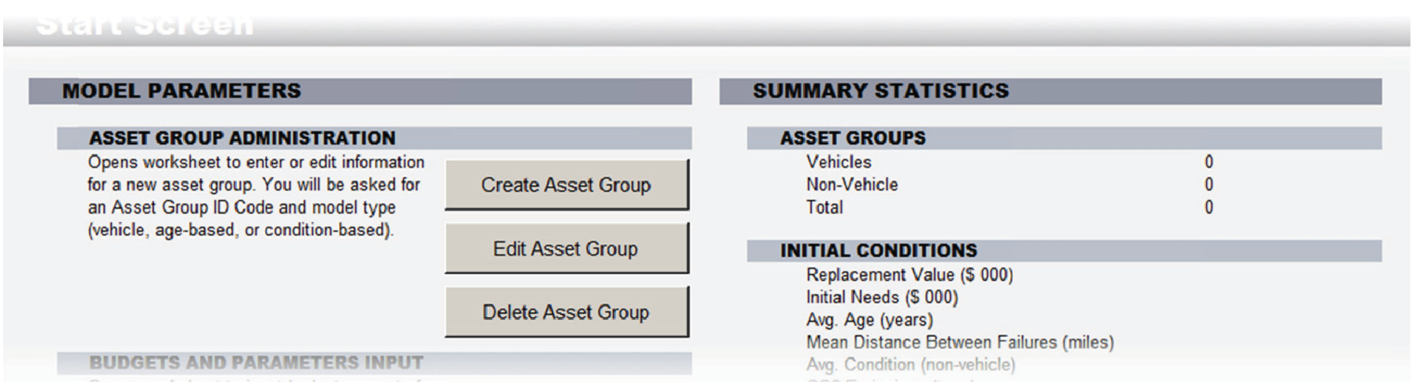


Figure 3.38. Asset Group Administration.

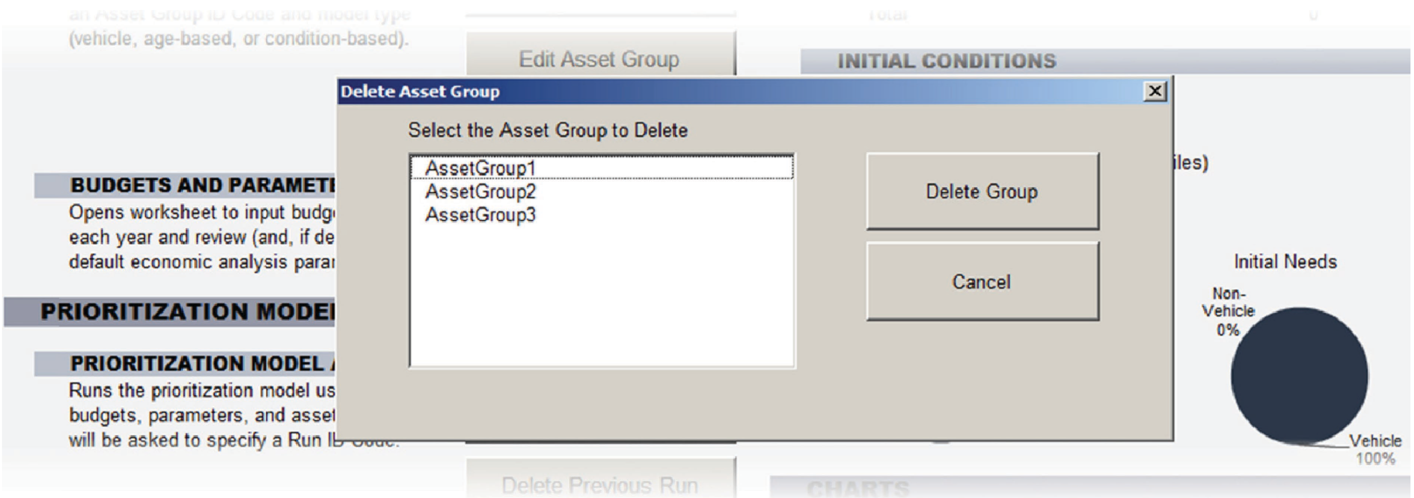


Figure 3.39. Delete Asset Group.

3. Click on the Delete Selected Asset Group button.
   Note: If no asset group has been selected, an error message will appear.
4. A menu item will appear prompting the user: "The selected sheet(s) will be permanently deleted. To delete the selected sheet, click OK. To cancel the deletion, click Cancel." Click **OK** to continue.

Prioritization Model

Once a set of asset models have been defined, you can use the prioritization model to predict future conditions and recommend priorities for asset rehabilitation and replacement. Use of the model is described here.

Review the Summary Data

Before running the prioritization model, review the summary statistics to ensure that all of the assets have been accurately added to the model (Figure 3.40). The summary statistics section includes assets currently in the model that have not been specifically excluded from the analysis on the model worksheet.

Summary statistics will provide the following information:

- **Asset Groups:** The number of asset groups modeled in the most recent prioritization run, for Vehicles, Non-Vehicle, and Total.
- **Initial Conditions:**
  - **Replacement Value:** The cost of replacing all assets, in thousands of dollars.
  - **Initial Needs:** The amount of money needed to replace all assets with a prioritization score more than the **PI Threshold for Replacement** defined in the **Budgets and Parameters**.
  - **Average Age:** The average age, measured in years, of all assets.
  - **Mean Distance Between Failures (miles):** The average miles between failures/road calls for all vehicle assets.
  - **Average Condition (non-vehicle):** The average condition of all non-vehicle assets.
  - **CO_2 Emissions (tons):** Tons of emissions for all assets in the analysis.

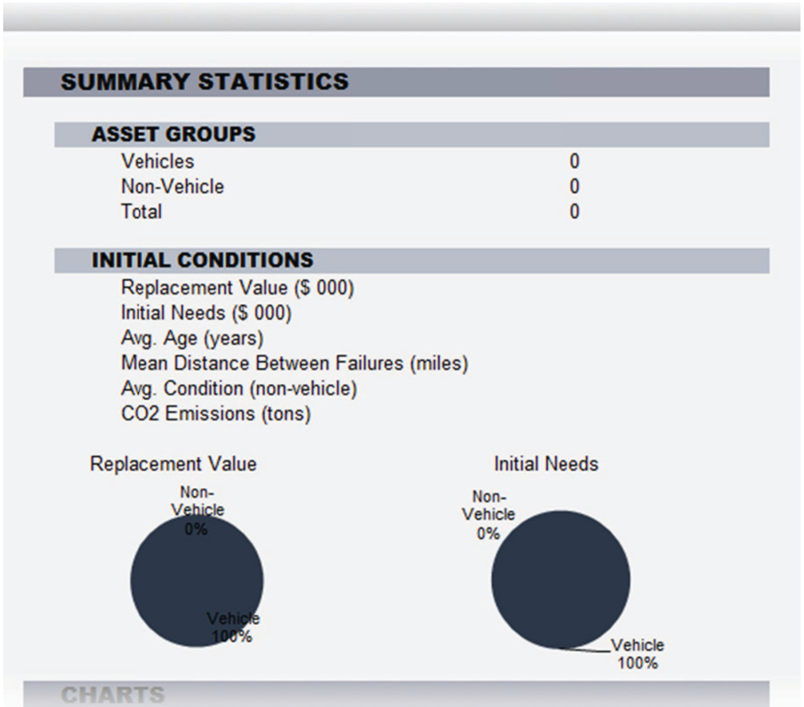


Figure 3.40. Summary Statistics.

- **Replacement Value Graph:** A breakdown showing the percent of vehicle and non-vehicle assets replacement values.
- **Initial Needs Graph:** A breakdown showing the percent of vehicle and non-vehicle assets initial needs.

Running the Prioritization Model

1. From the Start Screen, click on the **Run Prioritization Model** button to launch an Excel form (Figure 3.41).
2. Enter an ID code for the run (Figure 3.42).
3. Click **OK** when finished.

   Note: If an ID code has not been entered, an error message will appear.

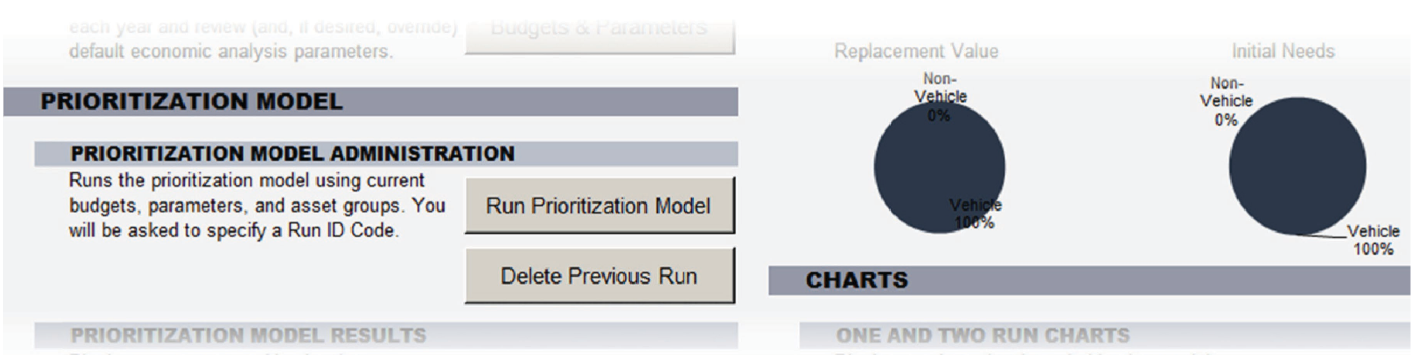


Figure 3.41. Prioritization Model Administration.

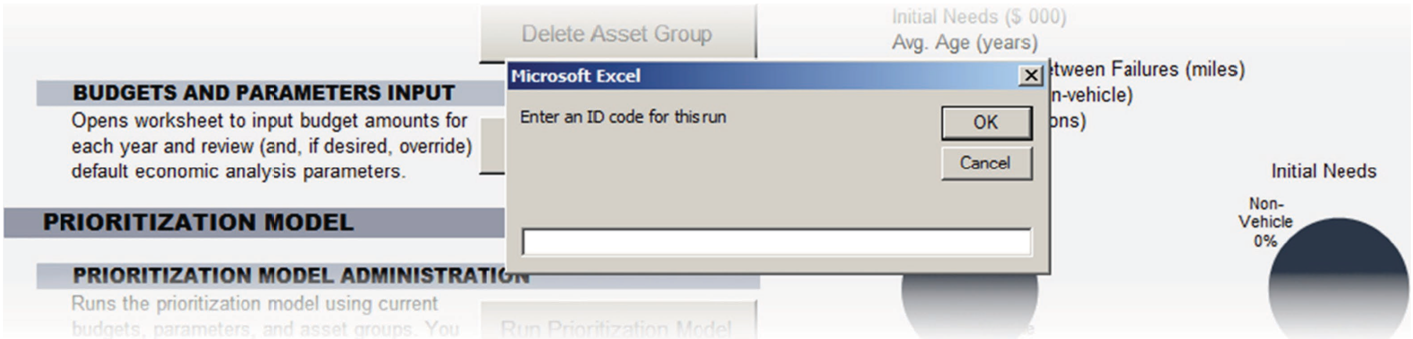


Figure 3.42. Run Prioritization Model.

4. Review the results of the prioritization run in the **Program List** (Figure 3.43). The projects are listed in the order they are programmed to occur.
   - The **Program Year** is the year a project is programmed to occur.
   - The **Asset ID Code** is the code that defines the asset group worksheet.
   - The **Description** is the detailed description from the asset group worksheet.
   - The **Number of Assets** is the quantity of assets in the asset group.
   - The **Replacement Costs** is the total cost of replacing all assets in the asset group.
   - The **Project Rank** is the project rank based on the prioritization index.
   - The **PI** is the prioritization index, used for prioritizing replacement. Projects are prioritized in decreasing order of PI.
   - The field **Pipelined?** indicates whether the project was pipelined.
   - The **Project Code** is used to indicate cases where multiple assets have been grouped into a single project.
5. When finished, use the **Click for Main Menu** button to navigate back to the Start Screen.

Deleting a Prioritization Run

1. From the start screen, click on the **Delete Previous Run** button (Figure 3.44).
2. Select the RUN ID for the run to be deleted (Figure 3.45).
3. Click on the **Delete** button.

   Note: If no asset group has been selected, an error message will appear on the screen.

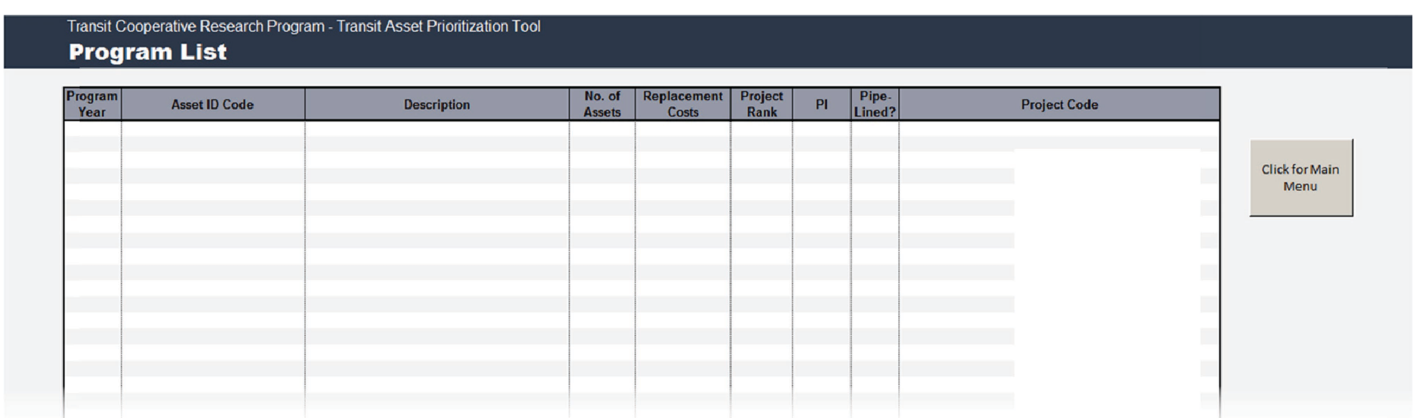


Figure 3.43. Prioritization Model Program List.

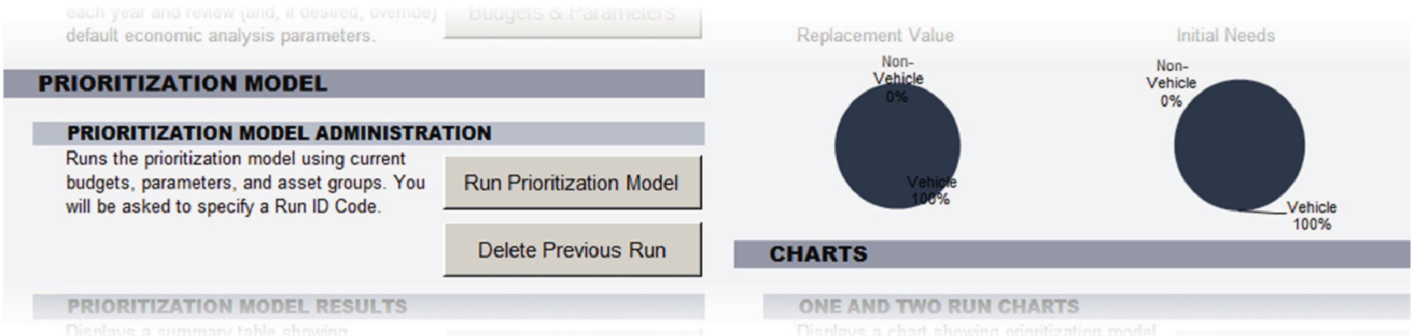


Figure 3.44. Prioritization Model Administration.

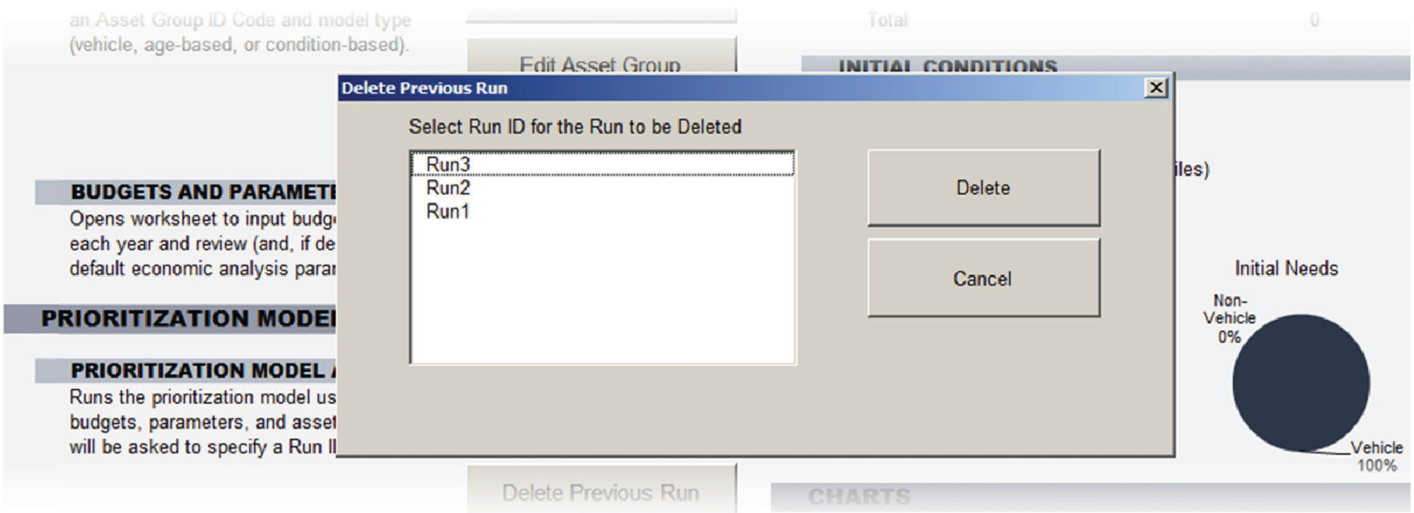


Figure 3.45. Delete Previous Run.

4. A menu item will appear prompting the user: "The selected sheet(s) will be permanently deleted. To delete the selected sheet, click OK. To cancel the deletion, click Cancel." Click **OK** to continue.

Results

Prioritization Model Results Summary Table

1. From the start screen, click on the **Display Summary Table** button (Figure 3.46).
2. Select the Run ID Code for the Summary Table to be displayed (Figure 3.47).

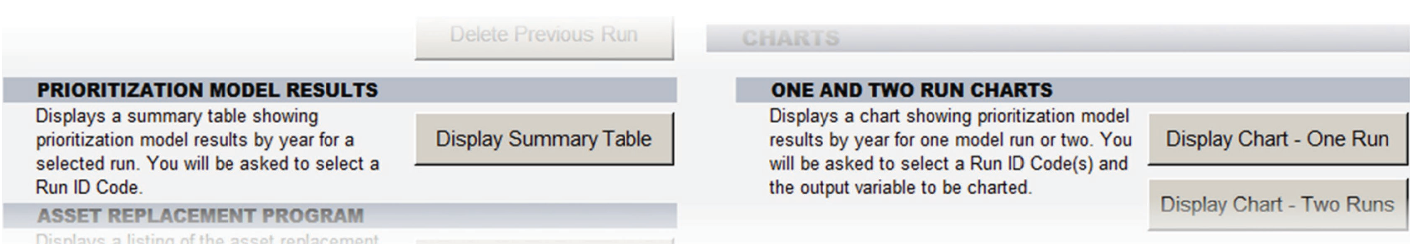


Figure 3.46. Prioritization Model Results.

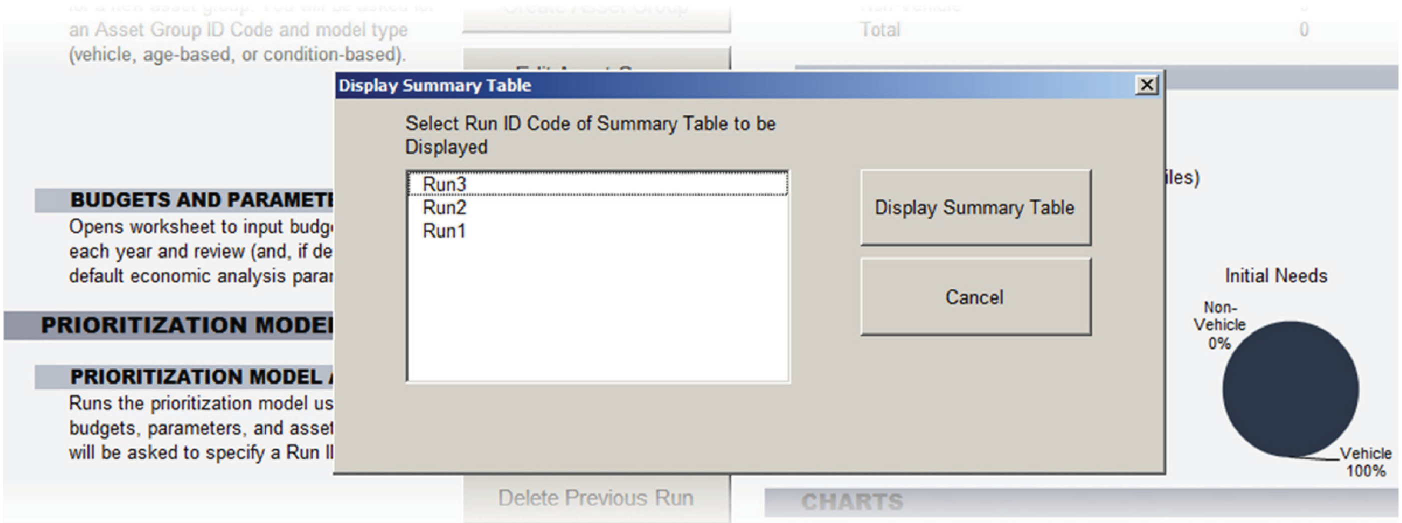
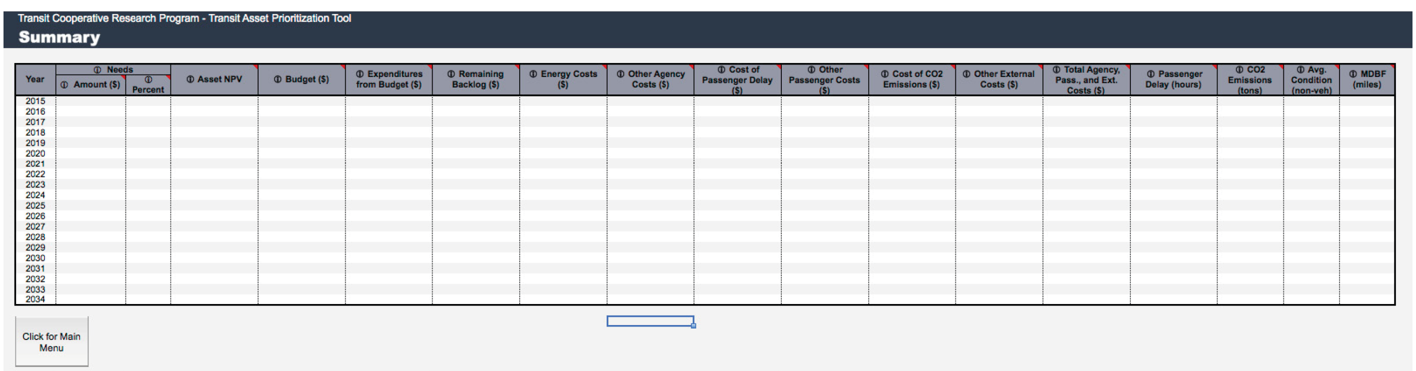


Figure 3.47. Display Summary Table.

3. Click on the Display Summary Table button.
   Note: If no asset group has been selected, an error message will appear.
4. Review the Summary Table (Figure 3.48).
   Note: All dollar amounts are expressed in constant dollars.
   - The **Year** is the analysis year.
   - The **Needs Amount ($)** is the cost of meeting all asset needs that are economically justified (have a PI value greater than the specified threshold).
   - The **Needs Percent** is the needs divided by asset replacement value.
   - The **Asset Net Present Value (NPV)** is the sum of lifecycle costs of assets replaced in the year.
   - The **Budget ($)** is the total available budget for asset rehabilitation and replacement, including any carryover from the previous year.
   - The **Expenditures from Budget ($)** are the capital funds expended in the period.
   - The **Remaining Backlog ($)** is the needs left unmet at the end of the year, calculated by subtracting **Expenditures from Budget ($)** from **Needs Amount ($)**.
   - The **Energy Costs ($)** are the total energy costs in the program year. This value includes transit agency costs for gallons of fuel and kilowatt hours of energy for vehicles, as well as any energy costs modeled for non-vehicle assets.



Transit Cooperative Research Program - Transit Asset Prioritization Tool

Summary

Year	Needs Amount ($)	Needs Percent	Asset NPV	Budget ($)	Expenditures from Budget ($)	Remaining Backlog ($)	Energy Costs ($)	Other Agency Costs ($)	Cost of Passenger Delay ($)	Other Passenger Costs ($)	Cost of CO2 Emissions ($)	Other External Costs ($)	Total Agency, Pass., and Ext. Costs ($)	Passenger Delay (hours)	CO2 Emissions (tons)	Avg. Condition (non-veh)	MDBF (miles)
2015																	
2016																	
2017																	
2018																	
2019																	
2020																	
2021																	
2022																	
2023																	
2024																	
2025																	
2026																	
2027																	
2028																	
2029																	
2030																	
2031																	
2032																	
2033																	
2034																	

Click for Main Menu

Figure 3.48. Summary Table.

- The **Other Agency Costs ($)** are the total transit agency costs in the program year, excluding replacement costs and energy costs.
- The **Cost of Passenger Delay ($)** is the number of hours of delay multiplied by the delay cost per hour.
- The **Other Passenger Costs ($)** are other passenger costs besides delay, which may be optionally specified.
- The **Cost of CO_2 Emissions ($)** is the tons of emissions multiplied by the cost per ton.
- The **Other External Costs ($)** are the total cost of other external factors besides CO_2 emissions in the program year.
- The **Total Agency, Passenger, and External Costs ($)** is the sum of all costs incurred during the period, including capital costs, maintenance costs, user costs, and emissions costs.
- The **Passenger Delay (hours)** is the total delay for the assets modeled.
- The **CO_2 Emissions (tons)** are total emissions.
- The **Average Condition (non-vehicle assets)** is the average TERM Lite condition rating.
- The **Mean Distance Between Failures or MDBF (miles)** is the average MDBF for all vehicles.

5. When finished, use the **Click for Main Menu** button to navigate back to the Start Screen.

Asset Replacement Program List

1. From the start screen, click on the **Display Program List** button (Figure 3.49).
2. Select the Run ID Code for the Summary Table to be displayed (Figure 3.50).

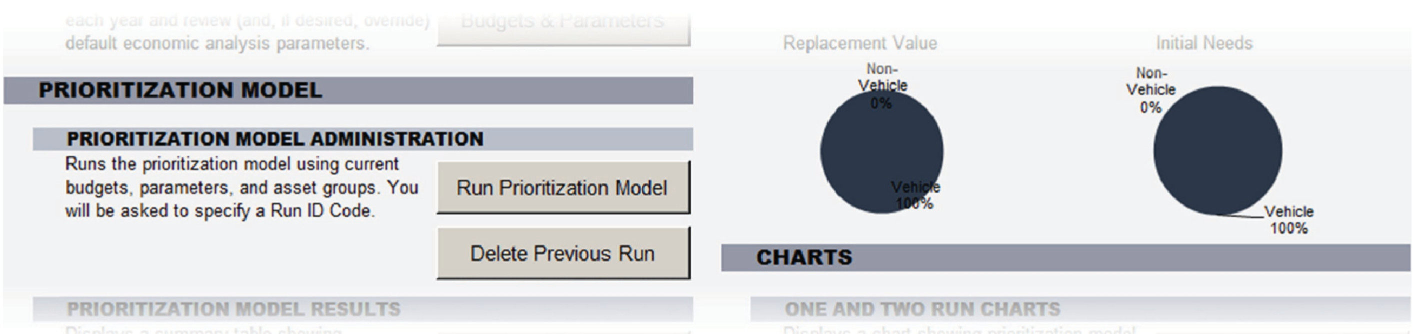


Figure 3.49. Prioritization Model Administration.

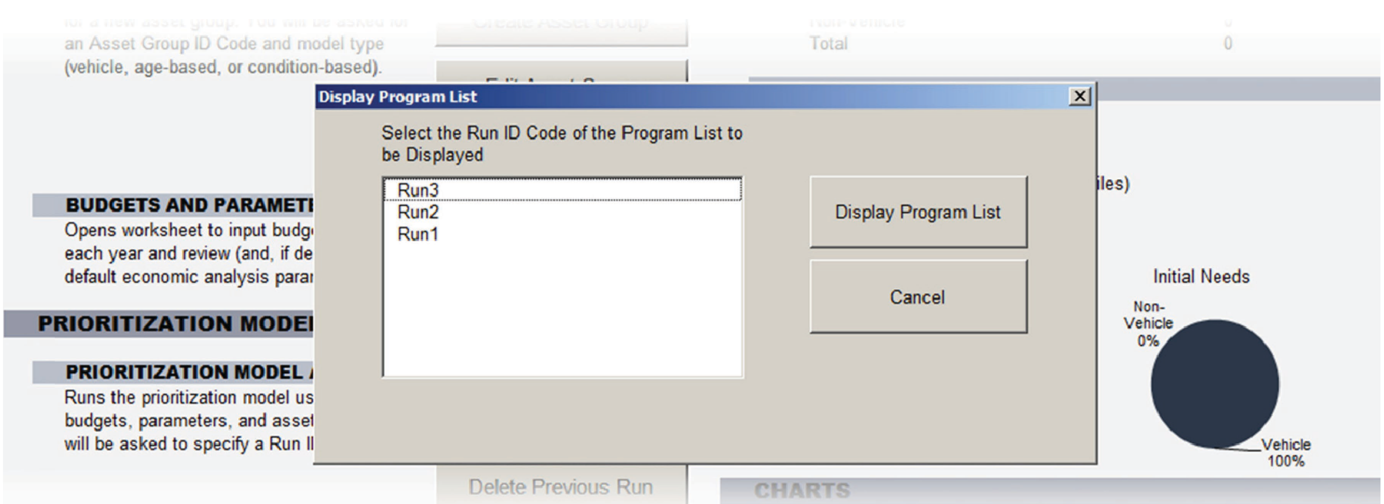


Figure 3.50. Display Program List.

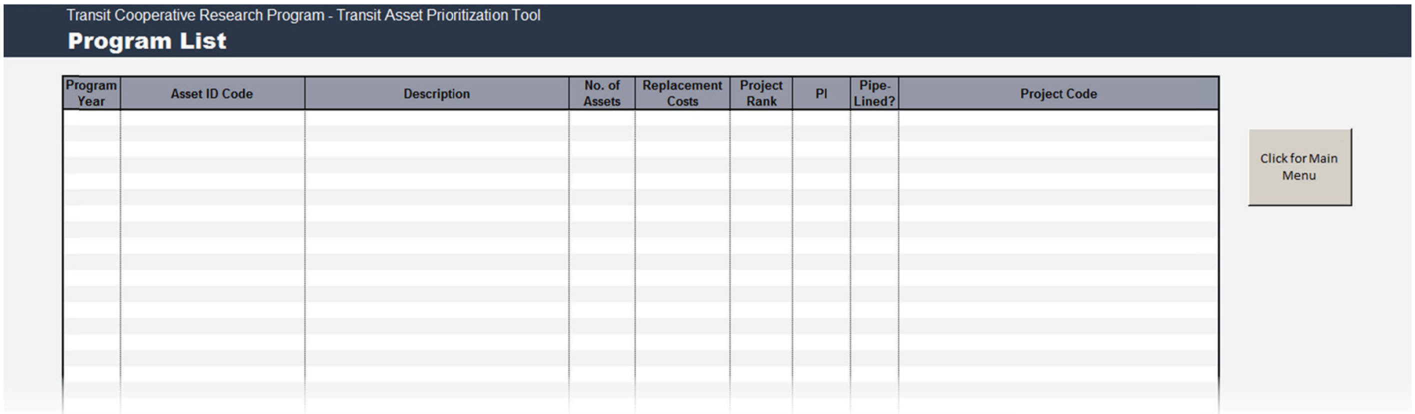


Figure 3.51. Program List.

3. Click on the Display Program List button.
   Note: If no asset group has been selected, an error message will appear on the screen prompting the user: "Select the ID Code of the Run to Display."
4. Review the Program List (Figure 3.51). A list of the data items on the **Program List** is provided in the "Running the Prioritization Model" section.
5. When finished, use the **Click for Main Menu** button to navigate back to the Start Screen.

Display Charts

To create a graph using data from a single prioritization run, complete the following steps:

1. From the start screen, click on the **Display Chart—One Run** button (Figure 3.52).
2. Select the prioritization model output variable to be charted (Figure 3.53). Options include the following:
   - Needs ($)
   - Needs as % of Total Asset Replacement Cost
   - Net Present Value of Asset Replacement Projects
   - Budget
   - Expenditures from Capital Budget
   - Remaining Backlog
   - Energy Costs
   - Other Non-Capital Agency Costs
   - Delay Costs

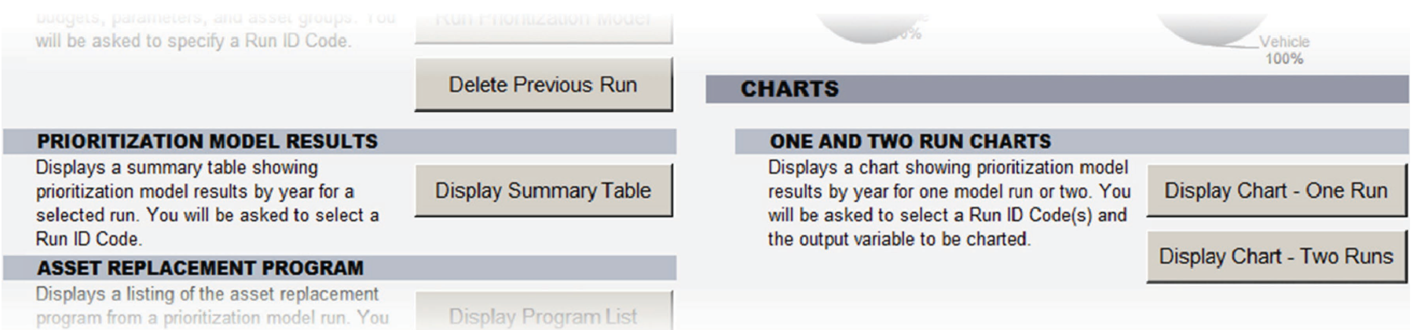


Figure 3.52. Charts.

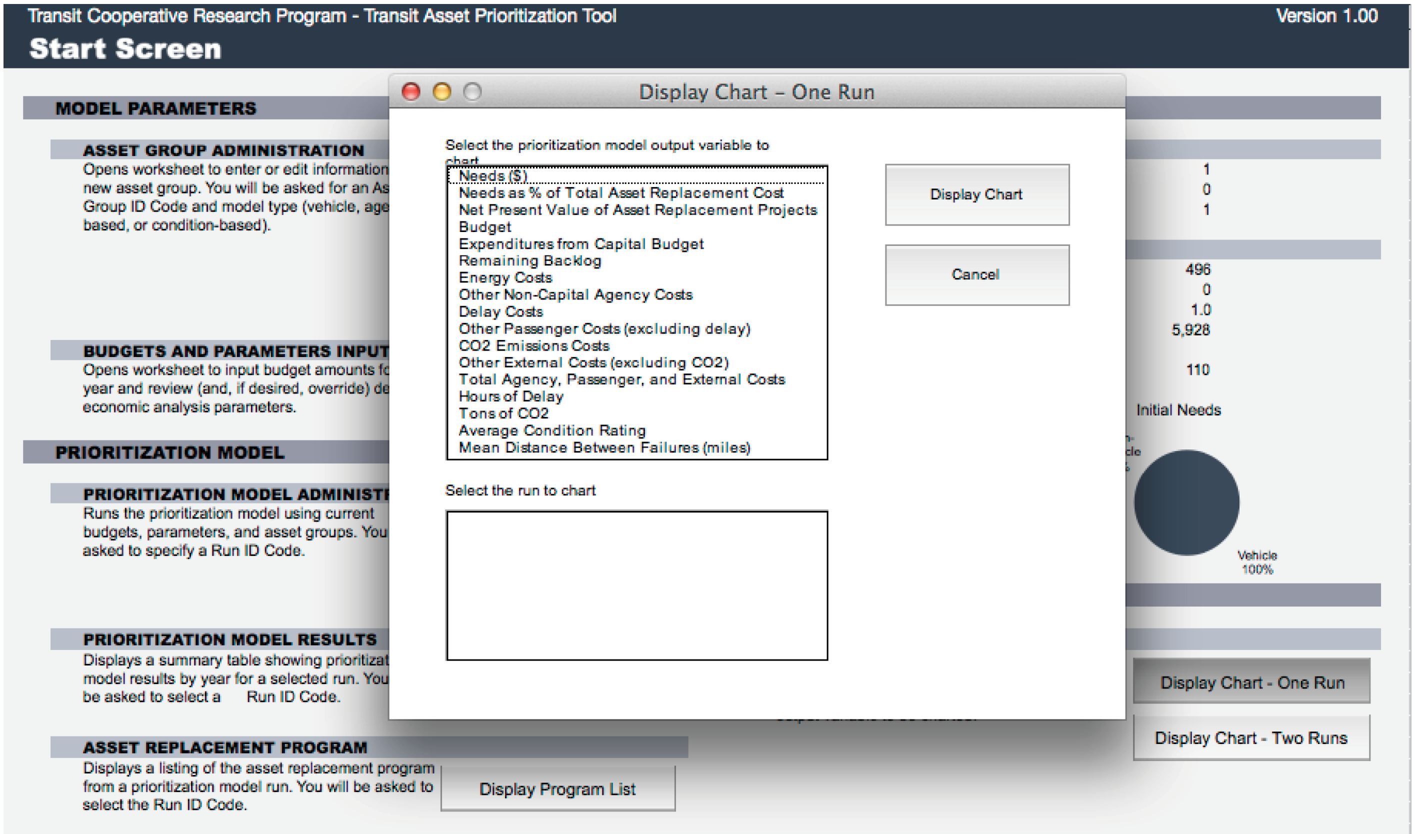


Figure 3.53. Display Chart—One Run.

- Other Passenger Costs (excluding delay)
- CO_2 Emissions Costs
- Other External Costs (excluding CO_2)
- Total Agency, Passenger, and External Costs
- Hours of Delay
- Tons of CO_2
- Average Condition Rating
- Mean Distance Between Failures (miles)

3. Select the Prioritization model run to be charted.
4. Click on the **Display Chart** button.

   Note: If no output variable has been selected, an error message will appear on the screen prompting the user: "Select the output variable to chart." If no run has been selected, an error message will appear on the screen prompting the user: "Select the ID Code of the run to chart."
5. When finished, use the **Click for Main Menu** button to navigate back to the Start Screen.

To launch a chart with data from two runs, perform the following steps:

1. From the start screen, click on the **Display Chart—Two Run** button.
2. Select the prioritization model output variable to be charted (Figure 3.54). The output variables that can be charted are listed in the directions in the "Display One Run Chart" section.
3. Select two Prioritization model runs to be charted.
4. Click on the **Display Chart** button.

   Note: If no output variable has been selected, an error message will appear on the screen. When finished, use the **Click for Main Menu** button to navigate back to the Start Screen.

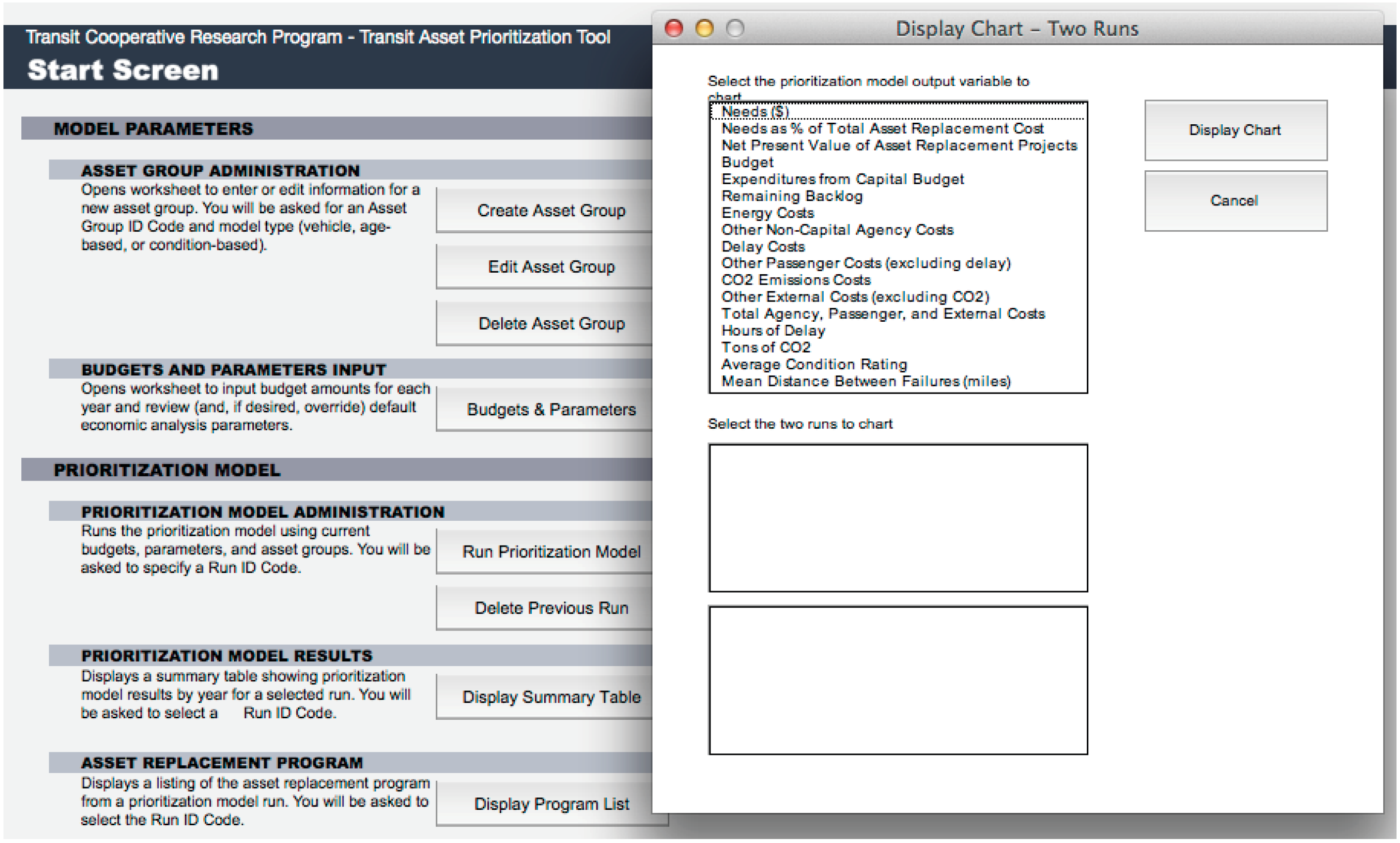


Figure 3.54. Display Chart—Two Runs.

CHAPTER 4

TAPT Tutorials

Introduction

The following chapter includes two, step-by-step tutorials illustrating the use of TAPT using two fictitious transit agencies as examples. They provide users with applications of the tool, and will help transit agency staff see how to apply the tool to their assets.

The first tutorial, **Main Street Transit (MST)**, is a small transit agency with a fleet of 39 buses. The agency is in the process of developing a TAMP and the tutorial will show how the agency uses TAPT as a tool for determining their funding needs and developing a prioritized program to incorporate into their TAMP.

The second tutorial, **Springfield Transit Authority (STA)**, is a mid-sized agency responsible for managing a variety of assets, including buses, light rail vehicles, track, guideway, administrative and maintenance facilities, and major systems for their building facilities, including roof and heating, ventilation, and cooling (HVAC). STA, as a relatively new agency, has historically had relatively modest rehabilitation and replacement needs, and has handled these on an as-needed basis. As the average age of their assets increases, the agency is looking for long-term solutions to maintain a SGR and is using TAPT to determine ways of prioritizing their funding to maintain SGR.

Main Street Transit

MST was established in 1996 as a transit agency providing bus service to a small urban area. The transit agency maintains five major bus routes, connecting the local downtown to the rest of the region, and a demand response fleet. The MST bus fleet is made up of three vehicle types:

- HB Buses—10 hybrid buses, maintained in three subfleets;
- DB Buses—24 diesel buses, maintained in six subfleets; and
- DR Buses—5 vans for demand response service, maintained individually.

MST is embarking on creating their first TAMP, to be completed in 2015. As the staff member responsible for compiling the TAMP, you have been in touch with peer agencies, which have suggested TAPT as an easy and straightforward tool that can simplify the process of creating a TAMP. For the final document, you have decided to provide a 10-year program for replacing vehicle assets that would maintain the fleet in a SGR. To help compile your TAMP, read Chapter 2: Steps in Developing a Transit Asset Management Plan, and decide to follow the TAMP Development process outlined in this chapter.

Before entering data, first review the software guidance. Based on the information provided, develop a list of the data that will be required to effectively use the tool. To complete the required NTD inputs for the vehicle model, work with MST staff to compile the following forms:

- Service form S-10
- Identification form B-10
- Operating Expense form F-30
- Federal Funding Allocation Statistics form FFA-10
- Source of Funds form F-10
- Maintenance Performance form R-20
- Energy Consumption form R-30
- Uses of Capital form F-20
- Employees form R-10

At the same time, also make note of other input fields that are relevant to the agency and contact MST staff members to provide any necessary historical or agency-specific data.

Step 1: Create Vehicle Models and Define Parameters

The first step in the TAMP development process is to Inventory Assets and Data. In the process of collecting data inputs for TAPT, you will begin to compile some of the inventory data needed to develop a capital asset inventory for all vehicle assets.

Budgets and Parameters

1. From the start screen, click **Budgets & Parameters** (Figure 4.1).
2. Using Table 4.1, adjust the following parameters (Figure 4.2):
   - The **First Budget Year** is adjusted to reflect the first budget year that will be included in the TAMP.
   - The **Discount Rate** is changed to reflect MST policy.
   - The **Agency Cost per Gallon of Fuel** is adjusted to account for MST historical fuel costs, which have typically been higher than the default.
3. Select **Click for Main Menu** to return to the start screen.

Hybrid Buses

Before developing the TAMP for MST, you spoke with leadership in the agency and determined that the document will focus on the current state of vehicle assets. For this reason, you chose to use only the vehicle model in TAPT. Using the tool, you will model each of the three bus fleets separately, starting with hybrid buses.

4. From the start screen, click **Create Asset Group** (Figure 4.3).
5. Name the **Asset Group ID Code** "Hybrid" and specify that the asset group will be using the "Vehicle Model," before selecting **Create New Group**.

In the Hybrid vehicle model, perform the following steps (Figure 4.4):

6. Set the **Vehicle Type** to "Bus."
7. In the **Asset Description** text field, name the assets "Hybrid."
8. Use Table 4.2 to input the **Inventory Description** data for the hybrid bus fleet.

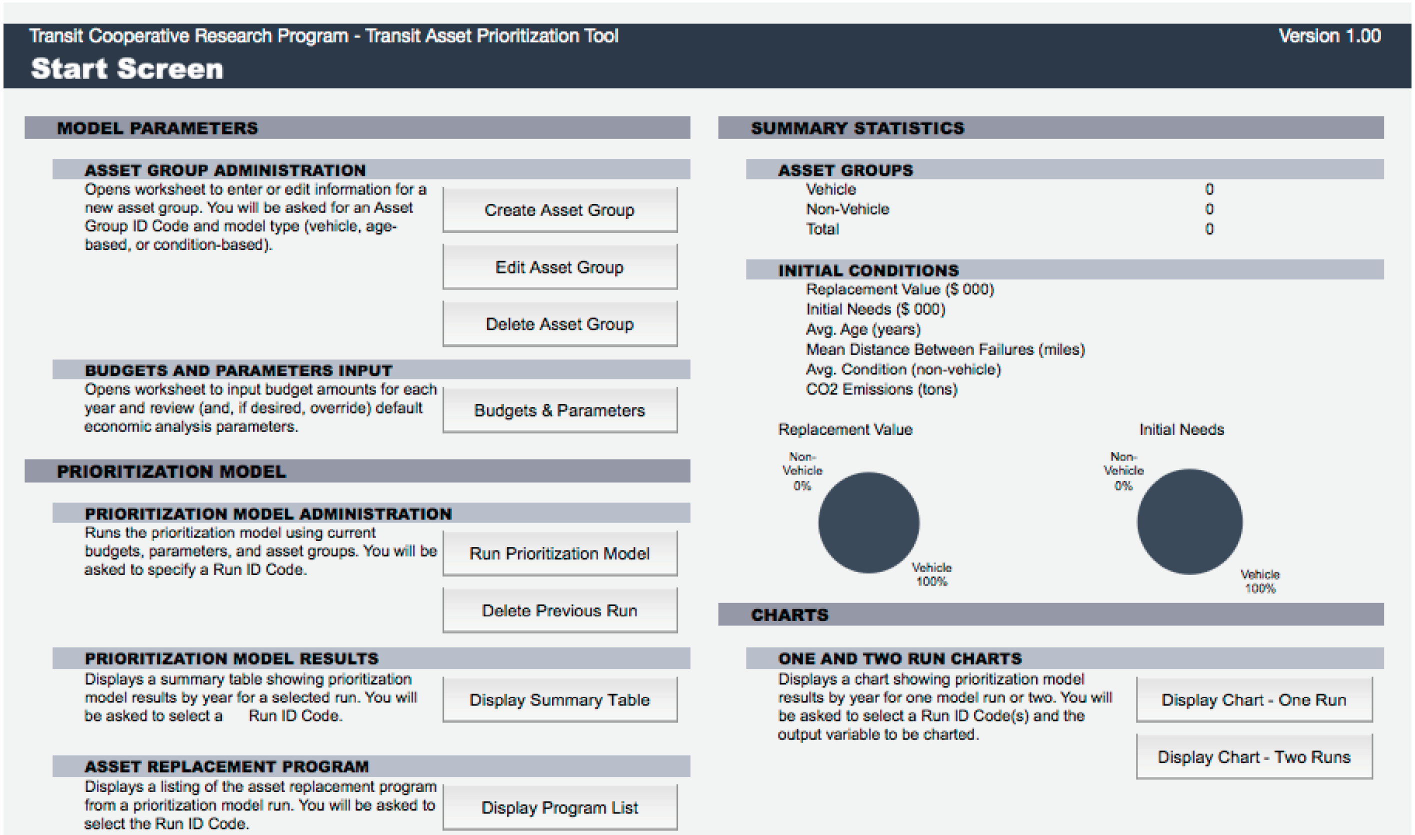


Figure 4.1. TAPT Start Screen.

Table 4.1. Budgets and Parameters.

Parameters	Value
First Budget Year	2016
Discount Rate	5.0%
Agency Cost per Gallon of Fuel ($)	3.10

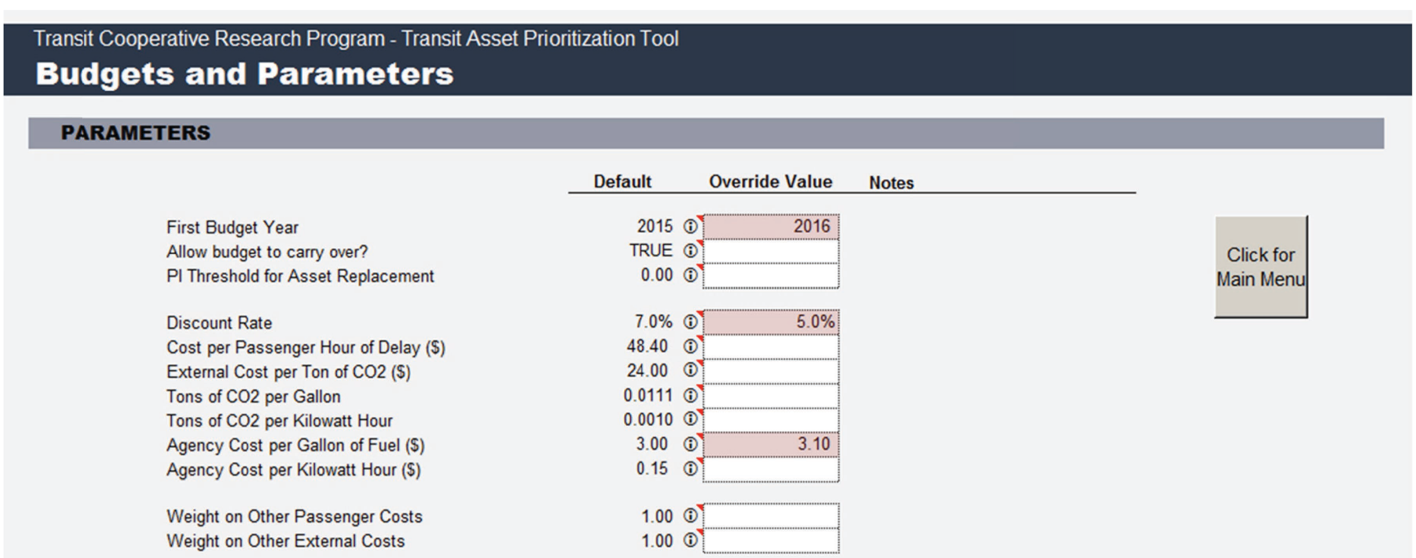


Figure 4.2. Budgets and Parameters.

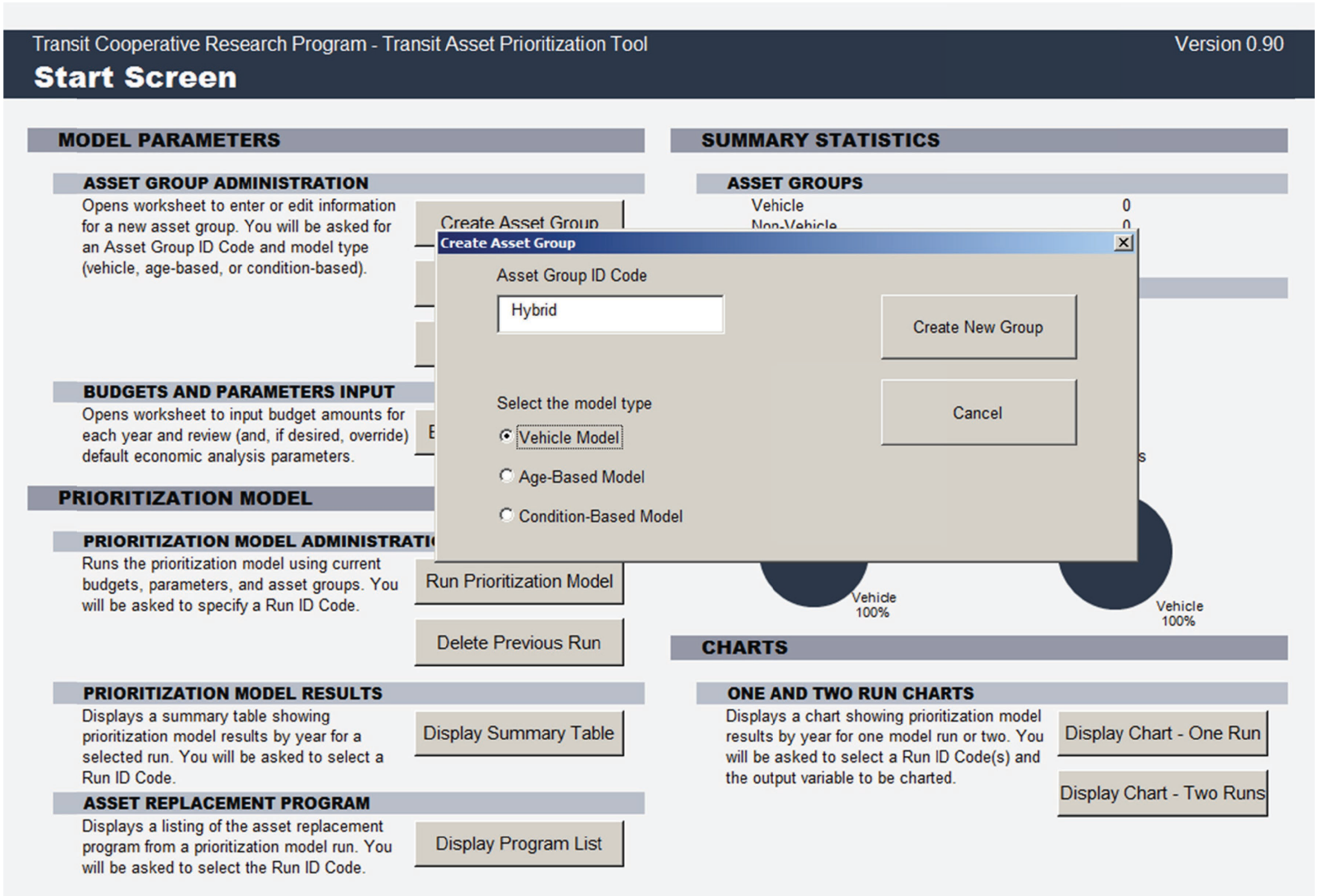


Figure 4.3. Create an Asset Group.

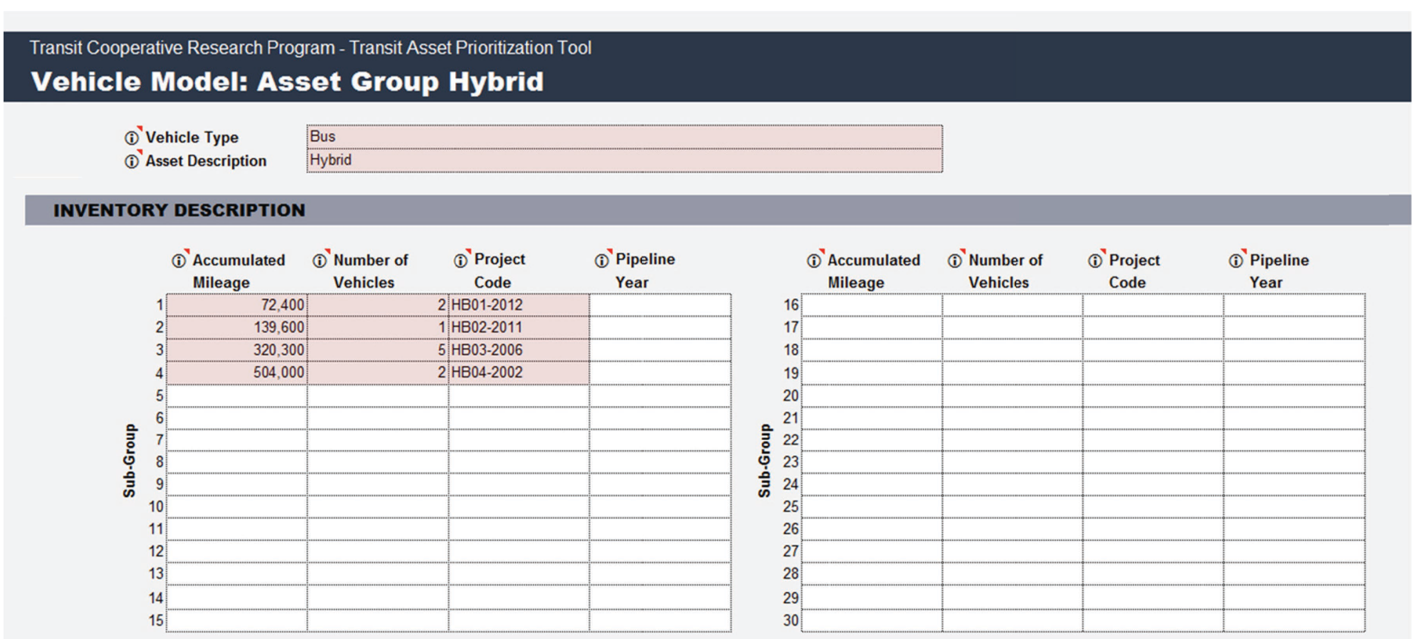


Figure 4.4. Hybrid Bus Vehicle Model.

Table 4.2. Hybrid Bus Inventory Description.

Average Accumulated Mileage	Number of Vehicles	Project Code
72,400	2	HB01-2012
139,600	1	HB02-2011
320,300	5	HB03-2006
504,000	2	HB04-2002

The next steps require entering NTD data for Hybrid buses. The data that MST currently reports to NTD combines statistics for hybrid and diesel buses; therefore, you must disaggregate the data for the two fleets before continuing. The data in Table 4.3 reflects the disaggregated figures calculated for Hybrid buses.

9. Use Table 4.3 to input the **Vehicle Data from the National Transit Database** for the hybrid bus fleet (Figure 4.5).

After completing the NTD data, you review the TAPT inputs to determine other factors that are relevant to the agency and might improve the results of the analysis. A complete list of the data inputs for the vehicle model can be found in Appendix A of the draft final report. Since MST has limited historical data, you decide to use the defaults for the remaining inputs. This decision includes using the default for the **New Vehicle Cost**, $495,951. Before moving on:

10. Review the **Summary Results**, shown in Figure 4.6. Note that the calculated **Cost-Minimizing Replacement Age** for hybrid buses is determined to be 14 years (or 588,000 miles) with an **Annual Cost** of $184,326.
11. Select **Click for Main Menu** when complete.

Table 4.3. Hybrid Bus Model Parameters.

Model Parameters	Value
Passenger Miles (000)	2,400
Unlinked Trips (000)	700
Vehicle Miles (000)	420
Revenue Vehicle Miles (000)	325
Revenue Vehicle Hours (000)	25
Number of Road Calls	70
Gallons of Fuel for Vehicle Operations (000)	110
Vehicle Maintenance Cost (000)	640

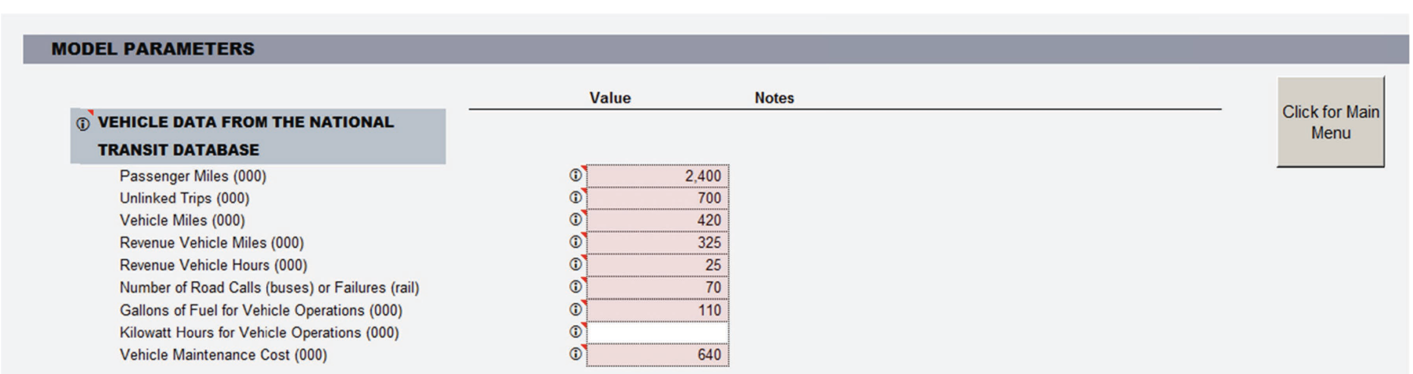


Figure 4.5. Hybrid Bus Vehicle Model Parameters.

Figure 4.6. Hybrid Bus Vehicle Summary Results.

Diesel Buses

The next step is to enter the data for the diesel bus fleet by creating a second Vehicle Model.

12. Create a new asset category for diesel buses uses the following information (Figure 4.7):
    - **Asset Group ID Code:** Diesel
    - **Model Type:** Vehicle Model
13. Input the following information into the diesel vehicle model:
    - **Vehicle Type:** Bus
    - **Asset Description:** Diesel
    - **Inventory Description:** Use the inputs from Table 4.4
    - **Vehicle Data from the National Transit Database** (Figure 4.8): Use the inputs from Table 4.5

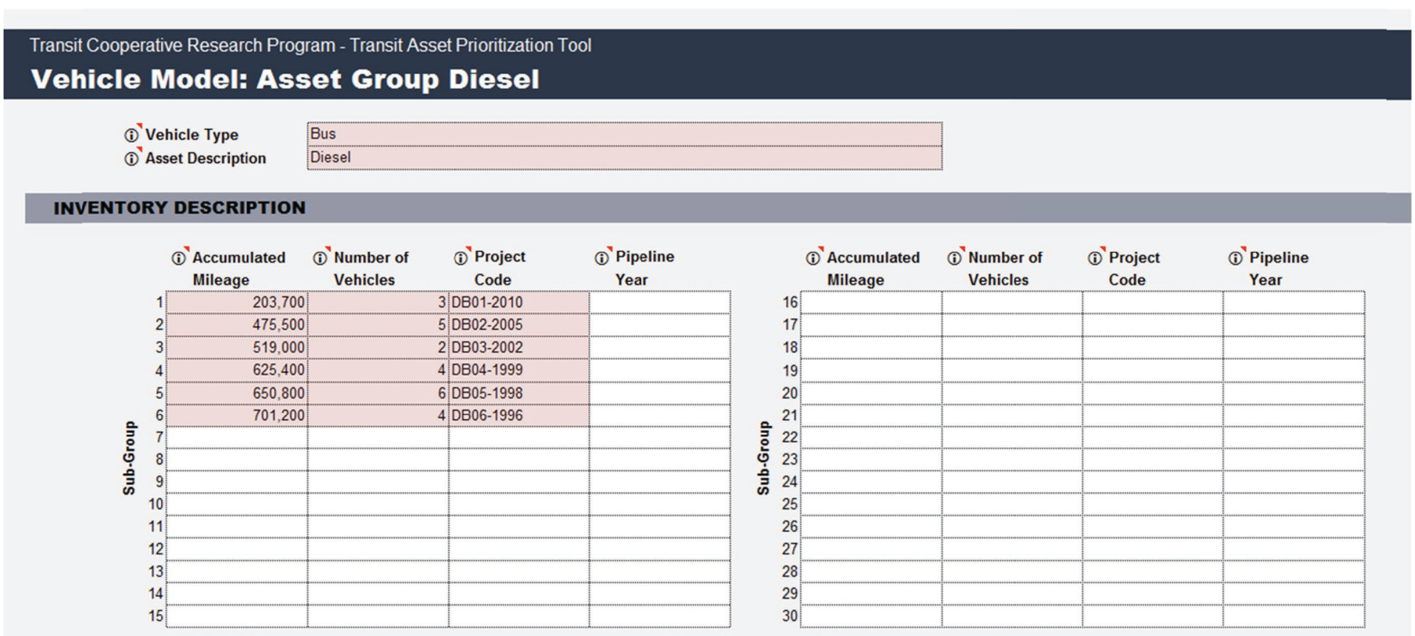


Figure 4.7. Diesel Bus Vehicle Model.

Table 4.4. Diesel Bus Inventory Description.

Average Accumulated Mileage	Number of Vehicles	Project Code
203,700	3	DB01-2010
475,500	5	DB02-2005
519,000	2	DB03-2002
625,400	4	DB04-1999
650,800	6	DB05-1998
701,200	4	DB06-1996

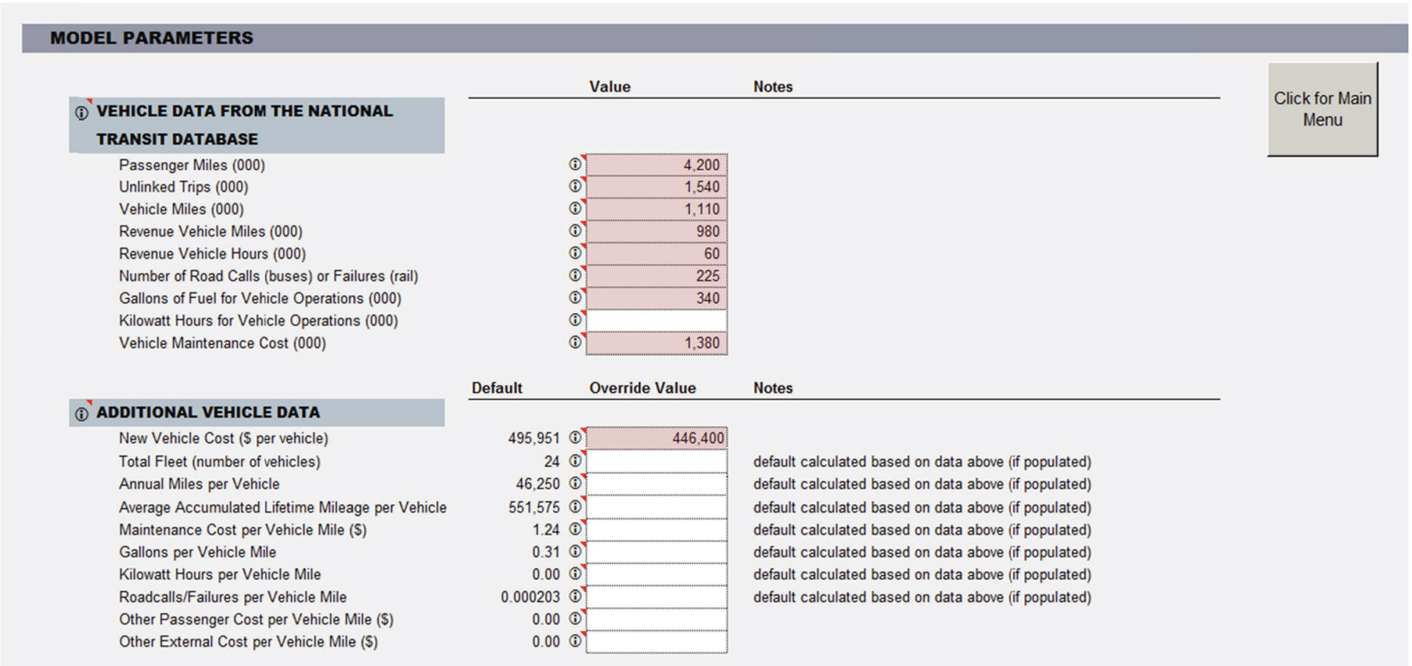


Figure 4.8. Diesel Bus Vehicle Model Parameters.

Table 4.5. Diesel Bus Model Parameters.

Model Parameters	Value
Passenger Miles (000)	4,200
Unlinked Trips (000)	1,540
Vehicle Miles (000)	1,110
Revenue Vehicle Miles (000)	980
Revenue Vehicle Hours (000)	60
Number of Road Calls	225
Gallons of Fuel for Vehicle Operations (000)	340
Vehicle Maintenance Cost (000)	1,380

After reviewing the remaining inputs for the vehicle model, you also choose to modify the New Vehicle Cost for diesel buses. After speaking with MST staff, you determine diesel buses typically cost less than hybrid buses.

14. Override the **New Vehicle Cost ($)** for diesel buses by inputting "446,400."
15. Review the **Summary Results**, shown at the bottom of Figure 4.9. Note that the calculated **Cost-Minimizing Replacement Age** for diesel buses is determined to be 14 years (or 647,500 miles) with an **Annual Cost** of $160,589. Select **Click for Main Menu** when complete.

Figure 4.9. Diesel Bus Vehicle Model Summary Results.

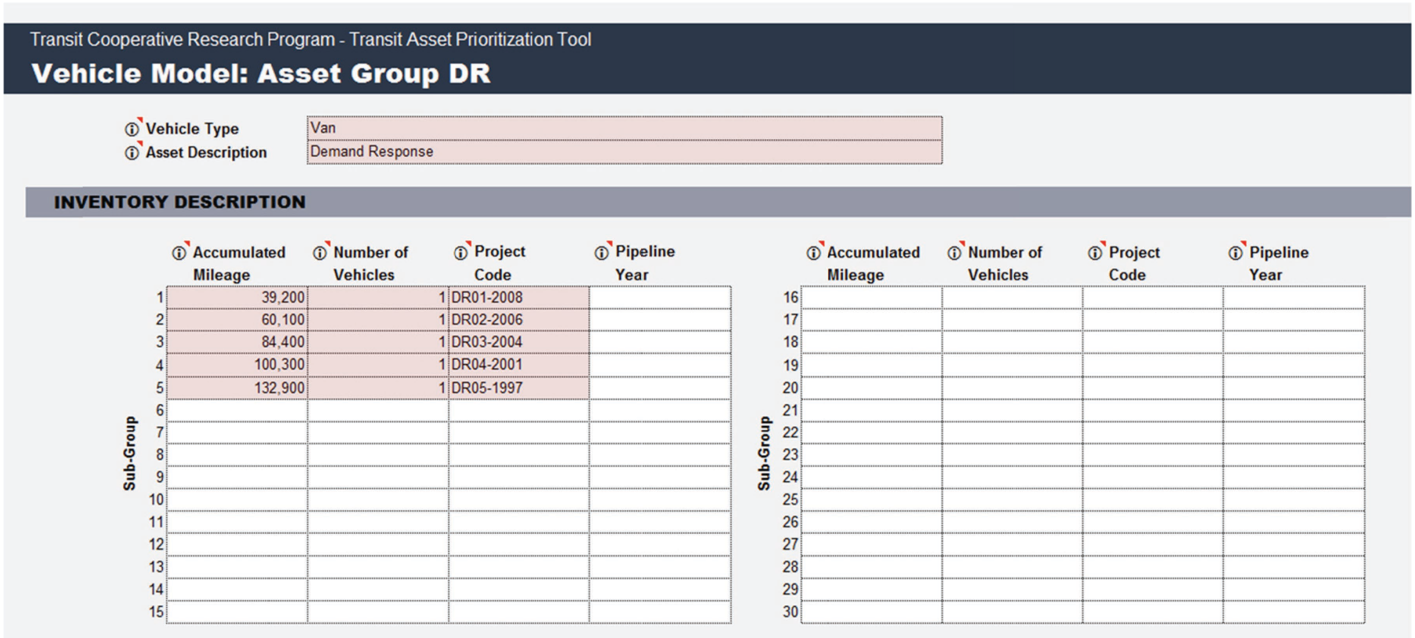


Figure 4.10. Demand Response Van Vehicle Model.

Table 4.6. DR Van Inventory Description.

Average Accumulated Mileage	Number of Vehicles	Project Code
39,200	1	DR01-2008
60,100	1	DR02-2006
84,400	1	DR03-2004
100,300	1	DR04-2001
132,900	1	DR05-1997

Demand Response Vans

The last model that you create is a Vehicle Model for the Demand Response fleet.

16. Create a new asset category for diesel buses using the following information:
    - **Asset Group ID Code:** DR
    - **Model Type:** Vehicle Model
17. Input the following information into the demand response vehicle model (Figure 4.10):
    - **Vehicle Type:** Van
    - **Asset Description:** Demand Response
    - **Inventory Description:** Use the inputs from Table 4.6
    - **Vehicle Data from the National Transit Database** (Figure 4.11): Use the inputs from Table 4.7
18. Review the **Summary Results**, shown in Figure 4.12. Note that the calculated **Cost-Minimizing Replacement Age** for demand response vans is determined to be 13 years (or 104,000 miles) with an **Annual Cost** of $10,250. Select **Click for Main Menu** when complete.

Step 2: Run the Prioritization Model

Before running a scenario with the agency budget, it is important to understand how the agency's assets are deteriorating or improving over time. Running the prioritization model with an unconstrained budget allows the agency to gain a better understanding of the model's recommendations.

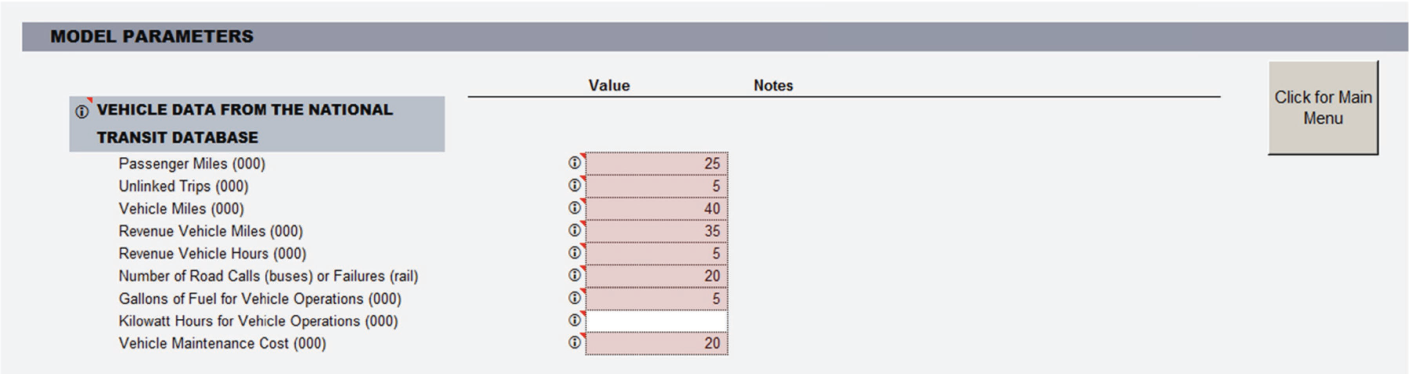


Figure 4.11. Demand Response Van Vehicle Model Parameters.

Table 4.7. DR Van Model Parameters.

Model Parameters	Value
Passenger Miles (000)	25
Unlinked Trips (000)	5
Vehicle Miles (000)	40
Revenue Vehicle Miles (000)	35
Revenue Vehicle Hours (000)	5
Number of Road Calls	20
Gallons of Fuel for Vehicle Operations (000)	5
Vehicle Maintenance Cost (000)	20

Figure 4.12. Demand Response Van Summary Results.

Unconstrained Scenario

After all of the vehicle data has been entered, you are ready to begin running the model to determine the program for MST. The first step is to run an unconstrained program.

1. From the start screen, click **Budgets & Parameters** (Figure 4.13).
2. Set the **Budget for Asset Replacement and Rehabilitation ($)** to "999,999,999" for years **2016** through **2025** to cover the span of the 10-year plan in the TAMP.
3. Select **Click for Main Menu** to return to the start screen.

The next step is to run the model using the unconstrained budget.

4. Select **Run Prioritization Model** and define the **ID Code** as "Unconstrained" to describe the run. Then click **OK** to run the model (Figure 4.14).

When the analysis has been completed, the model will open a **Program List** for the Unconstrained run, shown in Figure 4.15.

5. Review the **Program List** and select **Click for Main Menu** when you have finished. Note that with an unconstrained budget the following assets would be replaced between **2016** and **2025:**
   - 7 hybrid buses
   - 24 diesel buses
   - 5 demand response buses

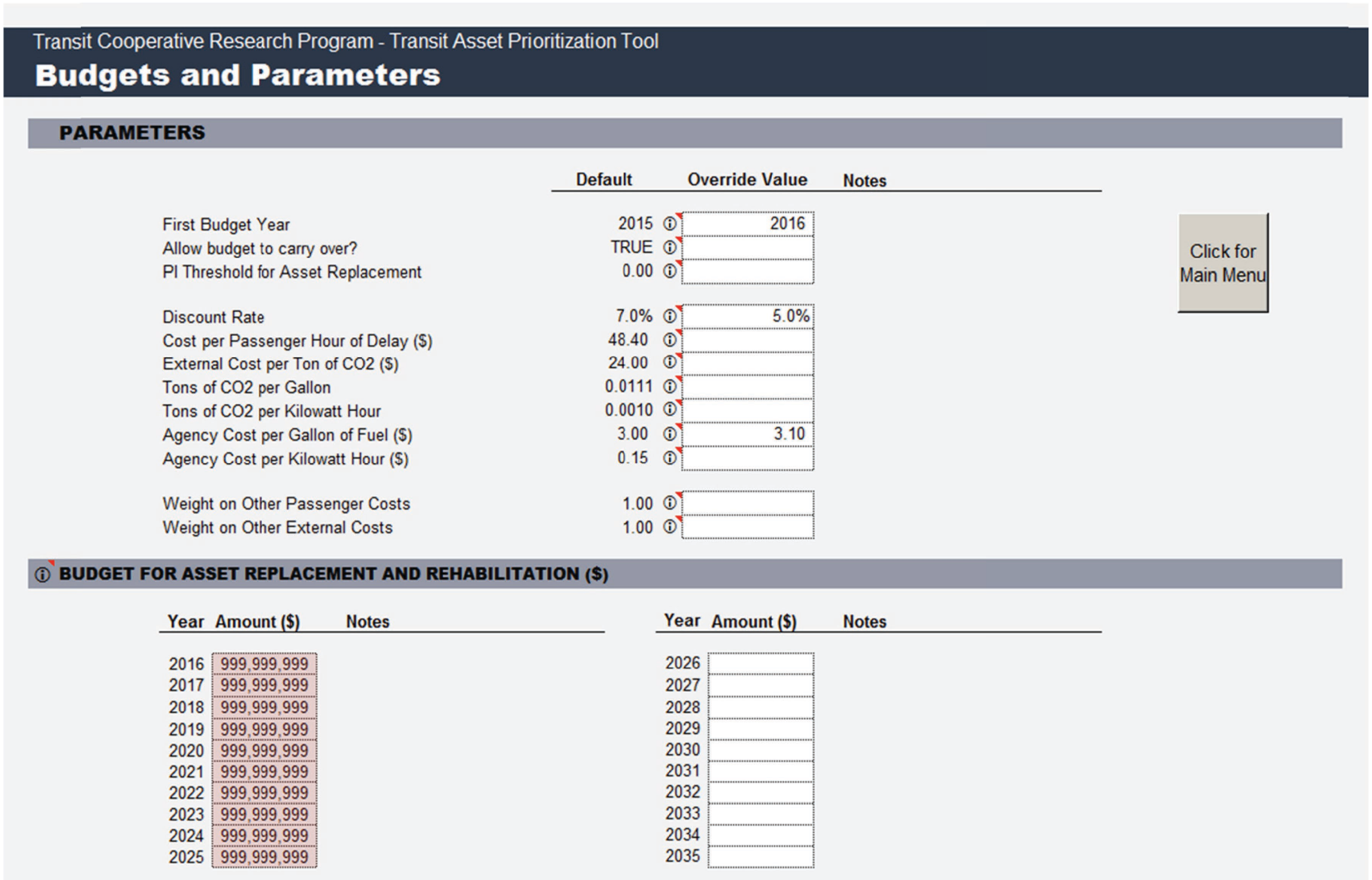


Figure 4.13. Budgets and Parameters for an Unconstrained Scenario.

Click **Display Summary Table** and select the "Unconstrained" run before clicking **Display Summary Table** (Figure 4.16).

The unconstrained budget is used to show MST all of the economically feasible tasks that would be eligible for programming during the analysis period. On the **Summary Table** page, shown in Figure 4.17, you note with an unconstrained budget the mean distance between failures would increase, improving service and the overall condition of the fleet. With an unconstrained budget, MST would spend $14,379,040 over the 10-year span in the TAMP. Table 4.8 shows a summary of the initial needs and condition of assets, compared to the value in 2025 if the agency had unconstrained funding over 10 years.

6. Review the **Summary Table** and select **Click for Main Menu** when you have finished.
7. From the start screen, select **Display Chart–One Run** (Figure 4.18).
8. Select "Needs ($)" as the **Prioritization Model Output Variable** to chart, then select "Unconstrained" as the **Run** to chart before clicking **Display Chart**.
9. Review the **Needs ($)** chart, shown in Figure 4.19, and select **Click for Main Menu** when you have finished.
10. Create a second chart using "Mean Distance Between Failures (miles)" as the **Prioritization Model Output Variable** to chart. This graph is shown in Figure 4.20. After reviewing the graph, select **Click for Main Menu** to return to the start screen.

Figures 4.19 and 4.20 show the distribution of **Needs ($)** and the **Mean Distance Between Failures (miles)** between 2016 and 2025 in an unconstrained scenario. These figures will serve as a point of comparison to the final prioritization run using the agency budget.

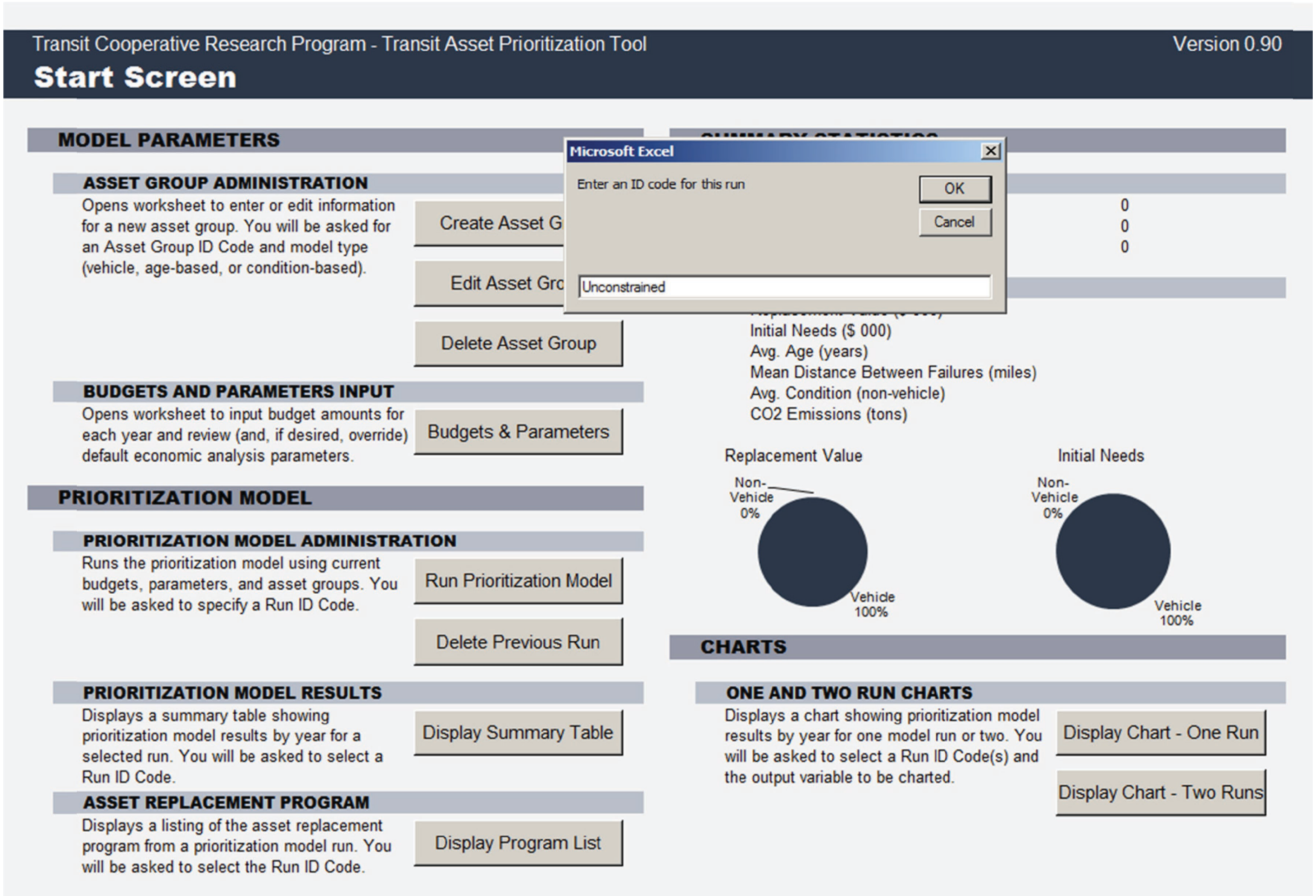


Figure 4.14. Run Prioritization Model.

Transit Cooperative Research Program - Transit Asset Prioritization Tool

Program List: Prioritization Run Unconstrained

Program Year	Asset ID Code	Description	No. of Assets	Replacement Costs	Project Rank	PI	Pipe-Lined?	Project Code
2016	DR 4	Demand Response	1	38,756	2	0.0398		DR04-2001
2016	DR 5	Demand Response	1	38,756	1	0.2084		DR05-1997
2016	Diesel 4	Diesel	4	1,785,600	4	0.0198		DB04-1999
2016	Diesel 5	Diesel	6	2,678,400	4	0.0198		DB05-1998
2016	Diesel 6	Diesel	4	1,785,600	3	0.0370		DB06-1996
2017	DR 3	Demand Response	1	38,756	1	0.0106		DR03-2004
2017	Hybrid 4	Hybrid	2	991,903	2	0.0049		HB04-2002
2018	Diesel 3	Diesel	2	892,800	1	0.0015		DB03-2002
2019	Diesel 2	Diesel	5	2,232,000	1	0.0015		DB02-2005
2020	DR 2	Demand Response	1	38,756	1	0.0106		DR02-2006
2021	Hybrid 3	Hybrid	5	2,479,757	1	0.0049		HB03-2006
2023	DR 1	Demand Response	1	38,756	1	0.0106		DR01-2008
2025	Diesel 1	Diesel	3	1,339,200	1	0.0015		DB01-2010

Figure 4.15. Unconstrained Scenario Program List.

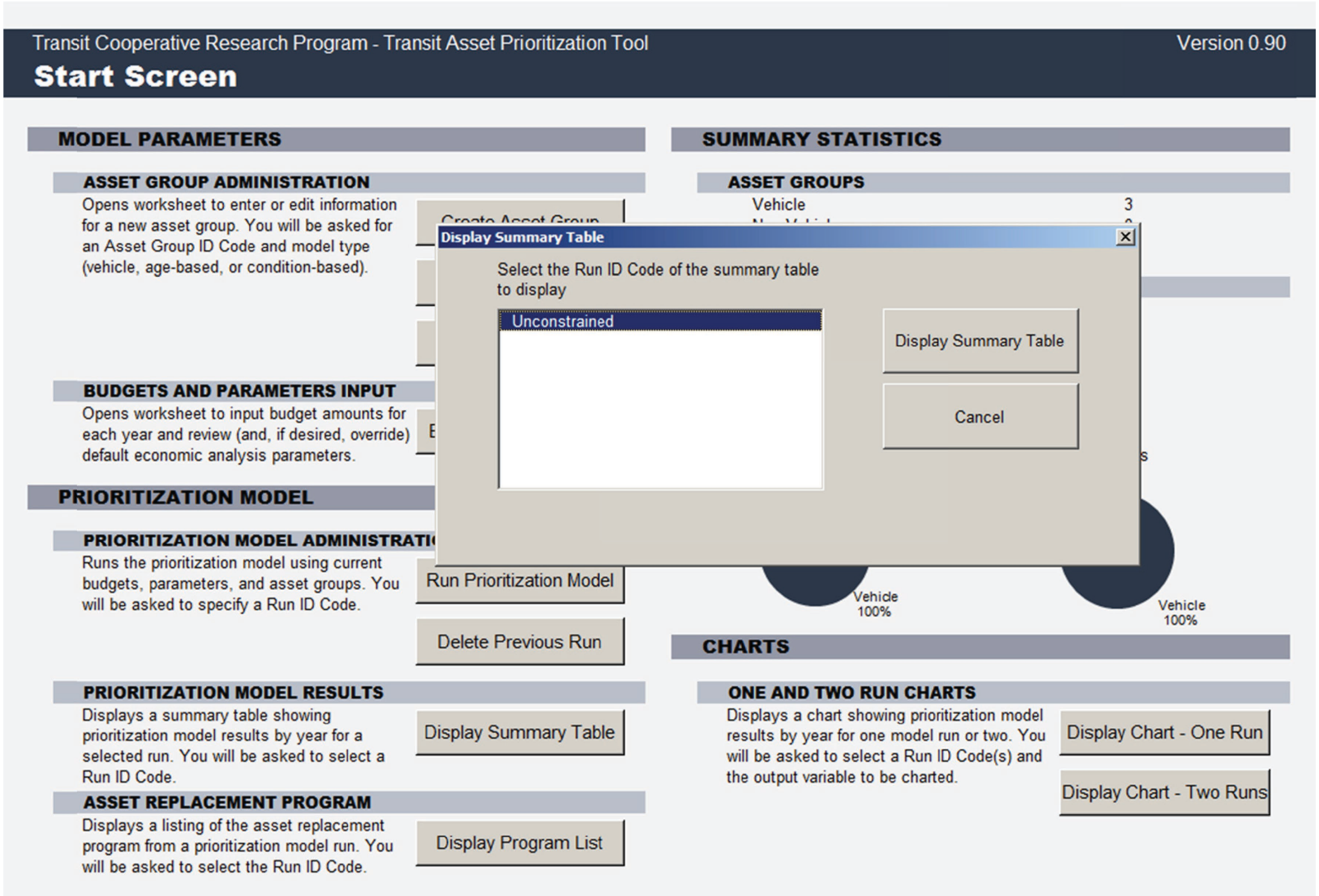


Figure 4.16. Display Summary Table.

Transit Cooperative Research Program - Transit Asset Prioritization Tool

Summary: Prioritization Run Unconstrained

Year	Needs: Amount ($)	Needs: Percent	Asset NPV	Budget ($)	Expenditures from Budget ($)	Remaining Backlog ($)	Energy Costs ($)	Other Agency Costs ($)	Cost of Passenger Delay ($)	Other Passenger Costs ($)	Cost of CO2 Emissions ($)	Other External Costs ($)	Total Agency, Pass., and Ext. Costs ($)	Passenger Delay (hours)	CO2 Emissions (tons)	Avg. Condition (non-veh)	MDBF (miles)
2016	6,327,112	39.9%	163,882	999,999,999	6,327,112	-	1,453,459	3,208,014	256,665	-	149,644	-	11,394,894	5,303	6,235	-	4,300
2017	1,030,659	6.5%	5,283	1,993,672,886	1,030,659	-	1,244,576	2,490,719	172,219	-	111,055	-	5,049,228	3,558	4,627	-	6,705
2018	892,800	5.6%	1,334	2,992,642,226	892,800	-	1,253,669	2,550,660	171,459	-	111,358	-	4,979,947	3,543	4,640	-	6,765
2019	2,232,000	14.1%	3,334	3,991,749,425	2,232,000	-	1,257,273	2,604,023	174,341	-	116,709	-	6,384,346	3,602	4,863	-	6,644
2020	38,756	0.2%	411	4,989,517,424	38,756	-	1,212,896	2,485,909	157,936	-	104,977	-	4,000,473	3,263	4,374	-	7,335
2021	2,479,757	15.6%	12,181	5,989,478,667	2,479,757	-	1,247,087	2,622,642	171,973	-	115,836	-	6,637,296	3,553	4,827	-	6,858
2022	-	0.0%	-	6,986,998,909	-	-	1,217,370	2,420,445	147,282	-	104,884	-	3,889,980	3,043	4,370	-	7,721
2023	38,756	0.2%	411	7,986,998,908	38,756	-	1,252,018	2,559,618	161,000	-	108,343	-	4,119,735	3,326	4,514	-	7,040
2024	-	0.0%	-	8,986,960,151	-	-	1,287,661	2,674,100	175,534	-	110,910	-	4,248,205	3,627	4,621	-	6,569
2025	1,339,200	8.4%	2,000	9,986,960,150	1,339,200	-	1,324,327	2,789,694	191,870	-	119,102	-	5,764,194	3,964	4,963	-	5,995

Click for Main Menu

Figure 4.17. Unconstrained Scenario Summary Results.

Table 4.8. Unconstrained Summary Results.

Scenarios	Initial Value	Value in 2025
		Unconstrained
Remaining Backlog	$ 6,327,112	$ 0
Cumulative Spent	-	$ 14,379,040
MDBF (miles)	4,300	5,995
Passenger Delay (hours)	5,303	3,964
CO2 Emissions (tons)	5,215	4,963
Other Agency Costs	$ 3,208,014	$ 2,789,694
Total Agency, User and External Costs Excluding Budget Expenditures	$ 5,043,302	$ 5,764,194

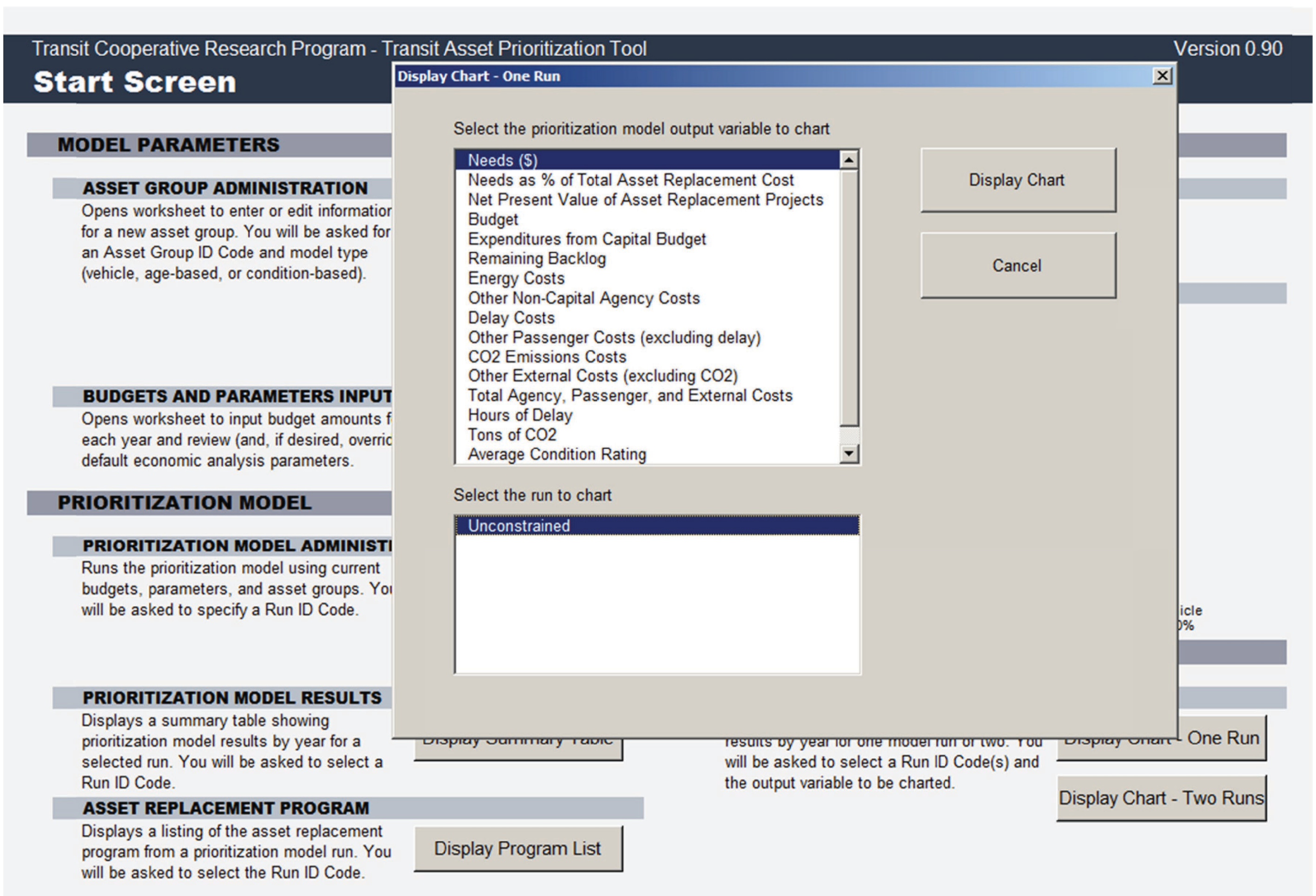


Figure 4.18. Display Chart—One Run.

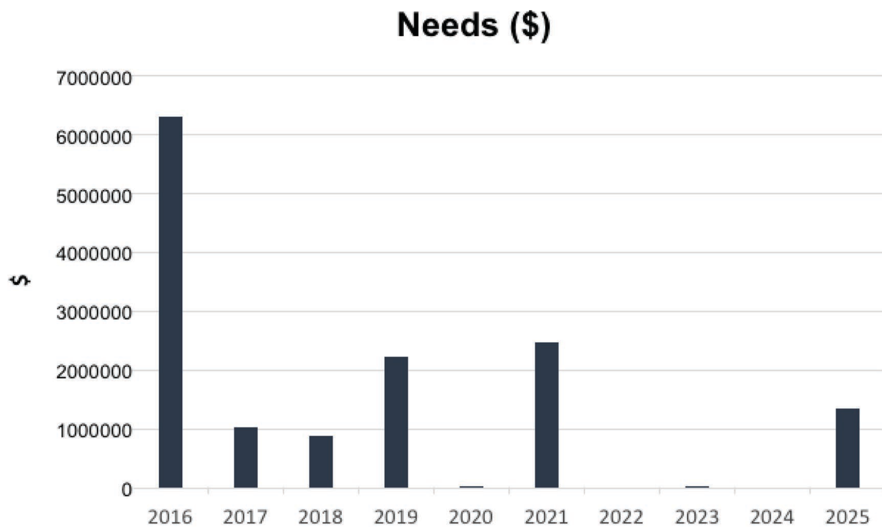


Figure 4.19. MST Needs ($) Unconstrained Scenario.

Do Nothing Scenario

Next, create a scenario for MST with no budget to understand how assets would deteriorate if no funding was available.

11. Adjust the following on the **Budgets and Parameters** page:
    - **Budget for Asset Replacement and Rehabilitation (Years 2016–2025):** 0
12. Run a prioritization model with the **ID Code** "Do Nothing."
13. Review the **Program List** and the **Summary Table**, shown in Figure 4.21.

Table 4.9 summarizes the results of the do nothing scenario. The table shows a significant decrease in mean distance between failures (see Figure 4.22), an increase in passenger hours of delay, and the large costs that would be incurred if the system were allowed to deteriorate.

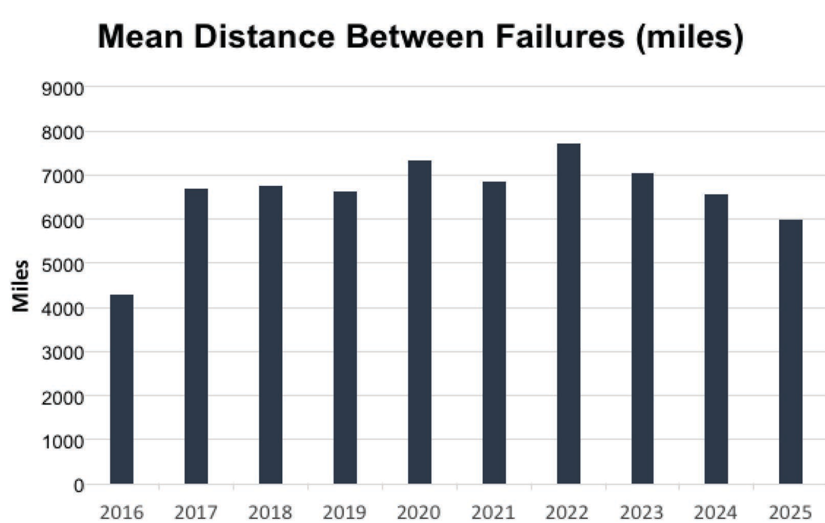


Figure 4.20. MST Mean Distance Between Failures (miles) Unconstrained Scenario.

Transit Cooperative Research Program - Transit Asset Prioritization Tool

Summary: Prioritization Run Do Nothing

Year	Needs Amount ($)	Needs Percent	Asset NPV	Budget ($)	Expenditures from Budget ($)	Remaining Backlog ($)	Energy Costs ($)	Other Agency Costs ($)	Cost of Passenger Delay ($)	Other Passenger Costs ($)	Cost of CO2 Emissions ($)	Other External Costs ($)	Total Agency, Pass., and Ext. Costs ($)	Passenger Delay (hours)	CO2 Emissions (tons)	Avg. Condition (non-veh)	MDBF (miles)
2016	6,327,112	39.9%	-	-	-	6,327,112	1,453,459	3,208,014	256,665	-	125,164	-	5,043,302	5,303	5,215	-	4,300
2017	7,357,771	46.4%	-	-	-	7,357,771	1,494,949	3,369,432	280,784	-	128,731	-	5,273,896	5,801	5,364	-	3,915
2018	8,250,571	52.0%	-	-	-	8,250,571	1,537,633	3,532,288	307,184	-	132,400	-	5,509,505	6,347	5,517	-	3,563
2019	10,482,571	66.1%	-	-	-	10,482,571	1,581,545	3,697,649	336,080	-	136,175	-	5,751,448	6,944	5,674	-	3,242
2020	10,521,327	66.3%	-	-	-	10,521,327	1,626,719	3,871,083	367,711	-	140,059	-	6,005,572	7,597	5,836	-	2,949
2021	13,001,084	81.9%	-	-	-	13,001,084	1,673,194	4,053,370	402,338	-	144,054	-	6,272,955	8,313	6,002	-	2,682
2022	13,001,084	81.9%	-	-	-	13,001,084	1,721,005	4,245,371	440,247	-	148,164	-	6,554,787	9,096	6,173	-	2,439
2023	13,039,840	82.2%	-	-	-	13,039,840	1,770,192	4,446,467	481,752	-	152,392	-	6,850,804	9,954	6,350	-	2,216
2024	13,039,840	82.2%	-	-	-	13,039,840	1,820,795	4,657,520	527,198	-	156,742	-	7,162,255	10,893	6,531	-	2,014
2025	14,379,040	90.6%	-	-	-	14,379,040	1,872,854	4,878,120	576,963	-	161,217	-	7,489,154	11,921	6,717	-	1,830

Click for Main Menu

Figure 4.21. Do Nothing Scenario Summary Results.

Table 4.9. Do Nothing Summary Results.

Scenarios	Initial Value	Value in 2025	
		Unconstrained	**Do Nothing**
Remaining Backlog	$ 6,327,112	$ 0	$ 14,379,040
Cumulative Spent	-	$ 14,379,040	-
MDBF (miles)	4,300	5,995	1,830
Passenger Delay (hours)	5,303	3,964	11,921
CO2 Emissions (tons)	5,215	4,963	6,717
Other Agency Costs	$ 3,208,014	$ 2,789,694	$ 4,878,120
Total Agency, User and External Costs Excluding Budget Expenditures	$ 5,043,302	$ 4,475,883	$ 7,489,154

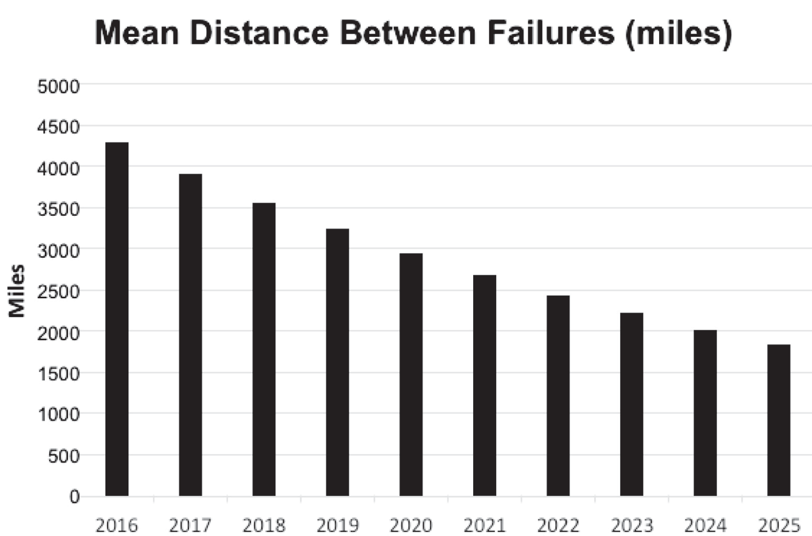


Figure 4.22. MST Mean Distance Between Failures (miles) Do Nothing Scenario.

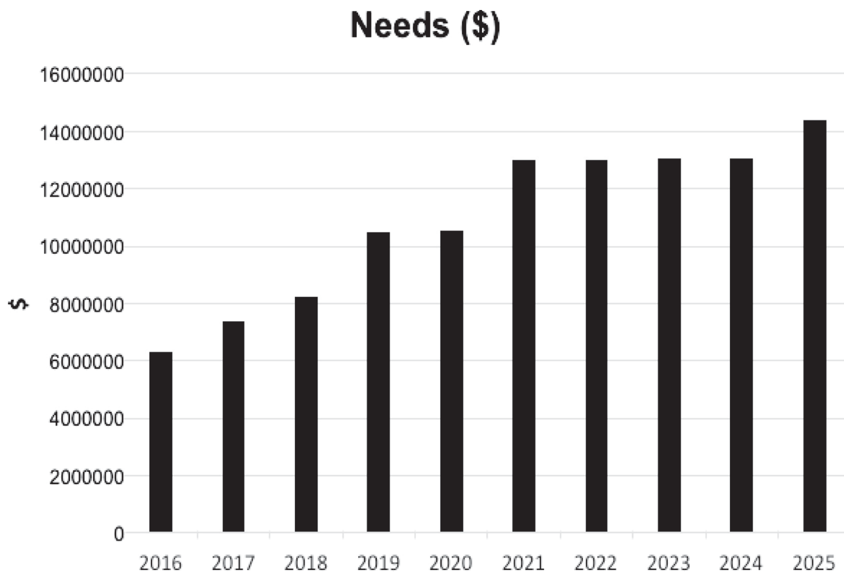


Figure 4.23. MST Needs ($) Do Nothing Scenario.

14. Input the following information to create two charts, showing conditions between 2016 and 2025 in a "Do Nothing" scenario:
    - **Chart One**, shown in Figure 4.23, with the **Prioritization Model Output Variable** selected as "Needs ($)" the **Run** "Do Nothing."
    - **Chart Two**, shown in Figure 2.22, with the **Prioritization Model Output Variable** selected as "Mean Distance Between Failures (miles)" and the **Run** "Do Nothing."

Step 3: Incorporate the Constrained Budget

The third step of the TAMP Development Process, *Define Investment Scenarios*, involves applying a constrained budget and prioritizing project selection. In this section, you will input MST's annual budget and run a scenario to determine a prioritized program in TAPT.

Annual Budget Scenario

For the last run, you input the MST budget into the model.

1. Adjust the following on the **Budgets and Parameters** page:
    - **Budget for Asset Replacement and Rehabilitation (Years 2016–2025):** 825,000
2. Run a prioritization model with the **ID Code** "Annual Budget."
3. Review the **Program List** and the **Summary Table**, shown in Figure 4.24.

First you review the proposed program with MST leadership and staff. In total, the suggested program, using the annual budget, replaces:

- 2 hybrid buses;
- 14 diesel buses; and
- 4 demand response vehicles.

The program list suggests the following replacement actions between 2016 and 2025:

- Demand response vehicle 4 is replaced in 2016
- Demand response vehicle 5 is replaced in 2016
- Diesel bus fleet 6, containing 4 vehicles, is replaced in 2018

Transit Cooperative Research Program - Transit Asset Prioritization Tool

Program List: Prioritization Run Annual Budget

Program Year	Asset ID Code	Description	No. of Assets	Replacement Costs	Project Rank	PI	Pipe-Lined?	Project Code
2016	DR 4	Demand Response	1	38,756	2	0.0398		DR04-2001
2016	DR 5	Demand Response	1	38,756	1	0.2084		DR05-1997
2018	Diesel 6	Diesel	4	1,785,600	1	0.0732		DB06-1996
2019	DR 3	Demand Response	1	38,756	1	0.0735		DR03-2004
2023	Diesel 4	Diesel	4	1,785,600	1	0.1533		DB04-1999
2023	Diesel 5	Diesel	6	2,678,400	1	0.1533		DB05-1998
2024	DR 2	Demand Response	1	38,756	1	0.1569		DR02-2006
2024	Hybrid 4	Hybrid	2	991,903	2	0.1400		HB04-2002

Figure 4.24. Annual Budget Scenario Program List.

- Demand response vehicle 3 is replaced in 2019
- Diesel bus fleet 4, containing 4 vehicles, is replaced in 2023
- Diesel bus fleet 5, containing 6 vehicles, is replaced in 2023
- Demand response vehicle 2 is replaced in 2024
- Hybrid bus fleet 4, containing 2 vehicles, is replaced in 2024

Summary Results for this scenario, as compared to previous scenarios, are shown in Table 4.10. In addition to reviewing the summary results, you also create a series of graphs to show the effects of the program over time.

4. Input the following information to create two charts:
   - **Chart One**, shown in Figure 4.25, with the **Prioritization Model Output Variable** selected as "Needs ($)" the **Run** "Annual Budget."
   - **Chart Two**, shown in Figure 4.26, with the **Prioritization Model Output Variable** selected as "Mean Distance Between Failures (miles)" and the **Run** "Annual Budget."

The annual budget prioritization run and the results showed that over a 10-year period, Main Street Transit was able to maintain their vehicle assets without significantly increasing their needs (see Figure 4.25), only increasing the overall agency needs by $655,401. Meanwhile there was a

Table 4.10. Annual Budget Results.

Scenarios	Initial Value	Value in 2025		
		Unconstrained	Annual Budget Scenario	Do Nothing
Remaining Backlog	$ 6,327,112	-	$ 6,982,513	$ 14,379,040
Cumulative Spent	-	$ 14,379,040	$ 7,396,527	-
MDBF (miles)	4,300	5,995	4,088	1,830
Passenger Delay (hours)	5,303	3,964	5,874	11,921
CO_2 Emissions (tons)	5,215	4,963	5,133	6,717
Other Agency Costs	$ 3,208,014	$ 2,789,694	$ 3,238,596	$ 4,878,120
Total Agency, User and External Costs Excluding Budget Expenditures	$ 5,043,302	$ 4,475,883	$ 5,076,463	$ 7,489,154

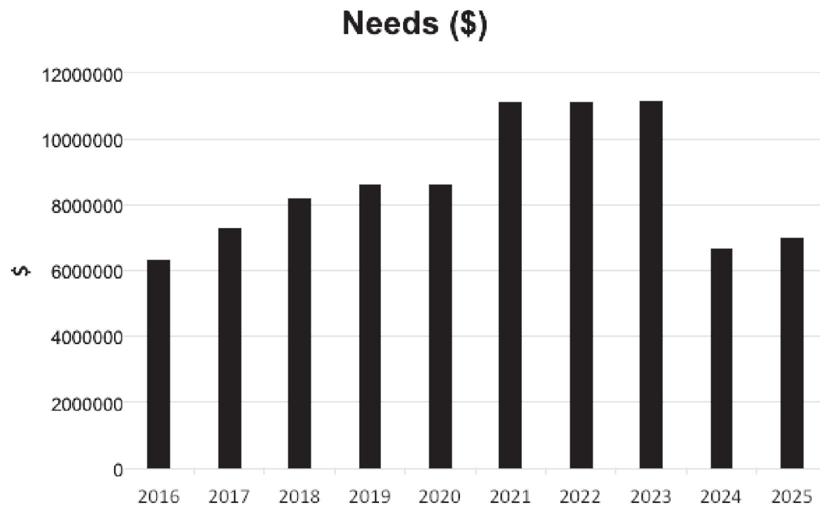


Figure 4.25. Needs ($) Annual Budget Scenario.

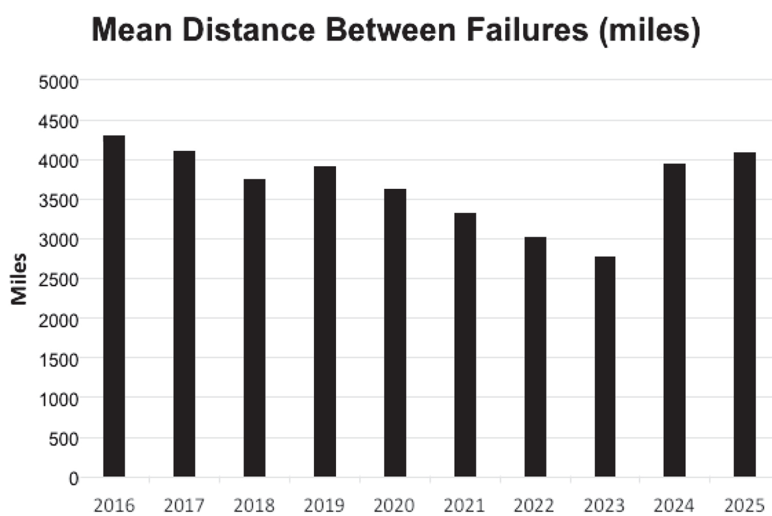


Figure 4.26. Mean Distance Between Failures (miles) Annual Budget Scenario.

not a noticeable decrease in the MDBFs (see Figure 4.26), as the average MDBF only decreased by approximately 200 miles.

Upon reviewing the results with MST staff, you determine that the program is not consistent with agency priorities. In the process of developing the agency TAMP, MST had determined that replacing diesel buses was a priority because (1) they are required for maintaining regular service, (2) they have more mileage than other vehicles owned by the agency, and (3) MST is committed to purchasing hybrid buses in the future for environmental reasons. With these considerations in mind, you return to the model to make adjustments.

Step 4: Refine the Prioritization Approach

The fourth step in the TAMP development process is to **Finalize Investment Scenarios**. Developing a program list is an iterative process that involves adjusting the parameters of the analysis until the agency arrives at a program that best reflects their needs. In this section, you will be responsible for adjusting the investment scenarios to arrive at an optimized plan for MST.

Adjusted Program Scenario

After determining that replacing diesel buses is an agency priority, you return to the vehicle model for diesel buses.

1. From the start screen, click **Edit Asset Group** and select "Diesel."
2. Using Table 4.11, adjust the following **Other Parameters** (Figure 4.27):
   - The **Energy Savings for a New Vehicle** quantifies the increased energy efficiency of the hybrid vehicles that will replace the diesel fleet.
   - The **Supplemental Replacement Benefit** approximates the additional benefits of a shift to hybrid technology not reflected in the TAPT models.
3. Delete the **New Vehicle Cost** to use the default for this value (Figure 4.28). Because diesel buses will be replaced with hybrid buses, the **New Vehicle Cost** should be the cost of purchasing a new hybrid vehicle.
4. Review the **Summary Results**. Note that the calculated **Cost-Minimizing Replacement Age** for diesel buses has increased to 15 years (or 693,750 miles) with a decreased **Annual Cost** of $157,854.
5. Return to the start screen and select **Run Prioritization Model**, defining the **ID Code** as "Adjusted Program" to describe the run. The annual budget should not be adjusted for this scenario.

Table 4.11. Adjustments to Other Parameters.

Model Parameters	Value
Energy Saving for a New Vehicle (%)	25.0%
Supplemental Replacement Benefit (% of repl. cost)	5.0%

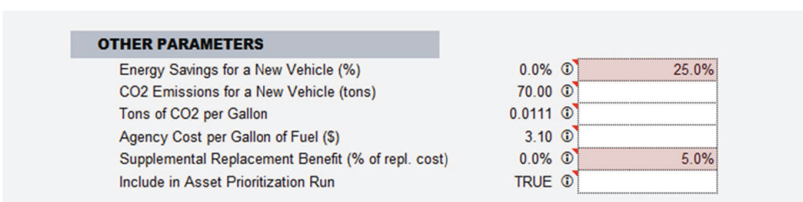


Figure 4.27. Adjustments to Other Parameters.

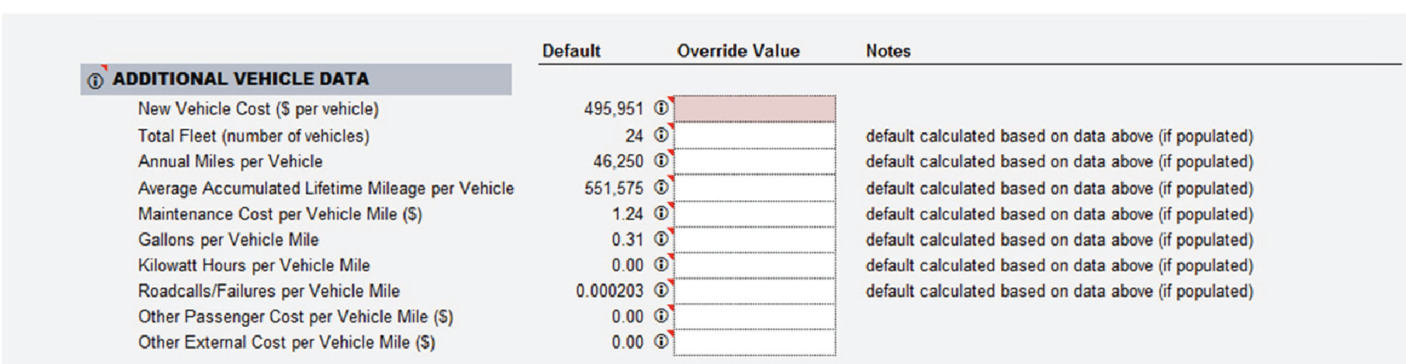


Figure 4.28. Adjustments to the Additional Vehicle Data.

Table 4.12. Annual Budget and Adjusted Program Results.

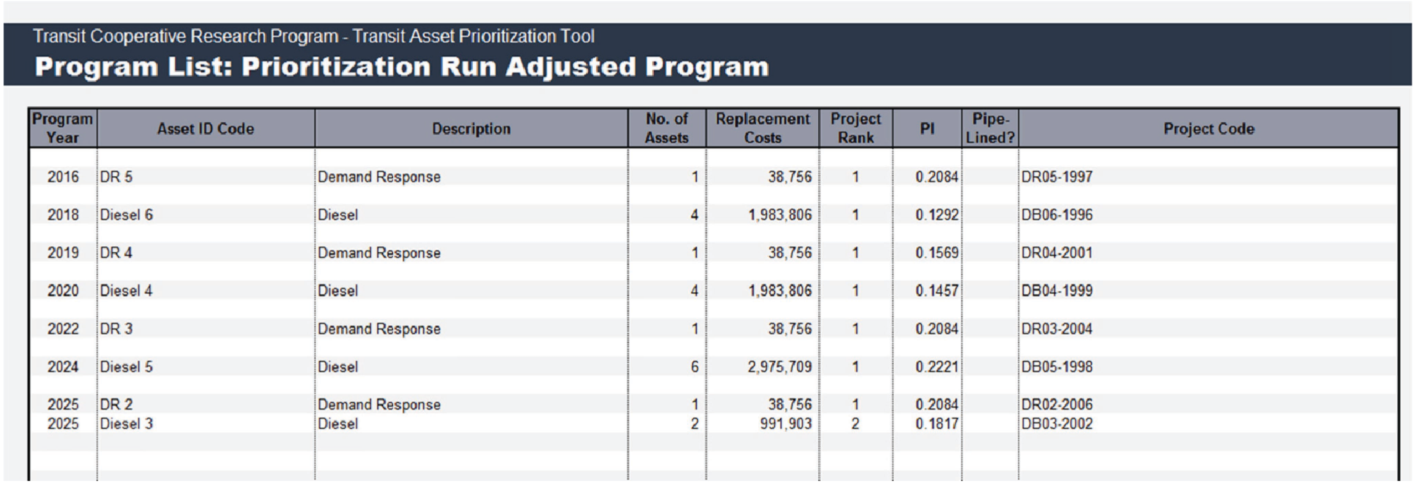
Scenarios	Initial Value	Value in 2025	
		Annual Budget Scenario	Adjusted Program Scenario
Remaining Backlog	$ 6,327,112	$ 6,982,513	$ 7,478,028
Cumulative Spent	-	$ 7,396,527	$ 8,090,247
MDBF (miles)	4,300	4,088	3,597
Passenger Delay (hours)	5,303	5,874	6,650
CO_2 Emissions (tons)	5,215	5,133	5,034
Other Agency Costs	$ 3,208,014	$ 3,238,596	$ 3,547,419
Total Agency, User and External Costs Excluding Budget Expenditures	$ 5,043,302	$ 5,076,463	$ 5,348,089

Table 4.12 shows the results of the adjusted program scenario compared to the annual budget scenario.

6. Review the **Program List** and select **Click for Main Menu** when you have finished. Note that with the adjusted program scenario the following assets would be replaced between **2016** and **2025** (Figure 4.29):
   - 16 diesel buses
   - 4 demand response vehicles

Before choosing the adjusted program scenario, you decide to compare the summary results to the annual budget scenario.

7. From the start screen, select **Display Chart–Two Runs**.
8. Select "Needs ($)" as the **Prioritization Model Output Variable** to chart, then select "Annual Budget" and "Adjusted Program" as the **Runs** to chart before clicking **Display Chart**.
9. Review the **Needs ($)** chart, shown in Figure 4.30, and select **Click for Main Menu** when you have finished.


Transit Cooperative Research Program - Transit Asset Prioritization Tool

Program List: Prioritization Run Adjusted Program

Program Year	Asset ID Code	Description	No. of Assets	Replacement Costs	Project Rank	PI	Pipe-Lined?	Project Code
2016	DR 5	Demand Response	1	38,756	1	0.2084		DR05-1997
2018	Diesel 6	Diesel	4	1,983,806	1	0.1292		DB06-1996
2019	DR 4	Demand Response	1	38,756	1	0.1569		DR04-2001
2020	Diesel 4	Diesel	4	1,983,806	1	0.1457		DB04-1999
2022	DR 3	Demand Response	1	38,756	1	0.2084		DR03-2004
2024	Diesel 5	Diesel	6	2,975,709	1	0.2221		DB05-1998
2025	DR 2	Demand Response	1	38,756	1	0.2084		DR02-2006
2025	Diesel 3	Diesel	2	991,903	2	0.1817		DB03-2002

Figure 4.29. Adjusted Program Scenario Program List.

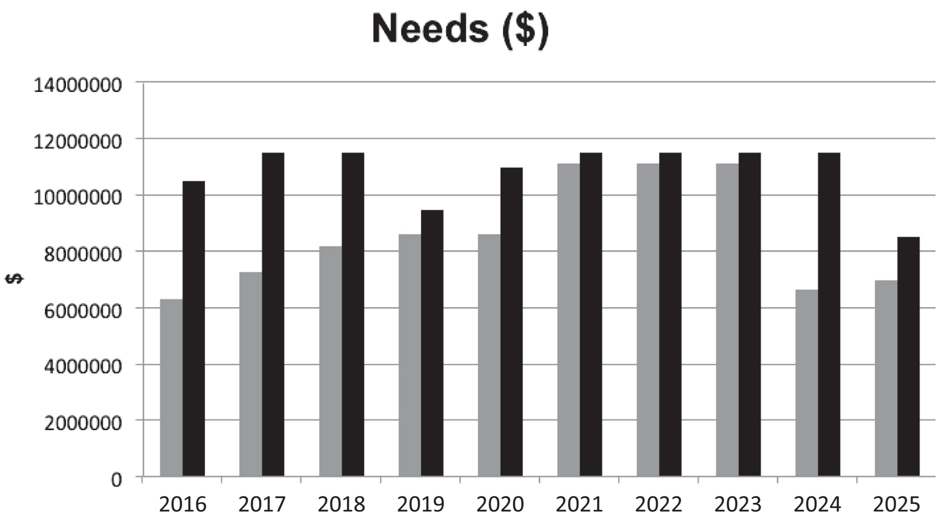


Figure 4.30. Comparing Needs ($) between the Annual Budget Scenario (gray) and Adjusted Program Scenario (black).

10. Input the following information to create two additional charts:
    - **Chart One**, shown in Figure 4.31, with the **Prioritization Model Output Variable** selected as "Mean Distance Between Failures (miles)" the **Runs** "Annual Budget" and "Adjusted Program."
    - **Chart Two**, shown in Figure 4.32, with the **Prioritization Model Output Variable** selected as "Tons of CO_2" and the **Runs** "Annual Budget" and "Adjusted Program."

These graphs show that using the Adjusted Program scenario, MST can reduce the tons of CO_2 used by the fleet. In the 10-year period, the CO_2 will decrease by 19%, almost 2% more than if the Annual Budget scenario was used. Although this scenario also increases the agency needs by almost $1.5 million, and will cause a slight decrease in the MDBFs, the agency

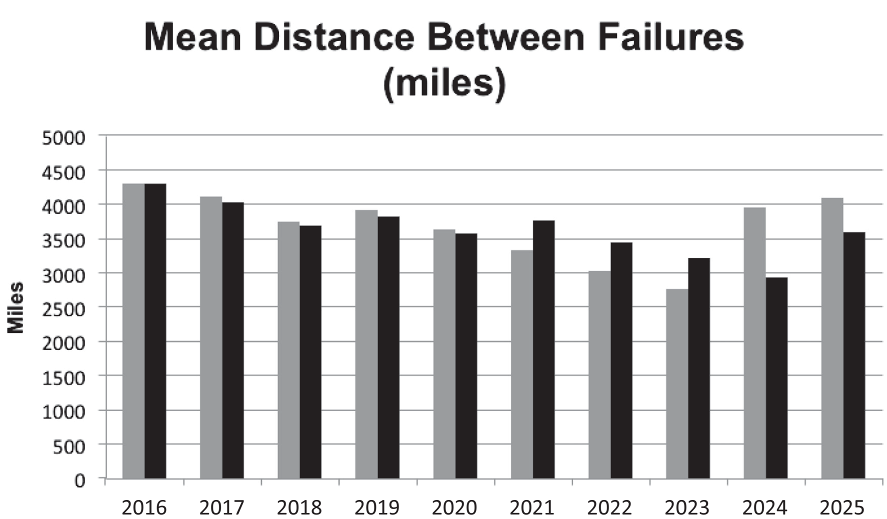


Figure 4.31. Comparing Mean Distance between Failures (miles) between the Annual Budget Scenario (gray) and Adjusted Program Scenario (black).

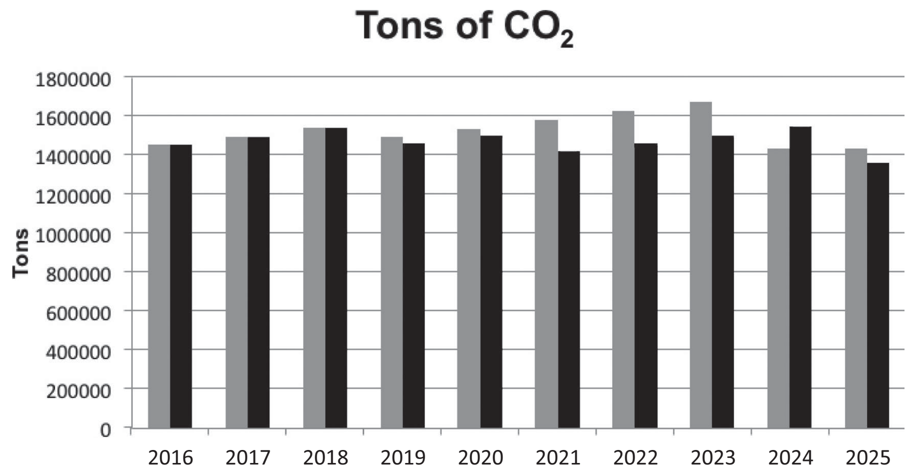


Figure 4.32. Comparing Tons of CO_2 between the Annual Budget Scenario (gray) and Adjusted Program Scenario (black).

believes that maintaining a hybrid fleet will have long-term benefits, both to the agency and to the environment.

When the analysis has been completed, you bring the results to the agency executives, who approve the Adjusted Program scenario for the TAMP.

Step 5: Prepare Data for the Asset Management Plan

Now that you have the results of the TAPT analysis, you are ready to incorporate the data into the MST TAMP. After returning to Chapter 2 to review the TAMP development process, you develop a plan documenting the current conditions of the MST fleet, and recommended priorities for the future, as reflected in Table 4.12 and Figures 4.30 to 4.32.

The final program list suggests the following replacement actions between 2016 and 2025:

- Demand response vehicle 5 is replaced in 2016
- Diesel bus fleet 6, containing 4 vehicles, is replaced in 2018
- Demand response vehicle 4 is replaced in 2019
- Diesel bus fleet 4, containing 4 vehicles, is replaced in 2020
- Demand response vehicle 3 is replaced in 2022
- Diesel bus fleet 5, containing 6 vehicles, is replaced in 2024
- Demand response vehicle 2 is replaced in 2025
- Diesel bus fleet 3, containing 2 vehicles, is replaced in 2025

Springfield Transit Authority

Springfield Transit Authority (STA) provides transit service to the City of Springfield, USA. The agency was established in 1977. Initially STA provided bus service exclusively. In 1993, STA opened its first light rail line, the Central Line (CL), to meet the area's growing transit needs. Since then, three more light rail lines have been built: the North Line (NL) completed in 1999, the Airport Link (AL) completed in 2005, and the West Line (WL) completed in 2012.

At present STA has a fleet of 270 buses. The majority of the fleet was purchased in 2000 with a federal grant, but the agency recognizes that these buses will soon need to be replaced. Also, the agency has a fleet of 96 light rail vehicles. The light rail system includes 475,233 linear feet of track and 241,163 linear feet of guideway (much of which is double-tracked). The agency also maintains 30 buildings, including maintenance and administrative facilities. These buildings are split into three complexes: the West Corridor, Southeast Corridor, and North Corridor. With the growing transit needs and the opening of the West Line, improvements are being planned for the North Corridor Maintenance Facilities, including a Safety and Training Facility, which was completed in the previous year, and a complete overhaul of the Fuel and Wash Building, planned for 2018.

2013 marked the 20th anniversary of the opening of the Central Line and STA recognizes that the light rail infrastructure will soon need to be updated. Also, the majority of the bus fleet is also nearing the end of its useful life. Faced with an aging system and a number of important projects that will need to occur during a short time frame, STA downloaded TAPT to help them better understand their upcoming needs and determine an optimized program.

As the Asset Manager for Springfield Transit, you have been tasked with using TAPT to analyze capital rehabilitation and replacement needs. After reviewing the guidance and collecting the necessary data for the tool inputs, you begin by grouping assets to determine the best method for modeling in a multi-asset analysis. This means grouping like assets that can 1) be used in the same model type, and therefore have the same basic data available, and 2) have similar deterioration rates and therefore can be defined as the same asset type. To analyze the assets, you choose to create separate models for the following assets:

- Buses
- Light Rail Vehicles
- Track
  - Grade Crossing and Embedded (XC/Embedded)
  - Tangent Ballasted
  - Curved Ballasted
  - Special
- Guideway
  - XC/Embedded
  - Ballasted
- Facilities
  - Maintenance Facilities
  - Administrative Facilities
  - Roof
  - HVAC

Budgets and Parameters

1. From the start screen, click **Budgets & Parameters** (Figure 4.33).
2. Using Table 4.13, adjust the following parameters:
   - The **First Budget Year** is adjusted to 2013, since the most recent agency inspections were performed in 2012.
   - The **Discount Rate** is adjusted to reflect STA policy.
   - The **Agency Cost per Gallon of Fuel** and **Agency Cost per Kilowatt Hour** are adjusted based on Springfield Transit historical data, modified to account for inflation. These costs tend to be slightly lower than the default values.

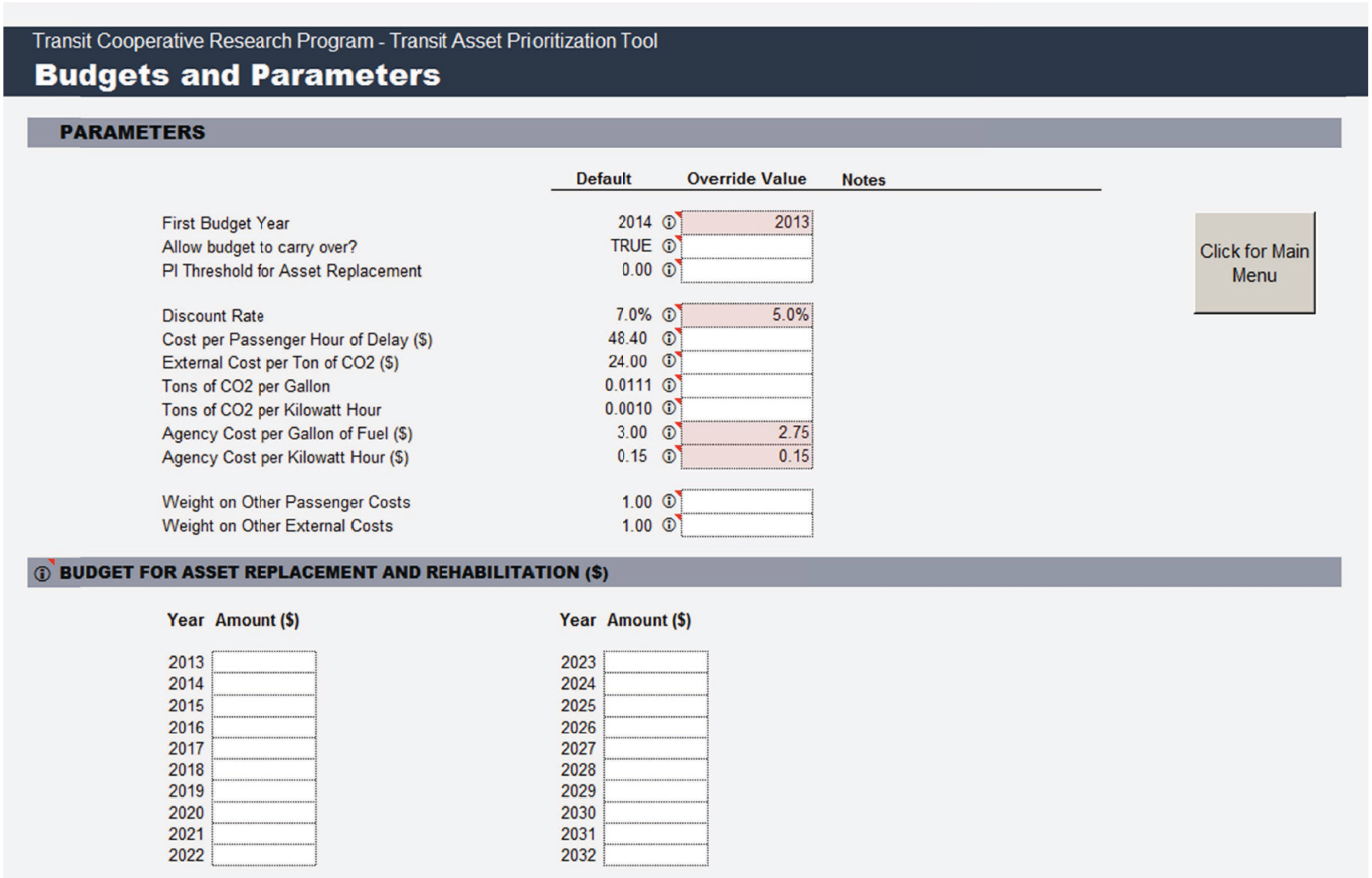


Figure 4.33. Budget and Parameters.

Table 4.13. Budgets and Parameters.

Parameters	Value
First Budget Year	2013
Discount Rate	5.0%
Agency Cost per Gallon of Fuel ($)	2.75
Agency Cost per Kilowatt Hour ($)	0.15

Bus

For buses, you consult STA staff and together choose to use the defaults for the majority of inputs. Beyond NTD data and cost histories, the agency has limited historical data that could be used to override the model defaults. STA has collected detailed cost data for recently purchased assets, therefore you update the **New Vehicle Cost** using an estimate based on this information.

3. On the **Start Screen**, select **Create Asset Group** (Figure 4.34).
4. Name the **Asset Group ID Code** "Bus" and for the model type select "Vehicle Model," before selecting **Create New Group**.
5. Select the **Vehicle Type** to "Bus."
6. In the **Asset Description** text field, name the assets "Bus" (Figure 4.35).
7. Using the data from Table 4.14, input the **Inventory Description** data (Figure 4.36).

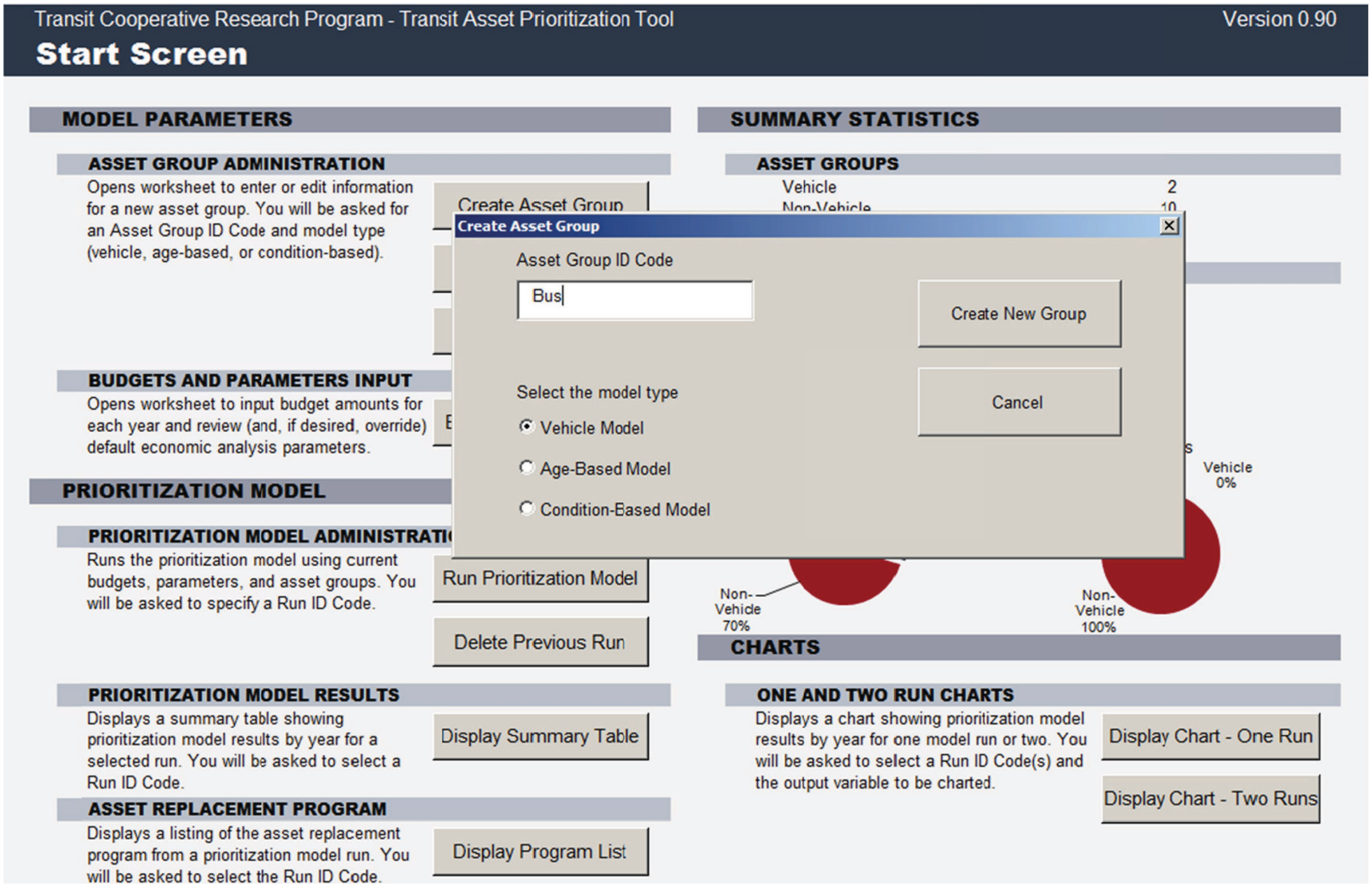


Figure 4.34. Create Asset Group.

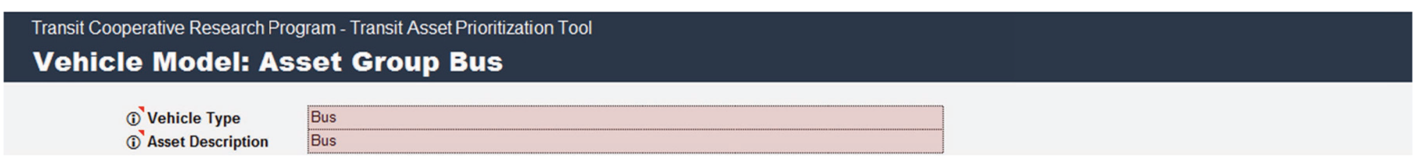


Figure 4.35. Bus Vehicle Model.

Table 4.14. Bus Inventory Data.

Accumulated Mileage	Number of Vehicles	Project Code
494,700	100	Bus01
473,900	100	Bus02
295,400	42	Bus03
171,100	4	Bus04
249,600	7	Bus05
170,200	6	Bus06
115,500	5	Bus07
84,000	6	Bus08

INVENTORY DESCRIPTION

Sub-Group	Accumulated Mileage	Number of Vehicles	Project Code	Pipeline Year
1	494,700	100	Bus01	
2	473,900	100	Bus02	
3	295,400	42	Bus03	
4	171,100	4	Bus04	
5	249,600	7	Bus05	
6	170,200	6	Bus06	
7	115,500	5	Bus07	
8	84,000	6	Bus08	
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				

Figure 4.36. Bus Vehicle Model Inventory Description.

8. Using the data from Table 4.15, input the **Vehicle Data from the National Transit Database** and **Additional Vehicle Data** (Figure 4.37).
9. Review the **Summary Results** and note that the **Average Annual Cost** is $142,785 and the **Cost-Minimizing Replacement Mileage** is 663,704 (or 14 years). Select **Click for Main Menu** when complete (Figure 4.38).

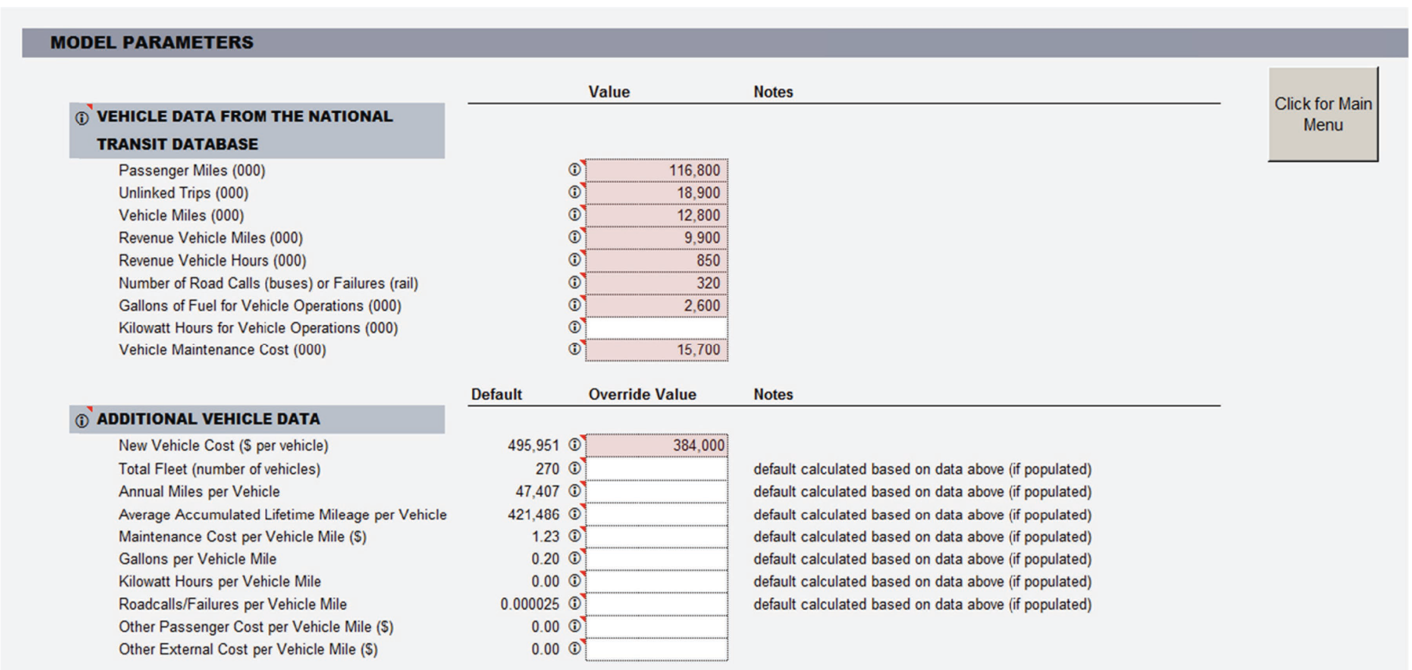
Light Rail

To develop the light rail, you use the vehicle model and recent NTD data. The override value provided for the **New Vehicle Cost** is based on the most recent light rail vehicle purchase. You also make additional adjustments to the model to account for the new West Line. This includes increasing the **Annual Miles per Vehicle**, the default for which is based on the accumulated mileage for the current fleet but does not account for the additional mileage required for the new line. You also increase the **Typical Failure Recovery Time** to account for the additional delay to subsequent operations when a light rail vehicle is disabled.

10. Create a new asset category for light rail:
    - **Asset Group ID Code:** Light Rail
    - **Model Type:** Vehicle Model
11. Input the following information into the model:
    - **Asset Type:** Light Rail
    - **Asset Description:** Light Rail
    - **Inventory Description:** Use the inputs from Table 4.16 (Figure 4.39)
    - **Vehicle Data from the National Transit Database:** Use the inputs from Table 4.17 (Figure 4.40)
    - **Additional Parameters:** Use the inputs from Table 4.18 (Figure 4.41)

Table 4.15. Bus Model Parameters.

Vehicle Data from the National Transit Database	Value
Passenger Miles	116,800
Unlinked Trips	18,900
Vehicle Miles	12,800
Revenue Vehicle Miles	9,900
Revenue Vehicle Hours	850
Number of Road Calls	320
Gallons of Fuel for Vehicle Operations	2,600
Vehicle Maintenance Cost	15,700
Additional Vehicle Data	**Value**
New Vehicle Cost ($)	384,000



MODEL PARAMETERS

Click for Main Menu

VEHICLE DATA FROM THE NATIONAL TRANSIT DATABASE	Value	Notes
Passenger Miles (000)	116,800	
Unlinked Trips (000)	18,900	
Vehicle Miles (000)	12,800	
Revenue Vehicle Miles (000)	9,900	
Revenue Vehicle Hours (000)	850	
Number of Road Calls (buses) or Failures (rail)	320	
Gallons of Fuel for Vehicle Operations (000)	2,600	
Kilowatt Hours for Vehicle Operations (000)		
Vehicle Maintenance Cost (000)	15,700	

ADDITIONAL VEHICLE DATA	Default	Override Value	Notes
New Vehicle Cost ($ per vehicle)	495,951	384,000	
Total Fleet (number of vehicles)	270		default calculated based on data above (if populated)
Annual Miles per Vehicle	47,407		default calculated based on data above (if populated)
Average Accumulated Lifetime Mileage per Vehicle	421,486		default calculated based on data above (if populated)
Maintenance Cost per Vehicle Mile ($)	1.23		default calculated based on data above (if populated)
Gallons per Vehicle Mile	0.20		default calculated based on data above (if populated)
Kilowatt Hours per Vehicle Mile	0.00		default calculated based on data above (if populated)
Roadcalls/Failures per Vehicle Mile	0.000025		default calculated based on data above (if populated)
Other Passenger Cost per Vehicle Mile ($)	0.00		
Other External Cost per Vehicle Mile ($)	0.00		

Figure 4.37. Bus Vehicle Model Parameters.

SUMMARY RESULTS

Click for Main Menu

Average Annual Cost (dollars)	142,785
Cost-Minimizing Replacement Mileage (miles)	663,704
Cost-Minimizing Replacement Age (years)	14

Figure 4.38. Bus Vehicle Model Summary Results.

Table 4.16. Light Rail Inventory Inputs.

Accumulated Mileage	Number of Vehicles	Project Code
1,143,000	6	LightRail01
992,800	8	LightRail02
768,900	7	LightRail03
439,400	15	LightRail04
414,200	10	LightRail05
289,200	12	LightRail06
117,600	20	LightRail07
24,800	18	LightRail08

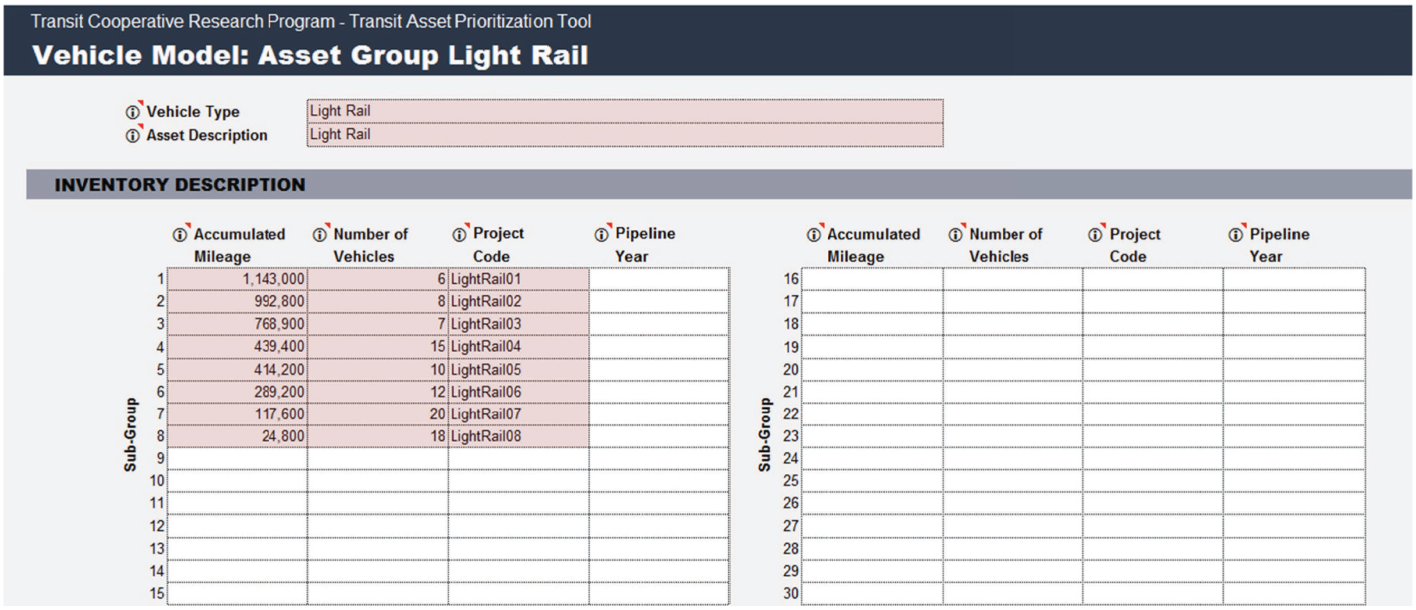


Figure 4.39. Light Rail Vehicle Model Inventory Inputs.

Table 4.17. Light Rail Model Parameters.

Model Parameters	Value
Passenger Miles	329,000
Unlinked Trips	41,300
Vehicle Miles	6,700
Revenue Vehicle Miles	4,800
Revenue Vehicle Hours	250
Number of Road Calls	210
Kilowatt Hours for Vehicle Operations	100,400
Vehicle Maintenance Cost	22,200

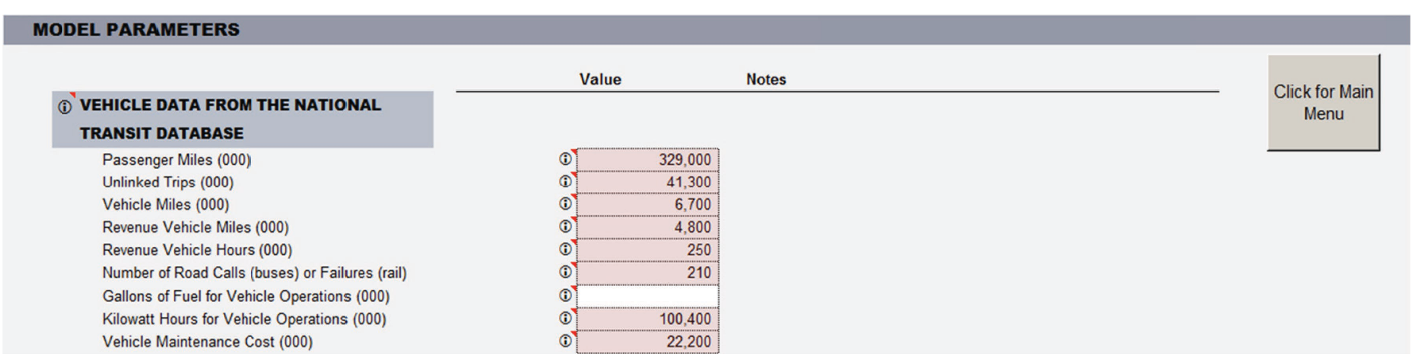


Figure 4.40. Light Rail Vehicle Model Parameters.

Table 4.18. Light Rail Additional Model Parameter Inputs.

Additional Vehicle Data	Value
New Vehicle Cost ($ per vehicle)	4,500,000
Annual Miles per Vehicle	73,000
Inputs for the Delay Calculation	**Value**
Typical Roadcall/Failure Recovery Time (minutes)	120

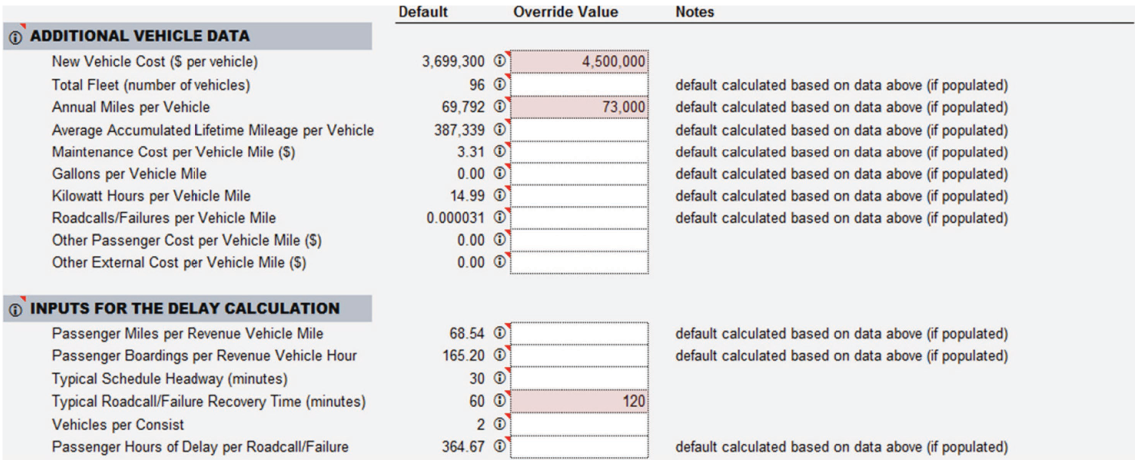


Figure 4.41. Light Rail Vehicle Model Additional Parameter Inputs.

To increase the expected lifecycle of light rail assets, STA has decided to perform midlife overhauls on the cars. To incorporate rehabilitation into the model, you set the cost of rehabilitating a vehicle to reflect what the agency is currently paying for rehab actions.

12. Input **Periodic Rehabilitation Costs** based on the values in Table 4.19 (Figure 4.42).
    - The **Percent of Vehicle Replacement Cost** is based on past vehicle rehab actions that have cost the agency $400,000. The input is based on the percent of the current replacement cost.
    - The **Rehab Interval** defines the number of miles traveled before a rehab action is performed.
    - **Convert to per Mile Rehabilitation Cost** is set to allow the agency to pay the cost of rehab actions over time, rather than as a lump sum.

Table 4.19. Light Rail Rehabilitation Costs.

Rehabilitation Costs	Value
Percent of Vehicle Replacement Cost	8.9%
Rehab Interval (miles)	1,000,000
Convert to per Mile Rehabilitation Cost	TRUE

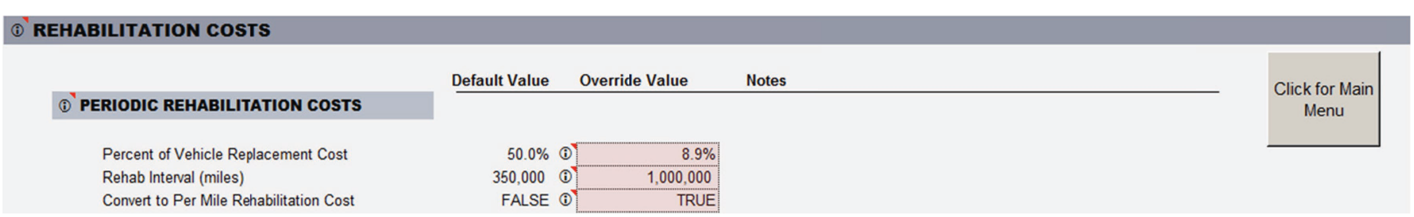


Figure 4.42. Light Rail Rehabilitation Cost Inputs.

Figure 4.43. Light Rail Summary Results.

13. Review the Summary Results and note that the **Average Annual Cost** is $921,034 and the **Cost-Minimizing Replacement Mileage** is 1,606,000 (or 22 years). Select **Click for Main Menu** when complete (Figure 4.43).

Track

Since STA does not collect condition data for all track assets, you choose to model track using the age-based model. STA currently has a maintenance contract for track that has historically resulted in lower costs for maintenance and replacement activities. In developing the track models, you assume that the **Agency Failure Costs** and **Other Passenger Failure Costs** are both set to 150% of the **Agency Replacement Cost**. Meanwhile, the **Annual Maintenance Cost** is set to 1% of **Agency Replacement Cost**. Since the majority of the track is relatively new, you decide that there is not enough replacement cost data to determine an override value for the **Agency Replacement Cost** defaults. Four types of track are modeled separately: tangent ballasted, tangent curved, special track, and embedded and grade crossing.

Tangent Ballasted Track

To create the Tangent Ballasted Track model, perform the following steps:

14. On the **Start Screen**, select **Create Asset Group**.
15. Name the **Asset Group ID Code** "Track (Tangent Ballasted)" and specify that the asset group will use the Age-Based Model. Then select **Create New Group**.
16. In the Tangent Ballasted Track model, define the **Asset Type** as "Guideway-Tangent Ballasted Track" using the dropdown menu.
17. Write in "Track (Tangent Ballasted)" for the **Asset Description**.
18. Enter "lineal feet" for **Asset Units of Measure**.
19. Use Table 4.20 to input the **Inventory Description** and **Additional Parameters** data for tangent ballasted track.
20. Review the **Summary Results**, shown at the bottom of Figure 4.44, to ensure that the **Average Annual Cost** is $54.99 and the **Cost-Minimizing Replacement Age** is 33 years. Select **Click for Main Menu** when complete.

Table 4.20. Track (Tangent Ballasted) Model Inputs.

Inventory Description		
Age of Assets	**Units of Assets**	**Project Code**
20	11,000	TrackBL01
14	128,200	TrackBL02
8	69,100	TrackBL03
1	68,250	TrackBL04
Failure Costs		
Input Field		**Value**
Agency Costs ($)		959
Other Passenger Costs ($)		959
Annual Costs		
Input Field		**Value**
Maintenance Cost ($/year)		6.39

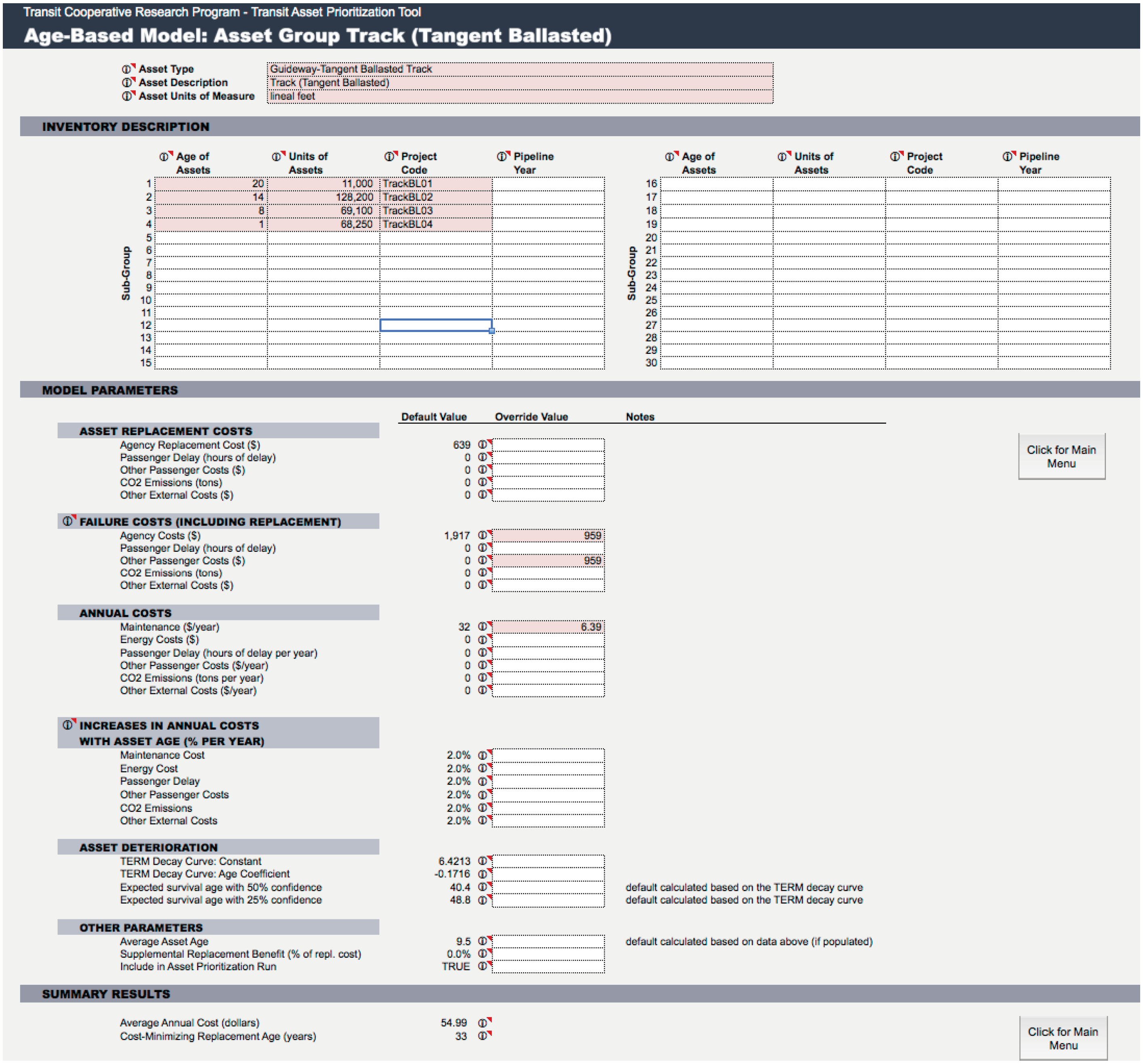


Figure 4.44. Track (Tangent Ballasted) Age-Based Model.

Curved Track

21. Create a new asset category for tangent curved track:
    - **Asset Group ID Code:** Track (Curved)
    - **Model Type:** Age-Based Model
22. Input the following information into the model:
    - **Asset Type:** Guideway-Curved Ballasted Track
    - **Asset Description:** Track (Curved)
    - **Asset Units of Measure:** lineal feet
    - **Inventory Description** and **Additional Parameters:** Use the inputs from Table 4.21

Table 4.21. Track (Curved) Model Inputs.

Inventory Description		
Age of Assets	**Units of Assets**	**Project Code**
20	15,000	TrackCR01
14	24,800	TrackCR02
8	73,050	TrackCR03
1	35,400	TrackCR04
Failure Costs		
Input Field		**Value**
Agency Costs ($)		1,386
Other Passenger Costs ($)		1,386
Annual Costs		
Input Field		**Value**
Maintenance Cost ($/year)		9.24

23. Review the **Summary Results** to ensure that the **Average Annual Cost** is $89.11 and the **Cost-Minimizing Replacement Age** is 27 years. Select **Click for Main Menu** when complete.

Special Track

24. Create a new asset category for special track:
    - **Asset Group ID Code:** Track (Special)
    - **Model Type:** Age-Based Model
25. Input the following information into the model:
    - **Asset Type:** Guideway-Special Trackwork
    - **Asset Description:** Track (Special)
    - **Asset Units of Measure:** lineal feet
    - **Inventory Description** and **Additional Parameters:** Use the inputs from Table 4.22
26. Review the **Summary Results** to ensure that the **Average Annual Cost** is $361.07 and the **Cost-Minimizing Replacement Age** is 28 years. Select **Click for Main Menu** when complete.

Embedded and Grade Crossing Track

27. Create a new asset category for embedded and grade crossing track:
    - **Asset Group ID Code:** Track (Embedded and XC)
    - **Model Type:** Age-Based Model
28. Input the following information into the model:
    - **Asset Type:** Guideway-Curved Embedded Track
    - **Asset Description:** Track (Embedded and XC)

Table 4.22. Track (Special) Model Inputs.

Inventory Description		
Age of Assets	**Units of Assets**	**Project Code**
20	2,100	TrackSP01
14	2,750	TrackSP02
8	950	TrackSP03
1	2,100	TrackSP04
Failure Costs		
Input Field		**Value**
Agency Costs ($)		5,664
Other Passenger Costs ($)		5,664
Annual Costs		
Input Field		**Value**
Maintenance Cost ($/year)		37.76

Table 4.23. Track (Embedded and XC) Inventory Inputs.

Inventory Description		
Age of Assets	**Units of Assets**	**Project Code**
20	24,250	TrackXC01
14	1,700	TrackXC02
8	1,500	TrackXC03
1	4,900	TrackXC04
Asset Replacement Costs		
Input Field		**Value**
Agency Replacement Cost ($)		820
Failure Costs		
Input Field		**Value**
Agency Costs ($)		1,230
Other Passenger Costs ($)		1,230
Annual Costs		
Input Field		**Value**
Maintenance Cost ($/year)		8.20

- **Asset Units of Measure:** lineal feet
- **Inventory Description** and **Additional Parameters:** Use the inputs from Table 4.23

29. Review the **Summary Results** to ensure that the **Average Annual Cost** is $88.35 and the **Cost-Minimizing Replacement Age** is 23 years. Select **Click for Main Menu** when complete.

Guideway

For guideway assets (in this case all of the assets in the guideway except track), you decide to use a similar method to track assets, concentrating on providing override values for **Agency Costs ($)**, **Other Passenger Costs ($)**, and **Maintenance ($/year)**. Some of the replacement costs were also updated to better reflect asset types. The model parameters are listed below.

Embedded and Grade Crossing Guideway

30. Create a new asset category for embedded and grade crossing guideway:
    - **Asset Group ID Code:** Guideway (Embedded and XC)
    - **Model Type:** Age-Based Model
31. Input the following information into the model:
    - **Asset Type:** Guideway-Grade Crossing
    - **Asset Description:** Guideway (Embedded and XC)
    - **Asset Units of Measure:** lineal feet
    - **Inventory Description** and **Additional Parameters:** Use the inputs from Table 4.24

Table 4.24. Guideway (Embedded and XC) Inventory Inputs.

Inventory Description		
Age of Assets	**Units of Assets**	**Project Code**
20	12,100	GuideXC01
14	1,000	GuideXC02
8	750	GuideXC03
1	2,500	GuideXC04
Failure Costs		
Input Field		**Value**
Agency Costs ($)		4,721
Other Passenger Costs ($)		4,721
Annual Costs		
Input Field		**Value**
Maintenance Cost ($/year)		31.41

32. Review the **Summary Results** to ensure that the **Average Annual Cost** is $447.58 and the **Cost-Minimizing Replacement Age** is 14 years. Select **Click for Main Menu** when complete.

Ballasted Guideway

33. Create a new asset category for ballasted guideway:
    - **Asset Group ID Code:** Guideway (Ballasted)
    - **Model Type:** Age-Based Model
34. Input the following information into the model:
    - **Asset Type:** Guideway-At Grade Ballasted or Expressway
    - **Asset Description:** Guideway (Ballasted)
    - **Asset Units of Measure:** lineal feet
    - **Inventory Description** and **Additional Parameters:** Use the inputs from Table 4.25
35. Review the **Summary Results** to ensure that the **Average Annual Cost** is $175.41 and the **Cost-Minimizing Replacement Age** is 72 years. Select **Click for Main Menu** when complete.

Facilities

STA maintains two facility types: maintenance facilities and administrative facilities. To reflect the varying cost of replacing these two building types, you create a separate model for each of these asset types, both using the Age-Based Model. For both facility types, square feet of floor area are used as the unit of measurement.

Maintenance Facilities

36. On the **Start Screen**, select **Create Asset Group**.
37. Name the **Asset Group ID Code** "Maint Facilities" and for the model type select Age-Based Model, before selecting **Create New Group**.
38. Select the **Asset Type** to "Facilities-Maintenance Building."
39. In the **Asset Description** text field, name the assets "Maintenance Facilities."
40. In the **Asset Units of Measure** text field enter "square feet."
41. Using the data from Table 4.26, input the **Inventory Description** data.

When reviewing the model inputs, you choose to adjust the following parameters:

42. Using the data from Table 4.27, input the **Additional Parameters**.
    - The default value for **Agency Replacement Cost** in the model is set to reflect the cost of replacing an entire building. To account for the units you chose to use for buildings,

Table 4.25. Guideway (Ballasted) Inventory Inputs.

Inventory Description		
Age of Assets	**Units of Assets**	**Project Code**
20	14,200	GuideBL01
14	83,000	GuideBL02
8	72,700	GuideBL03
1	54,800	GuideBL04
Agency Replacement Costs		
Input Field		**Value**
Agency Replacement Cost ($)		2,500
Failure Costs		
Input Field		**Value**
Agency Costs ($)		3,750
Other Passenger Costs ($)		3,750
Annual Costs		
Input Field		**Value**
Maintenance Cost ($/year)		25.00

Table 4.26. Maintenance Facilities Inventory Data.

Age	Units (sq ft)	Description	Pipeline Year
22	3,600	Maint01	
23	3,750	Maint02	
23	33,200	Maint03	
27	5,300	Maint04	
24	18,500	Maint05	
27	4,800	Maint06	
27	41,400	Maint07	
5	6,200	Maint08	
30	150	Maint09	
16	45,200	Maint10	
34	9,700	Project01	2018

Table 4.27. Maintenance Facilities Model Parameters.

Input Field	Value
Agency Replacement Cost ($)	1,250
Maintenance ($/year)	25.00

square feet, you adjust the replacement costs to reflect the cost of replacing a square foot of building.

- You adjust the **Maintenance Annual Costs** to reflect the units used in the model and historical maintenance costs. The value was calculated as 2% of the agency replacement cost.

43. Review the Summary Results (Figure 4.45) and note that the **Average Annual Cost** is $110.91 and the **Cost-Minimizing Replacement Age** is 41 years. Select **Click for Main Menu** when complete.

Administrative Facilities

44. Create a new asset category for administrative facilities:
    - **Asset Group ID Code:** Admin Facilities
    - **Model Type:** Age-Based Model
45. Input the following information into the model:
    - **Asset Type:** Facilities-Administrative Building
    - **Asset Description:** Administrative Facilities
    - **Asset Units of Measure:** square feet
    - **Inventory Description** and **Additional Parameters:** Use the inputs from Table 4.28
46. Review the Summary Results and note that the **Average Annual Cost** is $38.46 and the **Cost-Minimizing Replacement Age** is 68 years (Figure 4.46). Select **Click for Main Menu** when complete.

HVAC

You also decide to use the age-based model for HVAC assets, since the age of installation is readily available and not all units have been inspected. In order to standardize the units of HVAC, you decide to use the square footage of floor area of the building that the HVAC services as the unit of measure. Therefore, you scale the default value for agency replacement cost to reflect the cost of replacing a square foot of HVAC.

47. Create a new asset category for HVAC:
    - **Asset Group ID Code:** HVAC
    - **Model Type:** Age-Based Model

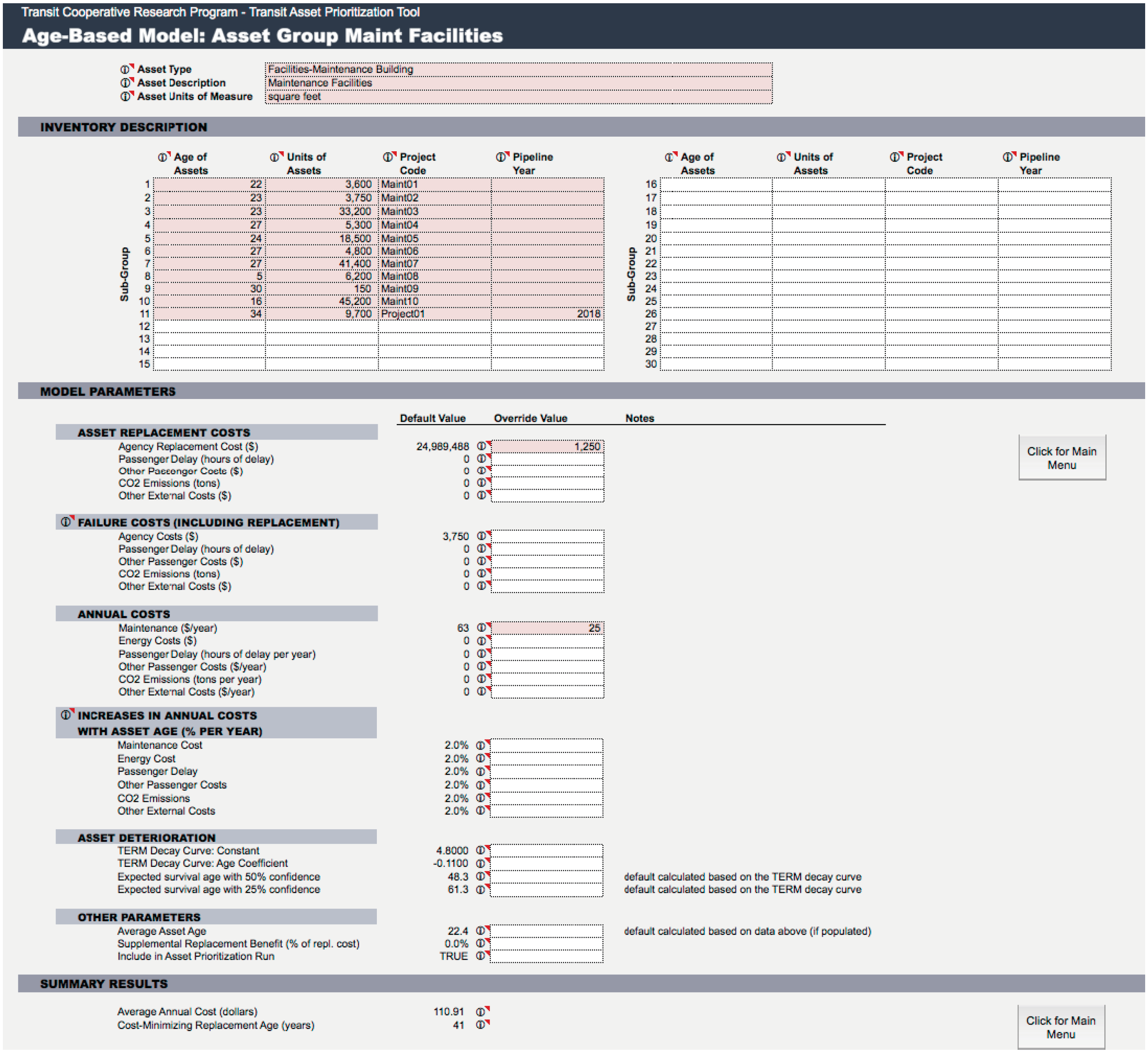


Figure 4.45. Maintenance Facilities Model.

Table 4.28. Administrative Facilities Inventory and Additional Parameters Inputs.

Age	Units (sq ft)	Description
8	6,100	Admin01
24	16,400	Admin02
34	9,100	Admin03
1	3,400	Admin04
Additional Parameters		**Value**
Agency Replacement Cost ($)		500
Maintenance ($/year)		10.00

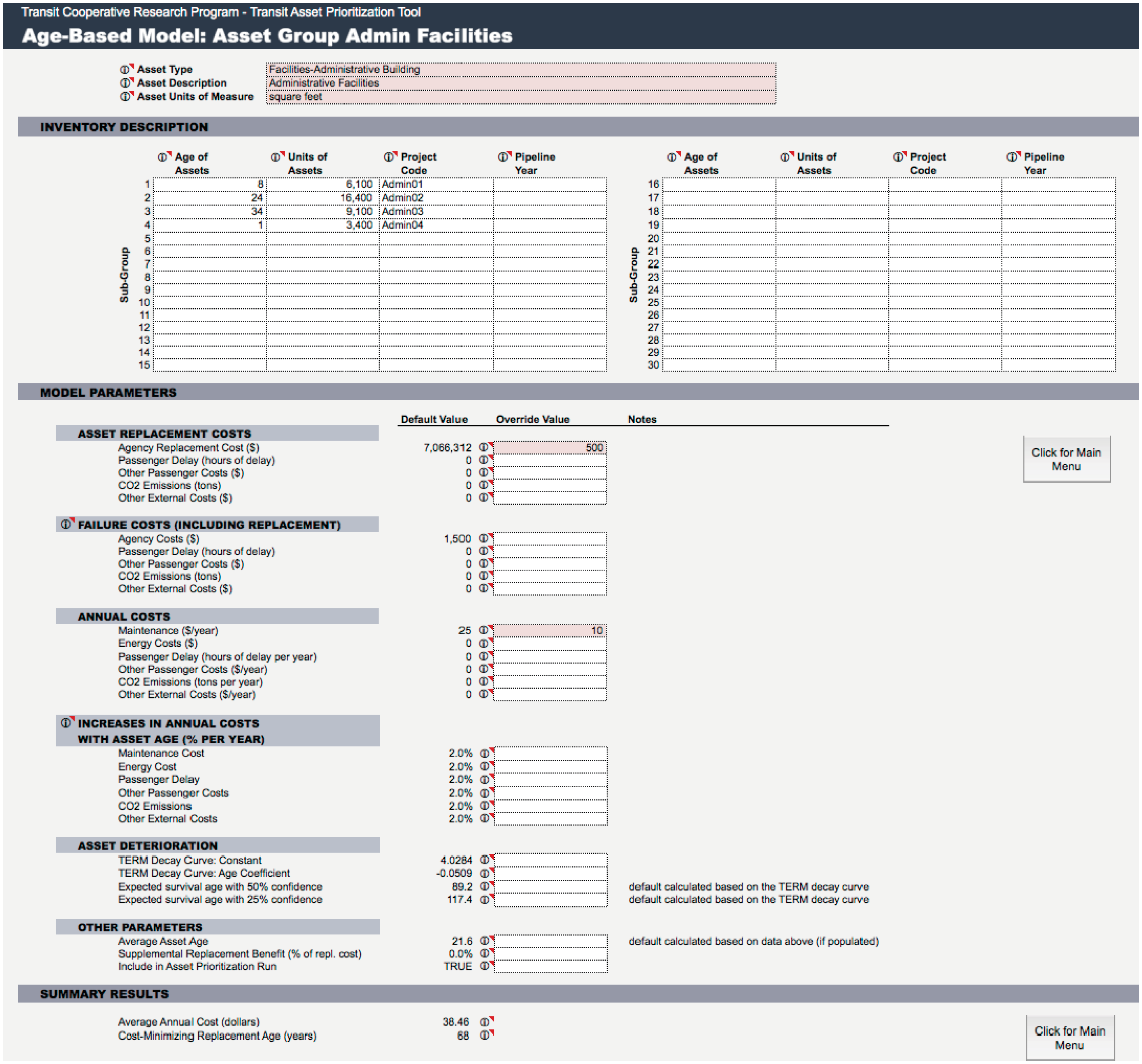


Figure 4.46. Administrative Facility Model.

48. Input the following information into the model:
    - **Asset Type:** Facilities-Building Utilities
    - **Asset Description:** HVAC
    - **Asset Units of Measure:** square feet
    - **Inventory Description** and **Additional Parameters:** Use the inputs from Table 4.29
49. Review the Summary Results and note that the **Average Annual Cost** is $25.03 and the **Cost-Minimizing Replacement Age** is 35 years (Figure 4.47). Select **Click for Main Menu** when complete.

Table 4.29. HVAC Inventory Data.

Age	Units (sq ft)	Description	Pipeline Year
1	3,600	HVAC-Maint01	
23	3,750	HVAC-Maint02	
1	33,200	HVAC-Maint03	
27	5,300	HVAC-Maint04	
24	18,500	HVAC-Maint05	
27	4,800	HVAC-Maint06	
27	41,400	HVAC-Maint07	
5	6,200	HVAC-Maint08	
1	150	HVAC-Maint09	
16	45,200	HVAC-Maint10	
34	9,700	Project01	2018
8	6,100	HVAC-Admin01	
2	16,400	HVAC-Admin02	
34	9,100	HVAC-Admin03	
1	3,400	HVAC-Admin04	
Asset Replacement Costs			**Value**
Agency Replacement Cost ($)			200

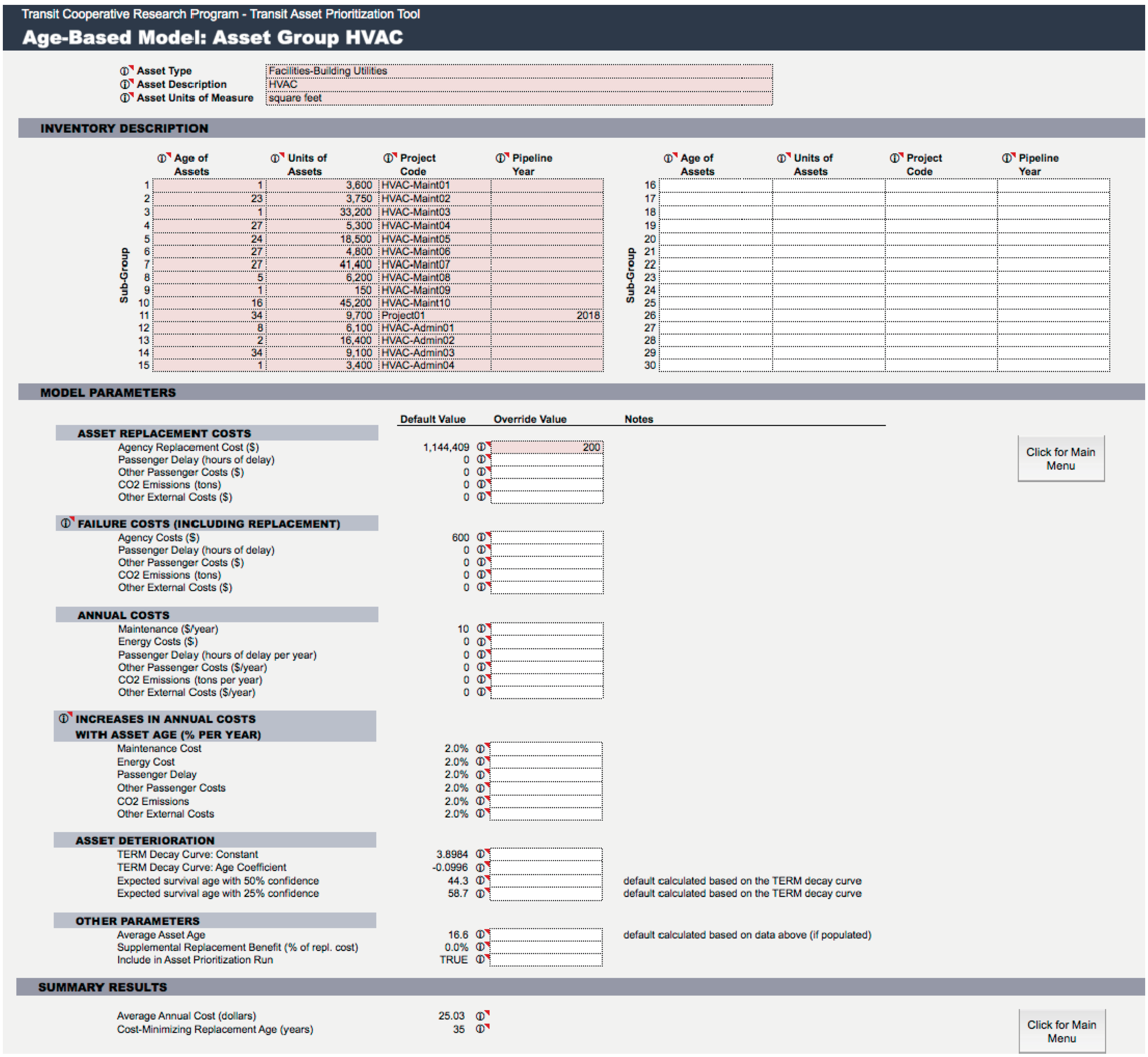


Figure 4.47. HVAC Model.

Roof

STA maintains condition data for roof assets maintained by the Authority. The condition data is collected based on a five-point scale used by TERM Lite. Therefore, you decide to use the condition-based model for roof assets. The units are measured in square feet of roof area.

50. On the **Start Screen**, select **Create Asset Group**.
51. Name the **Asset Group ID Code** "Roof" and for the model type select Condition-Based Model, before selecting **Create New Group**.
52. Select the **Asset Type** "Facilities-Maintenance Building."
53. In the **Asset Description** text field name the asset "Roof."
54. In the **Asset Units of Measure** text field enter "square feet."
55. Using the data from Table 4.30, input the **Replacement** and **Rehabilitation** cost data.
56. Using the data from Table 4.31, input the **Inventory Description** data.

You also determined that the deterioration rate of roofs is higher than the default assets populated in the model. You are able to discern this based on your history of condition data. (More detail on roofs and condition data is available in the King County Pilot Memo, included in the Final Research Report at http://www.trb.org/Main/Blurbs/171285.aspx.) Therefore, you increase the chance that roof condition would decrease if the agency did the minimum.

57. Using the data from Table 4.32, input the **Transition Probabilities** data.

Review the Summary Results and note that the model suggests that the **Recommended Action** for assets in State 5, 4, and 3 is Do Minimum (Figure 4.48). When the asset is in State 2 or 1, the recommended action is Replace (with a **Prioritization Index** of 0.40 and 0.92, respectively). The **Average Annual Cost** for roof is $1.46 per square foot. Select **Click for Main Menu** when complete.

Table 4.30. Roof Inventory Data.

Unit Agency Replacement Cost ($)	$20.75
Unit Agency Rehabilitation Cost ($)	$20.75

Table 4.31. Roof Inventory Data.

Condition	Units (Sq Ft)	Description	Pipeline Year
2-Marginal	3,600	Roof-Maint01	
3-Adequate	3,750	Roof-Maint02	
2-Marginal	33,200	Roof-Maint03	
4-Good	5,300	Roof-Maint04	
2-Marginal	9,250	Roof-Maint05	
1-Poor	4,800	Roof-Maint06	
3-Adequate	41,400	Roof-Maint07	
4-Good	6,200	Roof-Maint08	
1-Poor	150	Roof-Maint09	
3-Adequate	45,200	Roof-Maint10	
3-Adequate	9,700	Project01	2018
4-Good	6,100	Roof-Admin01	
2-Marginal	4,100	Roof-Admin02	
5-Excellent	9,100	Roof-Admin03	
5-Excellent	1,700	Roof-Admin04	

Table 4.32. Transition Probabilities Data.

State	Action	5 Excellent	4 Good	3 Adequate	2 Marginal	1 Poor
5 Excellent	Do Minimum	85.0%	15.0%			
	Rehab					
	Replace					
4 Good	Do Minimum		75.0%	25.0%		
	Rehab					
	Replace					
3 Adequate	Do Minimum			60.0%	40.0%	
	Rehab					
	Replace					
2 Marginal	Do Minimum				50.0%	25.0%
	Rehab					
	Replace					
1 Poor	Do Minimum					50.0%
	Rehab					
	Replace					

Results: Springfield Transit Authority

Unconstrained Scenario

When all of the data inputs had been specified, you return to the **Budgets and Parameters** worksheet. The agency first wanted to run the prioritization model with an unconstrained budget to better understand the full extent of the agency's needs and to understand how the model would prioritize replacement projects if funding was not a factor.

1. From the start screen, click **Budgets & Parameters**.
2. Set the **Budget for Asset Replacement and Rehabilitation** (**$**) to "999,999,999" for years **2013** to **2032**.
3. Select **Click for Main Menu** to return to the start screen.

The next step is to run to model using the defined budget.

4. Select **Run Prioritization Model** and define the **ID Code** as "Unconstrained" to describe the run. Then click **OK** to run the model.

When the analysis has been completed, the model will open a **Program List** for the Unconstrained run.

5. Review the **Program List** and select **Click for Main Menu** when you have finished. Note that with an unconstrained budget the following assets would be replaced between **2013** and **2032**:
   - 470 buses replaced
   - 78 light rail cars replaced
   - 258,300 miles of track replaced
   - 30,200 miles of guideway replaced
   - 10 maintenance facilities replaced, totaling 130,100 square feet
   - 9 HVAC systems replaced, totaling 147,450 square feet
   - 28 roof replacement projects, totaling 356,300 square feet
6. Click **Display Summary Table** and select the "Unconstrained" run before selecting **Display Summary Table**. Figure 4.49 shows the summary table for the unconstrained run.
   - Average condition for non-vehicle assets is projected to remain the same with an unconstrained budget.

Transit Cooperative Research Program - Transit Asset Prioritization Tool

Condition-Based Model: Asset Group Roof

Asset Type	Facilities-Maintenance Building
Asset Description	Roof
Asset Units of Measure	square feet

DEFAULT REPLACEMENT AND REHABILITATION COSTS

Unit Agency Replacement Cost ($)	20.75
Unit Agency Rehabilitation Cost ($)	20.75

INVENTORY DESCRIPTION

Sub-Group

	Asset Condition	Units of Assets	Project Code	Pipeline Year		Asset Condition	Units of Assets	Project Code	Pipeline Year
1	2-Marginal	3,600	Roof-Maint01		16				
2	3-Adequate	3,750	Roof-Maint02		17				
3	2-Marginal	33,200	Roof-Maint03		18				
4	4-Good	5,300	Roof-Maint04		19				
5	2-Marginal	9,250	Roof-Maint05		20				
6	1-Poor	4,800	Roof-Maint06		21				
7	3-Adequate	41,400	Roof-Maint07		22				
8	4-Good	6,200	Roof-Maint08		23				
9	1-Poor	150	Roof-Maint09		24				
10	3-Adequate	45,200	Roof-Maint10		25				
11	3-Adequate	9,700	Project01	2018	26				
12	4-Good	6,100	Roof-Admin01		27				
13	2-Marginal	4,100	Roof-Admin02		28				
14	5-Excellent	9,100	Roof-Admin03		29				
15	5-Excellent	1,700	Roof-Admin04		30				

TRANSITION PROBABILITIES

State	Action	5-Excellent		4-Good		3-Adequate		2-Marginal		1-Poor		0-Failed
		Default	Override	Default	Override	Default	Override	Default	Override	Default	Override	Default
5-Excellent	Do Minimum	96.3%	85.0%	3.7%	15.0%	0.0%		0.0%		0.0%		0.0%
	Rehab	0.0%		100.0%		0.0%		0.0%		0.0%		0.0%
	Replace	100.0%		0.0%		0.0%		0.0%		0.0%		0.0%
4-Good	Do Minimum	0.0%		93.7%	75.0%	6.3%	25.0%	0.0%		0.0%		0.0%
	Rehab	0.0%		100.0%		0.0%		0.0%		0.0%		0.0%
	Replace	100.0%		0.0%		0.0%		0.0%		0.0%		0.0%
3-Adequate	Do Minimum	0.0%		0.0%		89.9%	60.0%	10.1%	40.0%	0.0%		0.0%
	Rehab	0.0%		100.0%		0.0%		0.0%		0.0%		0.0%
	Replace	100.0%		0.0%		0.0%		0.0%		0.0%		0.0%
2-Marginal	Do Minimum	0.0%		0.0%		0.0%		84.1%	50.0%	7.9%	25.0%	25.0%
	Rehab	0.0%		100.0%		0.0%		0.0%		0.0%		0.0%
	Replace	100.0%		0.0%		0.0%		0.0%		0.0%		0.0%
1-Poor	Do Minimum	0.0%		0.0%		0.0%		0.0%		84.1%	50.0%	50.0%
	Rehab	0.0%		100.0%		0.0%		0.0%		0.0%		0.0%
	Replace	100.0%		0.0%		0.0%		0.0%		0.0%		0.0%
0-Failed	Replace	100.0%		0.0%		0.0%		0.0%		0.0%		0.0%

Click for Main Menu

Notes

UNIT COSTS, DELAY, and CO2 EMISSIONS

State	Action	Agency Cost		Energy Cost		Delay (hours)		Other Pass. Cost		CO2 (tons)		Other Ext. Cost	
		Default	Override	Default	Override	Default	Override	Default	Override	Default	Override	Default	Override
5-Excellent	Do Minimum	0		0		0		0		0		0	
	Rehab	21		0		0		0		0		0	
	Replace	21		0		0		0		0		0	
4-Good	Do Minimum	0		0		0		0		0		0	
	Rehab	21		0		0		0		0		0	
	Replace	21		0		0		0		0		0	
3-Adequate	Do Minimum	0		0		0		0		0		0	
	Rehab	21		0		0		0		0		0	
	Replace	21		0		0		0		0		0	
2-Marginal	Do Minimum	1		0		0		0		0		0	
	Rehab	21		0		0		0		0		0	
	Replace	21		0		0		0		0		0	
1-Poor	Do Minimum	2		0		0		0		0		0	
	Rehab	21		0		0		0		0		0	
	Replace	21		0		0		0		0		0	
0-Failed	Replace	62		0		0		0		0		0	

Click for Main Menu

Notes

OTHER MODEL PARAMETERS

	Default	Override Value	Notes
Supplemental Replacement Benefit (% of repl. cost)	0.0%		
Include in Asset Prioritization Run	TRUE		

SUMMARY RESULTS

Average Annual Cost ($) $1.46

State	Recommended Action	Prioritization Index
5	Do Minimum	N/A
4	Do Minimum	N/A
3	Do Minimum	N/A
2	Replace	0.40
1	Replace	0.92

Click for Main Menu

Figure 4.48. Roof Condition Model.

Transit Cooperative Research Program - Transit Asset Prioritization Tool

Summary: Prioritization Run Unconstrained

Year	Needs		Asset NPV	Budget ($)	Expenditures from Budget ($)	Remaining Backlog ($)	Energy Costs ($)	Other Agency Costs ($)	Cost of Passenger Delay ($)	Other Passenger Costs ($)	Cost of CO2 Emissions ($)	Other External Costs ($)	Total Agency, Pass., and Ext. Costs ($)	Passenger Delay (hours)	CO2 Emissions (tons)	Avg. Condition (non-veh)	MDBF (miles)
	Amount ($)	Percent															
2013	45,985,188	2.6%	9,425,917	999,999,999	45,985,188	-	23,799,241	87,251,440	4,805,688	13,373,810	3,344,465	-	178,559,832	99,291	139,353	4.71	32,553
2014	-	0.0%	-	1,954,014,811	-	-	24,508,389	81,058,903	5,176,214	4,580,744	3,443,947	-	118,768,197	106,947	143,498	4.79	29,896
2015	19,885,000	1.1%	91,672	2,954,014,810	19,885,000	-	25,238,670	85,146,569	5,575,448	5,295,667	3,546,389	-	144,687,743	115,195	147,766	4.77	27,453
2016	91,066,275	5.1%	1,238,986	3,934,129,809	91,066,275	-	25,990,712	87,695,333	6,005,629	4,610,753	3,987,878	-	219,356,581	124,083	166,162	4.77	25,207
2017	365,200	0.0%	46,391	4,843,063,533	365,200	-	24,603,218	78,264,720	6,215,846	5,408,481	3,551,071	-	118,408,536	128,427	147,961	4.77	36,122
2018	43,622,025	2.4%	(1,005,622)	5,842,698,332	43,622,025	-	25,335,522	83,115,911	6,690,420	6,325,858	3,679,651	-	168,769,386	138,232	153,319	4.74	33,316
2019	13,860,000	0.8%	22,023	6,799,076,306	13,860,000	-	25,307,345	85,940,499	6,496,550	7,119,961	3,640,122	-	142,364,477	134,226	151,672	4.72	32,752
2020	70,357,600	3.9%	612,865	7,785,216,305	70,357,600	-	26,060,715	90,003,762	6,993,176	7,390,315	3,849,600	-	204,655,167	144,487	160,400	4.70	30,185
2021	4,082,000	0.2%	47,567	8,714,858,704	4,082,000	-	25,339,466	87,776,073	6,534,987	8,070,295	3,660,627	-	135,463,448	135,020	152,526	4.70	33,332
2022	3,840,000	0.2%	58,772	9,710,776,703	3,840,000	-	26,018,088	92,206,894	7,025,408	9,264,331	3,766,791	-	142,121,511	145,153	156,950	4.67	31,251
2023	35,611,600	2.0%	280,312	10,706,936,702	35,611,600	-	26,684,453	96,385,726	7,549,401	10,699,514	3,877,855	-	180,808,549	155,979	161,577	4.63	29,473
2024	7,992,088	0.4%	315,580	11,671,325,101	7,992,088	-	26,566,050	99,443,178	7,303,687	12,284,119	3,837,883	-	157,427,004	150,903	159,912	4.59	29,036
2025	37,796,700	2.1%	146,721	12,663,333,012	37,796,700	-	27,237,997	103,643,221	7,848,125	14,021,865	3,921,413	-	194,469,321	162,151	163,392	4.56	27,385
2026	74,759,000	4.2%	205,509	13,625,536,311	74,759,000	-	28,048,809	106,639,146	8,447,929	13,252,578	4,037,968	-	235,185,429	174,544	168,249	4.55	25,242
2027	42,377,100	2.4%	389,316	14,550,777,310	42,377,100	-	28,883,758	104,231,542	9,093,693	14,329,016	4,157,988	-	203,073,096	187,886	173,249	4.60	23,264
2028	112,865,200	6.3%	921,340	15,508,400,209	112,865,200	-	29,743,563	104,996,824	9,788,952	11,709,506	4,377,575	-	273,481,620	202,251	182,399	4.60	21,439
2029	23,125,000	1.3%	51,372	16,395,535,008	23,125,000	-	27,369,472	102,721,279	7,601,004	12,964,704	3,887,317	-	177,668,777	157,046	161,972	4.56	23,685
2030	176,987,500	9.9%	1,705,846	17,372,410,007	176,987,500	-	28,184,651	105,094,791	8,184,581	14,334,586	4,384,988	-	337,171,098	169,103	182,708	4.55	21,784
2031	162,958,000	9.1%	578,610	18,195,422,506	162,958,000	-	25,297,609	89,468,229	7,150,287	15,829,214	3,662,174	-	304,365,513	147,733	152,591	4.57	32,942
2032	95,942,950	5.3%	756,570	19,032,464,505	95,942,950	-	26,050,488	83,632,026	7,695,627	8,626,045	3,847,805	-	225,794,940	159,001	160,325	4.72	30,403

Click for Main Menu

Figure 4.49. STA Unconstrained Program Summary Results.

- Even with an unconstrained budget, passenger delay will increase somewhat over time, and MDBF will decrease. This is largely a result of the projected increase in age of light rail vehicles (many of which are now relatively new).
- The model shows there are unmet needs at the beginning of 2023, but with an unconstrained budget these are actually addressed by the end of the year in the simulation.

Table 4.33 shows the summary results calculated using the unconstrained program and compared to the initial values.

7. Review the **Summary Table** and select **Click for Main Menu** when you have finished.
8. From the start screen, select **Display Chart-One Run**.
9. Select "Needs ($)" as the **Prioritization Model Output Variable** to chart, then select "Unconstrained" as the **Run** to chart before clicking **Display Chart**.
10. Review the **Needs ($)** chart, shown in Figure 4.50, and select **Click for Main Menu** when you have finished.
11. Input the following information to create two additional charts:
    - **Chart One**, shown in Figure 4.51, with the **Prioritization Model Output Variable** selected as "Mean Distance Between Failures (miles)" the **Run** "Unconstrained."

Table 4.33. Summary Results Unconstrained Scenario.

Scenarios	Initial Value	Value in 2032
		Unconstrained
Remaining Backlog	$ 45,985,188	$ 0
Cumulative Spent	-	$ 1,063,478,425
MDBF (miles)	32,553	30,403
Average TERM Condition (non-vehicle Assets)	4.71	4.72
Passenger Delay (hours)	99,291	159,001
CO_2 Emissions (tons)	139,353	160,325
Other Agency Costs	$ 87,251,440	$ 83,632,026
Total Agency, User and External Costs Excluding Budget Expenditures	$ 132,574,644	$ 129,851,990

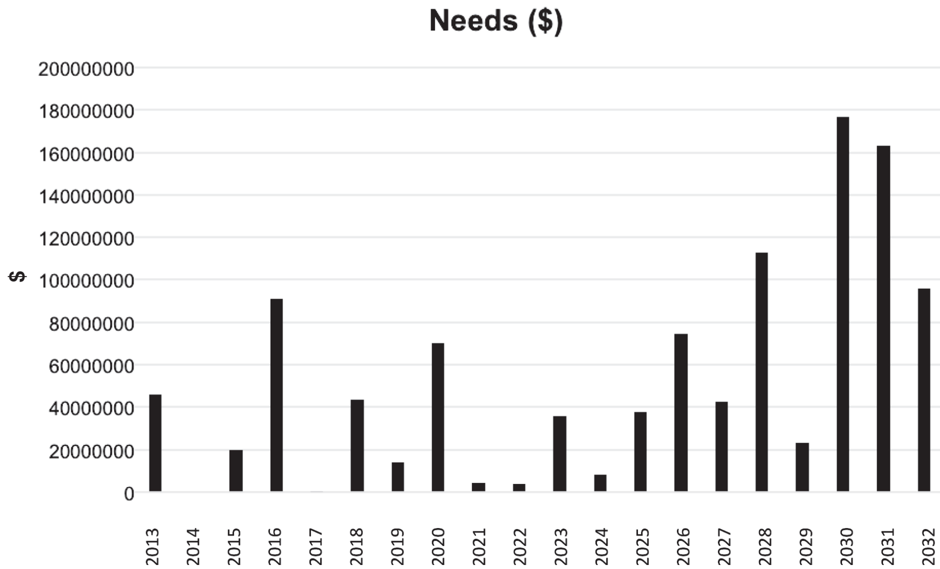


Figure 4.50. STA Needs ($) Unconstrained Scenario.

- **Chart Two**, shown in Figure 4.52, with the **Prioritization Model Output Variable** selected as "Average Condition Rating" and the **Run** "Unconstrained."

Do Nothing Scenario

Next, you run a scenario where no work is performed, to determine the worst-case scenario if all assets were allowed to deteriorate over a 20-year period. This will provide a comparison to the unconstrained program and also illustrates the effects of asset deterioration.

12. Adjust the following on the **Budgets and Parameters** page:
    - **Budget for Asset Replacement and Rehabilitation (Years 2013–2032):** 0
13. Run a prioritization model with the **ID Code** "Do Nothing."
14. Review the **Program List** and the **Summary Table**, shown in Figure 4.53.

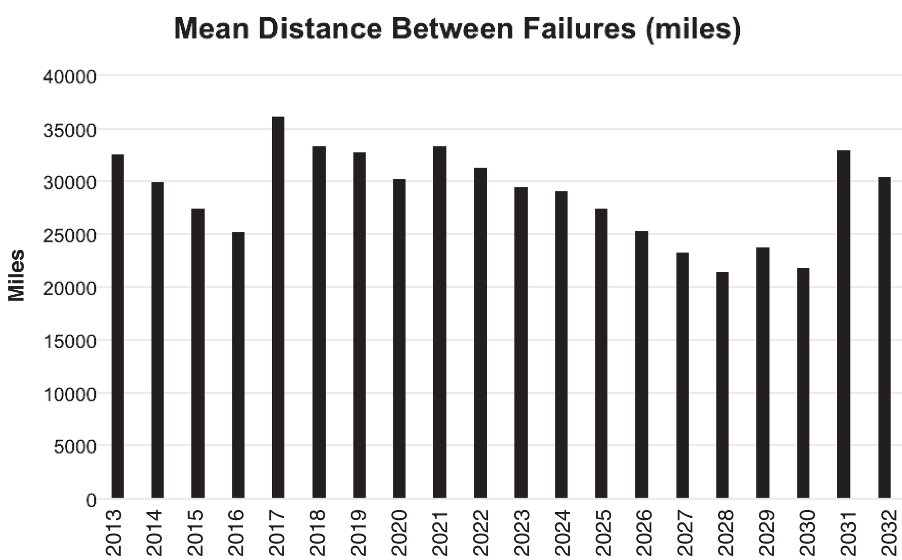


Figure 4.51. STA Mean Distance Between Failures (miles) Unconstrained Scenario.

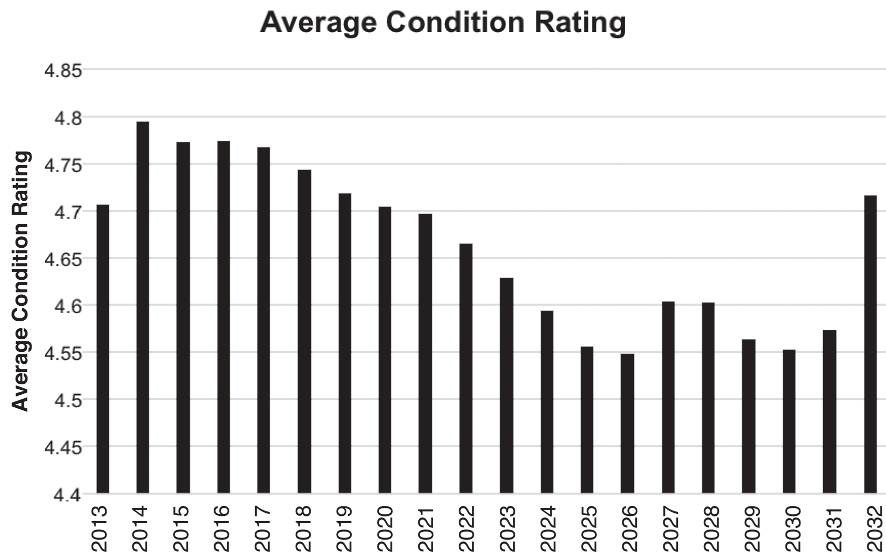


Figure 4.52. STA Average Condition Rating Unconstrained Scenario.

Table 4.34 shows the summary results of the Do Nothing scenario compared to the Unconstrained scenario, showing the condition of the assets in 20 years in a best-case scenario where all assets are replaced as needed and the worst-case scenario where no replacement activity is programmed. In the Do Nothing program, you note a significant decrease the mean distance between failures (see Figure 4.54), and in average condition (see Figure 4.55), as well as increases in passenger hours of delay and associated costs.

15. Input the following information to create three charts, showing conditions between 2016 and 2025 in a "Do Nothing" scenario:
    - **Chart One**, shown in Figure 4.56, with the **Prioritization Model Output Variable** selected as "Needs ($)" the **Run** "Do Nothing."
    - **Chart Two**, shown in Figure 4.54, with the **Prioritization Model Output Variable** selected as "Mean Distance Between Failures (miles)" and the **Run** "Do Nothing."
    - **Chart Three**, shown in Figure 4.55, with the **Prioritization Model Output Variable** selected as "Average Condition Rating" and the **Run** "Do Nothing."

Transit Cooperative Research Program - Transit Asset Prioritization Tool

Summary: Prioritization Run Do Nothing

Year	Needs		Asset NPV	Budget ($)	Expenditures from Budget ($)	Remaining Backlog ($)	Energy Costs ($)	Other Agency Costs ($)
	Amount ($)	Percent						
2013	45,985,188	2.6%	-	-	-	45,985,188	23,799,241	87,251,440
2014	45,985,188	2.6%	-	-	-	45,985,188	24,508,389	92,118,579
2015	65,870,188	3.7%	-	-	-	65,870,188	25,238,670	97,383,735
2016	156,936,463	8.7%	-	-	-	156,936,463	25,990,712	102,705,850
2017	157,301,663	8.8%	-	-	-	157,301,663	26,765,165	108,440,940
2018	186,657,413	10.4%	191,401	-	14,266,275	172,391,138	27,562,695	114,326,085
2019	186,251,138	10.4%	-	(14,266,275)	-	186,251,138	28,383,992	119,027,727
2020	256,608,738	14.3%	-	(14,266,275)	-	256,608,738	29,229,763	126,067,884
2021	260,690,738	14.5%	-	(14,266,275)	-	260,690,738	30,100,738	132,602,627
2022	264,530,738	14.7%	-	(14,266,275)	-	264,530,738	30,997,667	139,757,420
2023	300,142,338	16.7%	-	(14,266,275)	-	300,142,338	31,921,325	146,874,926
2024	305,116,338	17.0%	-	(14,266,275)	-	305,116,338	32,872,507	154,834,361
2025	342,913,038	19.1%	-	(14,266,275)	-	342,913,038	33,852,035	162,498,582
2026	417,672,038	23.3%	-	(14,266,275)	-	417,672,038	34,860,752	170,974,788
2027	418,902,038	23.3%	-	(14,266,275)	-	418,902,038	35,899,529	179,236,339
2028	531,402,038	29.6%	-	(14,266,275)	-	531,402,038	36,969,261	187,804,154
2029	554,527,038	30.9%	-	(14,266,275)	-	554,527,038	38,070,871	196,689,028
2030	654,714,538	36.4%	-	(14,266,275)	-	654,714,538	39,205,310	205,902,487
2031	817,672,538	45.5%	-	(14,266,275)	-	817,672,538	40,373,555	215,451,928
2032	911,259,738	50.7%	-	(14,266,275)	-	911,259,738	41,576,614	225,345,444

Year	Cost of Passenger Delay ($)	Other Passenger Costs ($)	Cost of CO2 Emissions ($)	Other External Costs ($)	Total Agency, Pass., and Ext. Costs ($)	Passenger Delay (hours)	CO2 Emissions (tons)	Avg. Condition (non-veh)	MDBF (miles)
2013	4,805,688	13,373,810	3,344,465	-	132,574,644	99,291	139,353	4.71	32,553
2014	5,176,214	15,090,632	3,443,947	-	140,337,762	106,947	143,498	4.68	29,896
2015	5,575,448	16,933,079	3,546,389	-	148,677,321	115,195	147,766	4.65	27,453
2016	6,005,629	18,901,531	3,651,878	-	157,255,600	124,083	152,162	4.62	25,207
2017	6,469,170	20,995,676	3,760,505	-	166,431,455	133,661	156,688	4.59	23,142
2018	6,968,674	23,214,606	3,872,363	-	190,210,698	143,981	161,348	4.56	21,244
2019	7,506,950	25,556,882	3,987,549	-	184,463,100	155,102	166,148	4.55	19,500
2020	8,087,027	28,020,593	4,106,161	-	195,511,429	167,087	171,090	4.52	17,897
2021	8,712,172	30,603,403	4,228,301	-	206,247,242	180,004	176,179	4.48	16,424
2022	9,385,910	33,302,593	4,354,075	-	217,797,666	193,924	181,420	4.44	15,071
2023	10,112,045	36,115,104	4,483,591	-	229,506,990	208,927	186,816	4.40	13,828
2024	10,894,679	39,037,583	4,616,959	-	242,256,089	225,097	192,373	4.36	12,686
2025	11,738,240	42,066,420	4,754,294	-	254,909,571	242,526	198,096	4.31	11,637
2026	12,647,506	45,197,790	4,895,715	-	268,576,550	261,312	203,988	4.26	10,674
2027	13,627,631	48,427,698	5,041,343	-	282,232,538	281,563	210,056	4.21	9,790
2028	14,684,177	51,752,013	5,191,303	-	296,400,908	303,392	216,304	4.16	8,978
2029	15,823,150	55,166,513	5,345,723	-	311,095,286	326,925	222,738	4.10	8,232
2030	17,051,028	58,666,922	5,504,738	-	326,330,485	352,294	229,364	4.04	7,548
2031	18,374,806	62,248,946	5,668,483	-	342,117,718	379,645	236,187	3.98	6,920
2032	19,802,031	65,908,312	5,837,099	-	358,469,499	409,133	243,212	3.92	6,344

Click for Main Menu

Figure 4.53. STA Do Nothing Program Summary Results.

Table 4.34. Summary Results Do Nothing and Unconstrained Scenarios.

Scenarios	Initial Value	Value in 2032	
		Do Nothing	Unconstrained
Remaining Backlog	$ 45,985,188	$ 911,259,738	$ 0
Cumulative Spent	-	$ 14,266,275	$ 1,063,478,425
MDBF (miles)	32,553	6,344	30,403
Average TERM Condition (non-vehicle Assets)	4.71	3.92	4.72
Passenger Delay (hours)	99,291	409,133	159,001
CO_2 Emissions (tons)	139,353	243,212	160,325
Other Agency Costs	$ 87,251,440	$ 225,345,444	$ 83,632,026
Total Agency, User and External Costs Excluding Budget Expenditures	$ 132,574,644	$ 358,469,499	$ 129,851,990

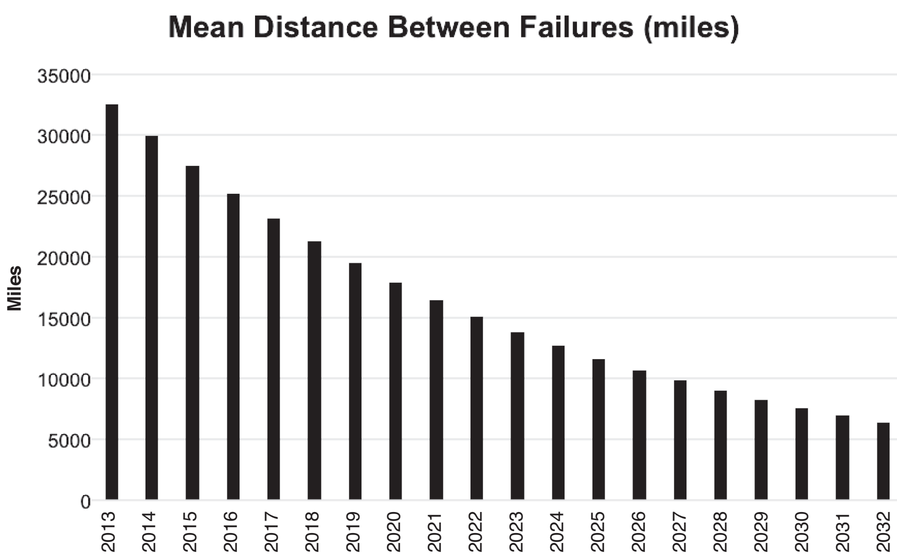


Figure 4.54. STA Mean Distance Between Failures (miles) Do Nothing Scenario.

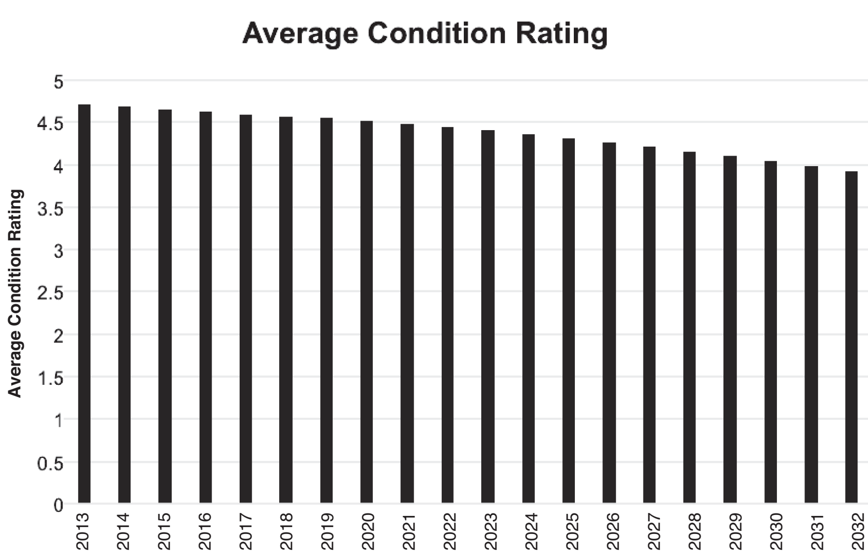


Figure 4.55. STA Average Condition Rating Do Nothing Scenario.

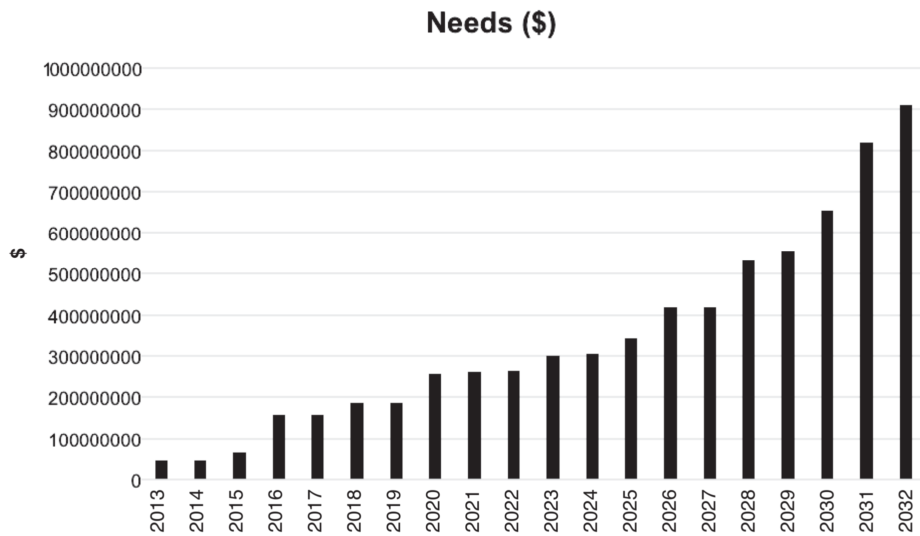


Figure 4.56. STA Needs ($) Do Nothing Scenario.

$35M Annual Budget Scenario

After reviewing the previous results, input the agency's approximate annual capital asset replacement budget of $35,000,000. Table 4.35 shows the results of this analysis compared to other scenarios.

16. Adjust the following on the **Budgets and Parameters** page:
    - **Budget for Asset Replacement and Rehabilitation (Years 2013–2032):** 35,000,000
17. Run a prioritization model with the **ID Code** "$35M Annual."
18. Review the **Program List** and the **Summary Table**, shown in Figure 4.57.

In reviewing the program list, STA noted the following actions are projected:

- 270 buses replaced
- 58 light rail cars replaced

Table 4.35. Summary Results Do Nothing, $35M Annually, and Unconstrained Scenarios.

Scenarios	Initial Value	Value in 2032		
		Do Nothing	$ 35M Annual Scenario	Unconstrained
Remaining Backlog	$ 45,985,188	$ 911,259,738	$ 405,013,450	$ 0
Cumulative Spent	-	$ 14,266,275	$ 644,198,700	$ 1,063,478,425
MDBF (miles)	32,553	6,344	21,010	30,403
Average TERM Condition (non-vehicle Assets)	4.71	3.92	4.42	4.72
Passenger Delay (hours)	99,291	409,133	162,157	159,001
CO_2 Emissions (tons)	139,353	243,212	164,241	160,325
Other Agency Costs	$ 87,251,440	$ 225,345,444	$ 113,453,518	$ 83,632,026
Total Agency, User and External Costs Excluding Budget Expenditures	$ 132,574,644	$ 358,469,499	$ 170,505,793	$ 129,851,990

Transit Cooperative Research Program - Transit Asset Prioritization Tool

Summary: Prioritization Run $35M Annual

Year	Needs		Asset NPV	Budget ($)	Expenditures from Budget ($)	Remaining Backlog ($)	Energy Costs ($)	Other Agency Costs ($)	Cost of Passenger Delay ($)	Other Passenger Costs ($)	Cost of CO2 Emissions ($)	Other External Costs ($)	Total Agency, Pass., and Ext. Costs ($)	Passenger Delay (hours)	CO2 Emissions (tons)	Avg. Condition (non-veh)	MDBF (miles)
	Amount ($)	Percent															
2013	45,985,188	2.6%	783,928	35,000,000	1,143,325	44,841,863	23,799,241	87,251,440	4,805,688	13,373,810	3,344,465	-	133,717,969	99,291	139,353	4.71	32,553
2014	44,841,863	2.5%	10,675,701	68,856,675	44,841,863	-	24,508,389	92,017,254	5,176,214	15,090,632	3,443,947	-	185,078,299	106,947	143,498	4.68	29,896
2015	19,885,000	1.1%	91,672	59,014,813	19,885,000	-	25,238,670	85,122,216	5,575,448	5,279,924	3,546,389	-	144,647,647	115,195	147,766	4.77	27,453
2016	91,066,275	5.1%	-	74,129,813	-	91,066,275	25,990,712	87,642,715	6,005,629	4,568,777	3,651,878	-	127,859,711	124,083	152,162	4.77	25,207
2017	91,431,475	5.1%	2,642,168	109,129,813	77,165,200	14,266,275	26,765,165	92,021,200	6,469,170	5,332,691	4,096,505	-	211,849,931	133,661	170,688	4.75	23,142
2018	43,622,025	2.4%	427,270	66,964,613	43,622,025	-	25,209,137	82,935,178	6,681,259	6,210,360	3,667,407	-	168,325,367	138,043	152,809	4.73	33,951
2019	13,860,000	0.8%	22,023	58,342,588	13,860,000	-	25,177,148	84,505,817	6,486,488	6,959,846	3,627,510	-	140,616,808	134,018	151,146	4.72	33,428
2020	70,357,600	3.9%	612,865	79,482,588	70,357,600	-	25,926,589	89,166,077	6,982,123	7,181,392	3,836,607	-	203,450,388	144,259	159,859	4.71	30,816
2021	4,082,000	0.2%	47,567	44,124,988	4,082,000	-	25,201,294	86,907,505	6,522,847	7,808,961	3,647,242	-	134,169,848	134,770	151,968	4.70	34,180
2022	3,840,000	0.2%	58,772	75,042,988	3,840,000	-	25,875,747	91,241,191	7,012,074	8,947,497	3,753,002	-	140,669,510	144,878	156,375	4.67	32,070
2023	35,611,600	2.0%	280,312	106,202,988	35,611,600	-	26,537,817	95,359,429	7,534,754	10,324,571	3,863,650	-	179,231,821	155,677	160,985	4.63	30,275
2024	6,117,325	0.3%	161,204	105,591,388	6,117,325	-	26,414,990	98,319,617	7,287,598	11,848,911	3,823,250	-	153,811,690	150,570	159,302	4.60	29,892
2025	39,671,463	2.2%	301,096	134,474,063	39,671,463	-	27,082,379	102,477,424	7,830,454	13,524,677	3,906,338	-	194,492,735	161,786	162,764	4.56	28,222
2026	74,759,000	4.2%	205,509	129,802,600	74,759,000	-	27,888,496	105,304,774	8,428,518	12,692,132	4,022,438	-	233,095,357	174,143	167,602	4.56	26,024
2027	1,230,000	0.1%	5,670	90,043,600	1,230,000	-	28,718,608	102,774,635	9,072,372	13,704,463	4,141,989	-	159,642,068	187,446	172,583	4.61	23,994
2028	154,012,300	8.6%	413,718	123,813,600	41,512,300	112,500,000	29,573,431	107,800,380	9,765,532	15,398,056	4,265,094	-	208,314,793	201,767	177,712	4.57	22,120
2029	135,625,000	7.6%	1,834,668	117,301,300	112,500,000	23,125,000	30,453,699	108,820,869	10,511,787	12,948,962	4,487,858	-	279,723,175	217,186	186,994	4.56	20,390
2030	123,312,500	6.9%	-	39,801,300	-	123,312,500	27,896,911	106,315,651	8,100,490	14,292,610	3,968,267	-	160,573,929	167,365	165,344	4.52	22,721
2031	363,070,500	20.2%	880,641	74,801,300	54,000,000	309,070,500	28,727,747	111,375,884	8,722,035	15,753,424	4,132,340	-	222,711,430	180,207	172,181	4.47	20,902
2032	405,013,450	22.5%	-	55,801,300	-	405,013,450	27,920,965	113,453,518	7,848,377	17,341,150	3,941,782	-	170,505,793	162,157	164,241	4.42	21,010

Click for Main Menu

Figure 4.57. STA Annual Budget Scenario Summary Results.

- 83,100 miles of track replaced
- 29,450 miles of guideway replaced
- 5 maintenance facilities replaced, totaling 61,350 square feet
- 7 HVAC systems replaced, totaling 92,550 square feet
- 27 roof replacement projects, totaling 346,600 square feet
- Every roof (15 total) replaced at least once during the analysis period

19. Input the following information to create three charts, showing conditions between 2013 and 2032 in a "Do Nothing" scenario:
    - **Chart One**, shown in Figure 4.58, with the **Prioritization Model Output Variable** selected as "Needs ($)" and the **Run** "$35M Annual."
    - **Chart Two**, shown in Figure 4.59, with the **Prioritization Model Output Variable** selected as "Mean Distance Between Failures (miles)" and the **Run** "$35M Annual."
    - **Chart Three**, shown in Figure 4.60, with the **Prioritization Model Output Variable** selected as "Average Condition Rating" and the **Run** "$35M Annual."

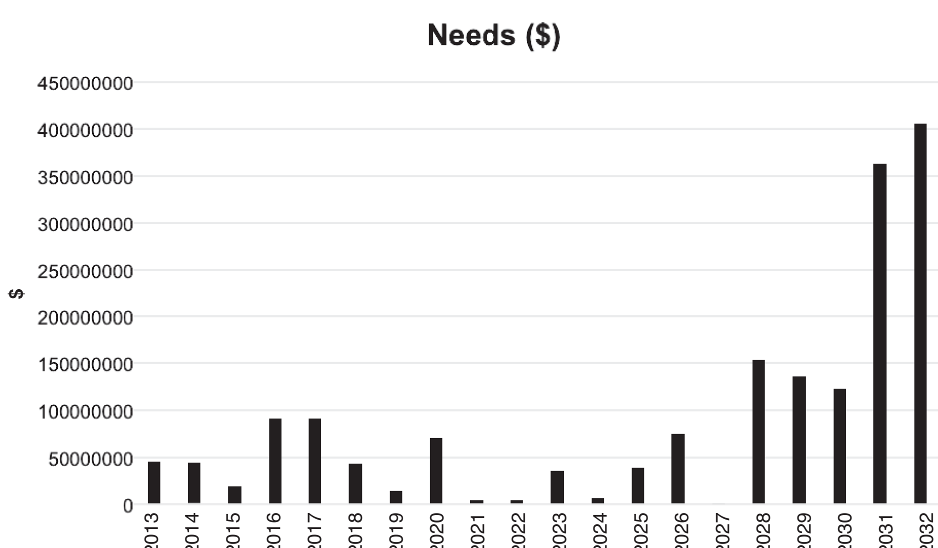


Figure 4.58. STA Needs ($) Annual Budget Scenario.

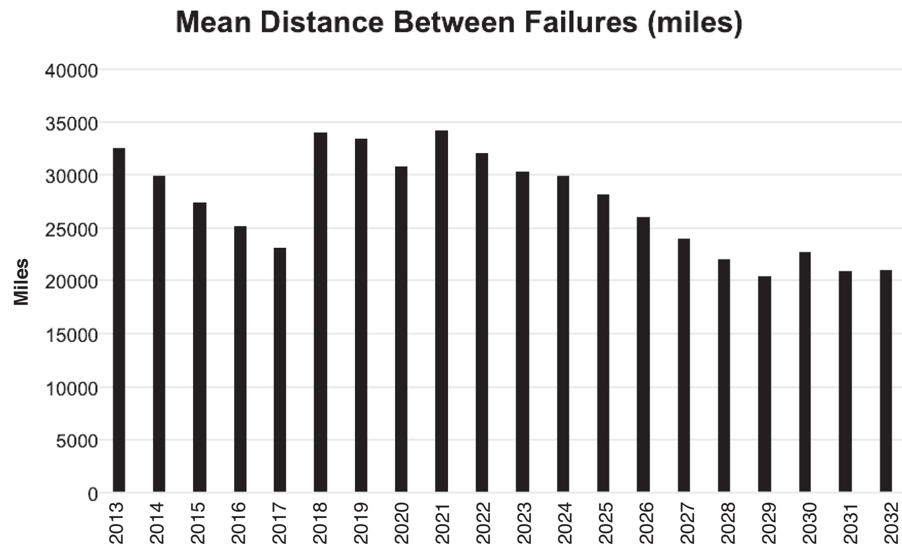


Figure 4.59. STA Mean Distance Between Failures (miles) Annual Budget Scenario.

After assessing the summary data, you review the suggested program. On the program list, you observe the following:

- Some roof projects are being programmed for replacement twice during the 20-year analysis-period.
- Multiple instances are occurring where roof, HVAC, and/or building overhauls are being programmed for the same building in multiple years over a short time period.

STA is worried that performing major replacement and overhaul tasks on the same building, spread out over multiple years, might have adverse effects for agency operations and disrupt normal business for longer periods. To address this issue, you decide to combine major replacement and overhaul tasks occurring on the same building into single projects, to be programmed together in the analysis. STA also noted the cost benefits of grouping tasks and allowing work

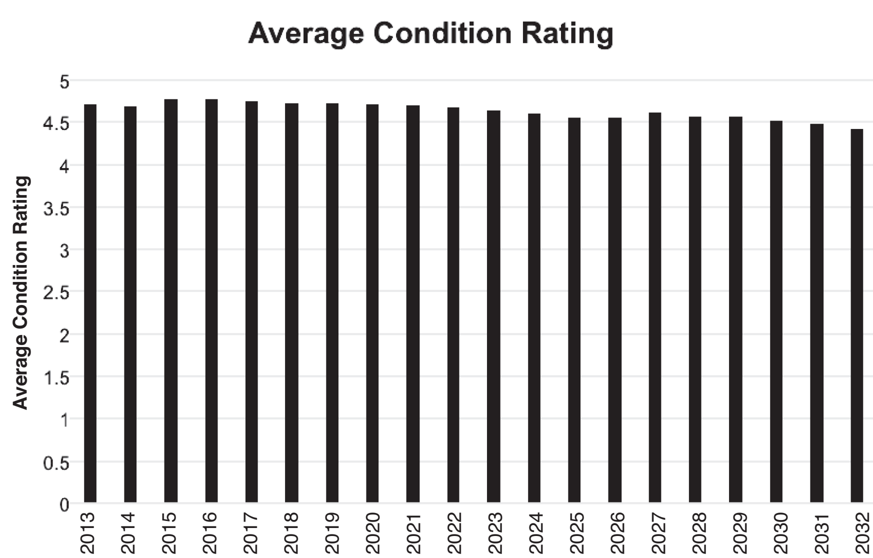


Figure 4.60. STA Average Condition Rating Annual Budget Scenario.

Table 4.36. Model Adjustments.

Building Code	HVAC Code	Roof Code	New Project Code
Maint04	Roof-Maint04	HVAC-Maint04	Project-Maint04
Maint06	Roof-Maint06	HVAC-Maint06	Project-Maint06
Maint07	Roof-Maint07	HVAC-Maint07	Project-Maint07
Maint09	Roof-Maint09	HVAC-Maint09	Project-Maint09

to be performed on all systems of the building. You decide only to group projects that have been programmed in the $35M annual scenario to ensure that the initial results are not changed significantly. Therefore, you choose to group the following projects:

20. Click **Edit Asset Group** and select "Maint Facilities." Then click **Edit Selected Group**.
21. In the **Project Code** column, change the building codes to the new project codes in Table 4.36. For example, change "Maint04" to "Project-Maint04." Complete this for all other buildings indicated in the table, then select **Click for Main Menu** when finished.
22. Repeat Steps 11–12 for HVAC and Roof assets, changing the appropriate **Project Code** to the new project code in Table 4.36. Each model must be updated individually.

$35M Adjusted Program Scenario

After combining replacement activities on various building in the analysis, STA ran the prioritization model a second time to determine an improved program list.

23. Return to the start screen and select **Run Prioritization Model**, defining the **ID Code** as "$35M Adjusted" to describe the run. The annual budget should not be adjusted for this scenario.

STA compared the two outputs in the Summary Results, shown in Table 4.37, and noted that despite the grouping of facility work there are only small differences in the Remaining Backlog and Cumulative Spent in the two scenarios shown in the table.

After comparing the annual budget and adjusted program scenarios, you notice that there are some small but significant changes in the final program. In the Adjusted Scenario, the cumulative

Table 4.37. Summary Results $35M Annually and $35M Adjusted.

Scenarios	Initial Value	Value in 2032	
		$ 35M Annual Scenario	$ 35M Adjusted Scenario
Remaining Backlog	$ 45,985,188	$ 405,013,450	$ 405,013,450
Cumulative Spent	-	$ 644,198,700	$ 643,156,963
MDBF (miles)	32,553	21,010	21,010
Average TERM Condition (non-vehicle Assets)	4.71	4.42	4.42
Passenger Delay (hours)	99,291	162,157	162,157
CO_2 Emissions (tons)	139,353	164,241	164,241
Other Agency Costs	$ 87,251,440	$ 113,453,518	$ 133,742,072
Total Agency,User and External Costs Excluding Budget Expenditures	$ 132,574,644	$ 170,505,793	$ 170,794,346

spent over the 20-year period increased a little over $1M dollars. While there was no change in the majority of projects programmed, there were 23 roof replacement projects in the Adjusted Program, as opposed to 27 roof replacements in the Annual Scenario.

A complete program list is provided in Table 4.38. Comparative graphs, showing the needs, average asset condition, and the mean distance between failures for the annual budget and adjusted program scenarios are shown in Figures 4.61, 4.62, and 4.63.

24. From the Start Screen, select **Display Chart-Two Runs**.
25. Select "Needs ($)" as the **Prioritization Model Output Variable** to chart, then select "$35M Annual" and "$35M Adjusted" as the **Runs** to chart before clicking **Display Chart**.
26. Review the **Needs ($)** chart, shown in Figure 4.61, and select **Click for Main Menu** when you have finished.

Input the following information to create two additional charts:

- **Chart One**, shown in Figure 4.62, with the **Prioritization Model Output Variable** selected as "Mean Distance Between Failures (miles)" the **Runs** "$35M Adjusted" and "$35M Annual."
- **Chart Two**, shown in Figure 4.63, with the **Prioritization Model Output Variable** selected as "Average Condition Rating" and the **Runs** "$35M Adjusted" and "$35M Annual."

Table 4.38. $35M Adjusted Program Scenario Complete Program List.

Program Year	Asset Description	Project Code	Units	Cost	Project Rank	PI
2013	Roof	Roof-Maint05	9,250	$ 191,938	1	0.6624
2013	Roof	Roof-Admin02	4,100	$ 77,813	1	0.6624
2013	Roof	Roof-Maint01	3,600	$ 85,075	3	0.6624
2013	Roof	Roof-Maint03	33,200	$ 688,900	3	0.6624
2014	Roof	Roof-Maint02	3,750	$ 77,813	1	0.2688
2014	Roof	Roof-Maint10	45,200	$ 937,900	1	0.2688
2014	Guideway (Embedded and XC)	GuideXC01	12,100	$ 38,006,100	3	0.2623
2014	Guideway (Embedded and XC)	GuideXC02	1,000	$ 3,141,000	4	0.0607
2014	HVAC	HVAC-Admin03	9,100	$ 1,820,000	5	0.0069
2015	Track (Embedded and XC)	TrackXC01	24,250	$ 19,885,000	1	0.0046
2017	Roof	Roof-Maint08	6,200	$ 128,650	1	0.1270
2017	Roof	Roof-Admin01	6,100	$ 126,575	1	0.1270
2017	Bus	Bus01	100	$ 38,400,000	3	0.0338
2017	Bus	Bus02	100	$ 38,400,000	3	0.0338
2018	Maintenance Facilities	Project01	9,700	$ 12,125,000	1	0.0134
2018	HVAC	Project01	9,700	$ 1,940,000	1	0.0134
2018	Roof	Project01	9,700	$ 201,275	1	0.0134
2018	Guideway (Embedded and XC)	GuideXC03	750	$ 2,355,750	4	0.0093
2018	Light Rail	LightRail01	6	$ 27,000,000	5	0.0079
2019	Track (Curved)	TrackCR01	15,000	$ 13,860,000	1	0.0016
2020	Bus	Bus03	42	$ 16,128,000	1	0.0153
2020	Light Rail	LightRail02	8	$ 36,000,000	2	0.0079
2020	Track (Special)	TrackSP01	2,100	$ 7,929,600	3	0.0060
2021	Bus	Bus05	7	$ 2,688,000	1	0.0153
2021	Track (Embedded and XC)	TrackXC02	1,700	$ 1,394,000	2	0.0046

Table 4.38. (Continued).

Program Year	Asset Description	Project Code	Units	Cost	Project Rank	PI
2021	Maintenance Facilities	Project-Maint06	4,800	$ 6,000,000	3	0.0023
2021	HVAC	Project-Maint06	4,800	$ 960,000	3	0.0023
2021	Roof	Project-Maint06	4,800	$ 99,600	3	0.0023
2022	Bus	Bus04	4	$ 1,536,000	1	0.0153
2022	Bus	Bus06	6	$ 2,304,000	1	0.0153
2022	Maintenance Facilities	Project-Maint07	41,400	$ 51,700,000	3	0.0052
2022	HVAC	Project-Maint07	41,400	$ 8,280,000	3	0.0052
2022	Roof	Project-Maint07	41,400	$ 859,050	3	0.0052
2022	Maintenance Facilities	Project-Maint09	150	$ 187,500	6	0.0027
2022	HVAC	Project-Maint09	150	$ 30,000	6	0.0027
2022	Roof	Project-Maint09	150	$ 3,113	6	0.0027
2022	Maintenance Facilities	Project-Maint04	5,300	$ 6,625,000	9	0.0020
2022	HVAC	Project-Maint04	5,300	$ 1,060,00	9	0.0020
2022	Roof	Project-Maint04	5,300	$ 109,975	9	0.0020
2023	Roof	Roof-Admin03	9,100	$ 188,825	1	0.0823
2023	Roof	Roof-Admin04	1,700	$ 35,275	1	0.0823
2023	Light Rail	LightRail03	7	$ 31,500,000	3	0.0079
2023	HVAC	HVAC-Maint05	18,500	$ 3,700,000	4	0.0032
2024	Roof	Roof-Maint05	9,250	$ 191,938	1	0.0823
2024	Roof	Roof-Admin02	4,100	$ 85,075	1	0.0823
2024	Roof	Roof-Maint01	3,600	$ 74,700	1	0.0823
2024	Roof	Roof-Maint03	33,200	$ 688,900	4	0.0823
2024	Bus	Bus07	5	$ 1,920,000	5	0.0153
2024	Bus	Bus08	6	$ 2,304,000	5	0.0153
2024	HVAC	HVAC-Maint02	3,750	$ 750,000	7	0.0032
2025	Roof	Roof-Maint02	3,750	$ 77,813	1	0.0823
2025	Roof	Roof-Maint10	45,200	$ 937,900	2	0.0823
2025	Guideway	GuideXC04	2,500	$ 7,852,500	3	0.0093
2025	Track (Tangent Ballasted)	TrackBL01	11,000	$ 7,029,000	4	0.0053
2025	Track (Tangent Curved)	TrackCR02	24,800	$ 22,915,200	5	0.0016
2026	Track (Special)	TrackSP02	2,750	$ 10,384,000	1	0.0060
2027	Track (Embedded and XC)	TrackXC03	1,500	$ 1,230,000	1	0.0046
2028	Roof	Roof-Admin01	6,100	$ 126,575	1	0.0823
2028	Roof	Roof-Maint08	6,200	$ 128,650	2	0.0823
2028	Guideway (Embedded and XC)	GuideXC01	12,100	$ 38,006,100	3	0.0093
2028	Guideway (Embedded and XC)	GuideXC02	1,000	$ 3,141,000	3	0.0093
2029	Light Rail	Light Rail04	15	$ 67,500,000	1	0.0163
2029	Light Rail	Light Rail05	10	$ 45,000,000	2	0.0163
2031	Light Rail	LightRail06	12	$ 54,000,000	1	0.0163

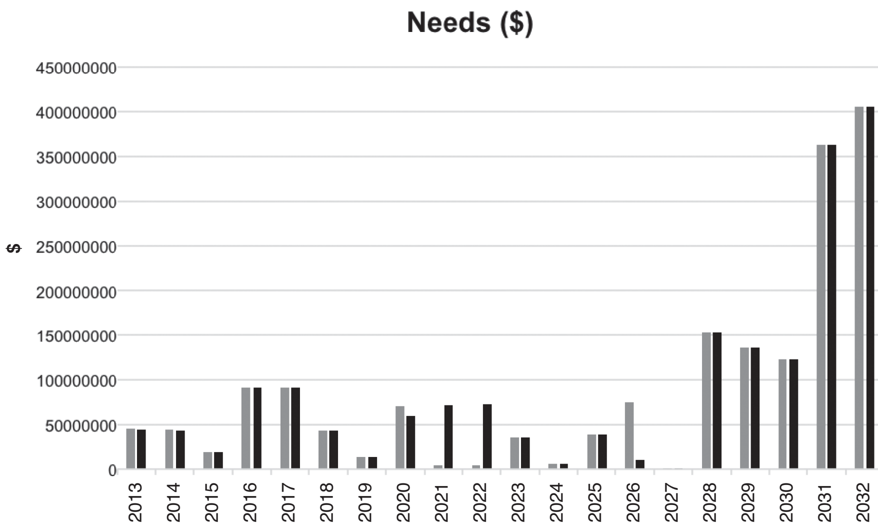


Figure 4.61. Comparing STA Needs ($) between the Annual Budget Scenario (gray) and the Adjusted Program Scenario (black).

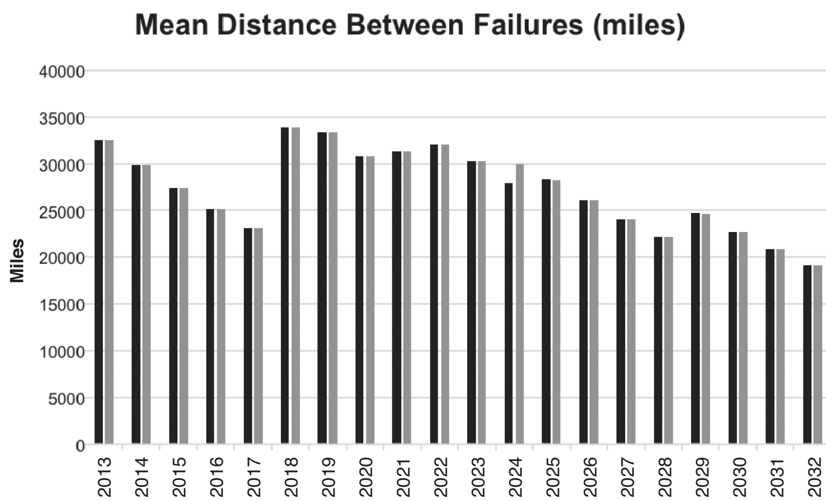


Figure 4.62. Comparing STA Mean Distance Between Failures (miles) between the Annual Budget Scenario (gray) and the Adjusted Program Scenario (black).

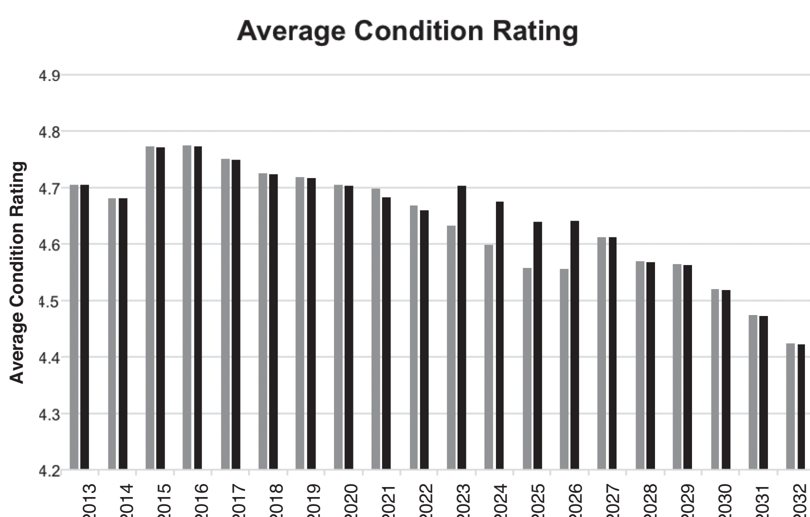


Figure 4.63. Comparing STA Average Condition Rating between the Annual Budget Scenario (gray) and the Adjusted Program Scenario (black).

CHAPTER 5

Additional Resources

***2012 NTD Annual Reporting Manual*. FTA, 2012.**

The NTD is the central repository for transit data from transit agencies throughout the United States. It serves to provide a standardized view of transit agencies serving metropolitan areas, and it is used by Congress to apportion FTA funds each year. All transit agencies receiving grant funding from FTA (under the Urbanized Area Formula Program or the Other than Urbanized Area (Rural) Formula Program) are required to report to the NTD. This manual provides specific instructions and guidance for reporting agencies. Elements of the NTD reporting guidelines and definitions are referenced in this guidebook and can assist agencies in developing the TAMP. For example, the NTD Asset Module Structure can serve as an agency's Capital Asset Inventory (see Step 1.1 of Chapter 2 in this guidebook), and some of the metrics required for NTD reporting can serve as performance measures in a TAMP (see Step 1.4 of Chapter 2 in this guidebook). The inventory description data required for the use of TAPT is formatted based on the NDT requirements (see Chapter 3 of this guidebook).

This document is available at the following URL (accessed June 2014): http://www.ntdprogram.gov/ntdprogram/pubs/ARM/2012/pdf/2012_annual_Manual_Complete.pdf

***Asset Management Guide: Focusing on the Management of Our Transit Investments*. FTA, 2012.**

This document offers targeted guidance for transit agencies interested in advancing the practice and implementation of transit asset management. It brings together relevant research and guidance on transportation asset management and best practices in the transit industry to create a practical and useful guidance document. The contents of the document include:

- An introduction to transit asset management—defines asset management for the transit industry, provides guidance for fitting asset management into other agency processes, etc.
- Business process framework—each business process component is outlined and includes a description of how it fits into the greater asset management framework. The guide indicates the ways in which the components will work together, and how each one can be improved independently.
- Information systems—provides an overview of existing information systems that can support asset management.
- Implementation—offers guidance for implementation of assessment and implementation of an asset management process.
- Asset management guide supplement—details the fundamental elements for consideration in lifecycle management by asset class.

The guide includes best practice examples, in the form of case studies, highlighting transit agencies that have adopted elements of asset management processes and systems.

Appendix A, *The Asset Manage Guide Supplement*, provides an overview by asset class on the practices of lifecycle management and industry standards. The document includes a chapter on each of the following: vehicles; facilities and stations; guideways; systems; and sustainability and asset management.

This document is available at the following URL (accessed June 2014): http://www.fta.dot.gov/documents/FTA_Report_No._0027.pdf

Cambridge Systematics, Inc., PB Consult, and Texas Transportation Institute. *NCHRP Report 551: Performance Measures and Targets for Transportation Asset Management*. Transportation Research Board of the National Academies, Washington, DC, 2006.

This report provides a comprehensive review of the use of performance measures for transportation asset management, focusing primarily on highway asset management. The report is divided into two volumes. Volume I is a research report that reviews current practices in use of performance measures for asset management, recommends criteria for selecting performance measures, discusses considerations in designing and using performance measures, and presents a framework for using performance measures to support asset management. Volume II is a practical guide for identifying performance measures and setting performance targets. It presents a step-by-step approach for agencies to follow, encompassing identification of measures, integration of performance measures into an organization, and establishing performance targets.

This document is available at the following URL (accessed June 2014): http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_551.pdf

***International Organization for Standardization (ISO) 55000 Series*, British Standards Institution, 2014.**

This series of three documents provides an overview of the international standard for asset management, and the use and implementation of asset management systems within the context of an organization. The guidance was developed through international cooperation and represents best practices that can be applied to a broad range of assets, and across a range of contexts and types of organizations. There are three documents in this series:

- *ISO 55000: Asset Management—Overview, Principles and Terminology*. This document serves as the background documentation for the series and discusses asset management, its principles, definitions and terminology, and the benefits agencies can expect from utilizing the practice.
- *ISO 55001: Asset Management—Management Systems—Requirements.* This document provides guidance on the organizational structure needed for best implementation of an asset management system. Topics include agency leadership, planning, support, operation, performance evaluation and improvement.
- *ISO 55002: Asset Management—Management Systems—Guidelines for the Application of ISO 55001*. The final document in the series supports 55001 by providing guidance on *how* to apply an asset management system within your organization.

Particularly relevant to the development of asset management plans are the planning requirements in the standard. Specifically, Requirement 6.2.2 requires that organizations develop asset management plans that document:

- The method and criteria for decision making and prioritizing of the activities and resources to achieve its asset management plan(s) and asset management objectives;
- The process and methods to be employed in managing its assets over their lifecycles;
- What will be done;

- What resources will be required;
- Who will be responsible;
- When it will be completed;
- How the results will be evaluated;
- The appropriate time horizon(s) for the asset management plan(s);
- The financial and non-financial implications of the asset management plan(s);
- The review period for the asset management plan(s);
- Actions to address risks and opportunities associated with managing the assets, taking into account how these risks and opportunities can change with time, by establishing processes for:
  - Identification of risks and opportunities;
  - Assessment of risks and opportunities;
  - Determining the significance of assets in achieving asset management objectives;
  - Implementation of the appropriate treatment, and monitoring, of risks and opportunities.

Kittleson & Associates, Urbitran, LKC Consulting, MORPACE International, Queensland University of Technology, and Nakanishi, Y. *TCRP Report 88: A Guidebook for Developing a Transit Performance–Measurement System*. Transportation Research Board of the National Academies, Washington, DC, 1995.

This report provides guidance for transit system managers in developing a performance-measurement system that addresses customer and community issues. It presents characteristics of an effective performance measurement system that reflects different points of view and emphasizes customer satisfaction. Twelve case studies provide examples of how transit agencies have successfully used performance measures. To implement a performance-measurement program, it proposes that agencies use an eight-step process: define goals and objectives; generate management support; identify users, stakeholders, and constraints; select performance measures and develop consensus; test and implement the program; monitor and report performance; integrate results into agency decision-making; and review and update the program. For each step, the report provides the tasks involved and examples of how transit agencies have accomplished that step.

The report also contains a library of performance measures and categorizes them based on their focus. For each measure, it provides the use, mode, scope, applicable system size, audience, example target values, data requirements, and the factors that influence it. It also discusses data collection sources and techniques, methods to manage the data, methods to set performance standards, and reporting performance.

This document is available at the following URL (accessed June 2014): http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_report_88/Guidebook.pdf

National Asset Management Steering Group (NAMS). *International Infrastructure Management Manual (IIMM)*. Association of Local Government Engineering NZ Inc (INGENIUM) and the Institute of Public Works Engineering of Australia (IPWEA), 2011.

This manual details principles, processes, and examples of infrastructure asset management. It introduces asset management concepts and describes how to implement an asset management approach, including enabling processes for asset management and supporting systems and data. The enabling processes discussed in the manual include levels of services, demand forecasting, condition assessment, optimized decision making (including optimizing resource allocation), maintenance management, and financial planning. Also, the manual includes country-specific guidance for Australia, New Zealand, South Africa, the UK, and the United States. The manual can be used for managing any infrastructure asset. Nonetheless, much of the guidance and many of the examples pertain to managing transportation assets. The manual is notable for its broad scope, and extensive set of examples and case studies.

***Publicly Available Specification (PAS) 55*. BSI, 2008.**

This document has been superseded by the ISO 55000 series. PAS 55 is a specification from the BSI and the International Asset Management Committee designed to provide guidance in managing physical assets. The standard includes two parts. PAS 55-1 is a standard for "optimized management of physical assets." PAS 55-2 is a set of guidelines for implementation. PAS 55 defines asset management as "the systematic and coordinated activities and practices through which an organization optimally and sustainably manages its assets and asset systems, their associated performance, risks and expenditures over their lifecycles for the purpose of achieving its organizational strategic plan." The asset management concepts detailed in PAS 55 are conceptually similar to those in the *AASHTO Transportation Asset Management Guide* and supplement, and in the IIMM. Like the IIMM, PAS 55 is intended to apply to a range of infrastructure assets, including, but not limited to, transportation assets. PAS 55 includes a 28-point requirements checklist describing mechanisms for establishing whole lifecycle planning, risk management, and cost/benefit analyses within the day-to-day activities of capital project implementation. Requirements include identifying and considering the needs of stakeholders over the lifecycle of the asset, specifying the interventions needed for minimum costs, and optimizing the timing of work to create the right groups of projects.

Spy Pond Partners, KKO & Associates, H. Cohen and J. Barr. *TCRP Report 157: State of Good Repair: Prioritizing the Rehabilitation and Replacement of Existing Capital Assets and Evaluating the Implications for Transit.* Transportation Research Board of the National Academies, Washington, DC, 2012.

This document serves as the foundational research for the project resulting in this guidebook. The work is based on a review of literature and a discussion of current agency practices related to characterizing the impacts and implications of investments. The report also includes a section outlining the related tools and approaches currently available to agencies. *TCRP Report 157* resulted in a framework for transit agencies to use for prioritization of capital asset rehabilitation and replacement decisions, which was used in the development of TAPT and this guidebook.

This document is available at the following URL (accessed June 2014): http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_157.pdf

***TERM Lite Quick Start Guide*. FTA, 2013.**

This document provides a practical guide for the use of FTA's Transit Economic Requirements Model Lite ("TERM Lite"). TERM Lite is an electronic tool designed to help agencies estimate their transit capital investment needs over a specified future time period. The guide provides information on what is needed for use, how to input asset inventory data, and how to utilize the TERM Lite model. This model can be a helpful analysis tool for use in development of the Transit Asset Management Plan (TAMP) (e.g., to develop deterioration models—Step 2.2 in Chapter 2 of this guidebook). The Quick Start Guide also includes an Asset Classification list, which can serve as a framework for agencies building a capital asset inventory (Step 1.1 of the TAMP, see Chapter 2 of this guidebook for more detail).

This document is available at the following URL (accessed June 2014): http://www.fta.dot.gov/documents/TERM-Lite_v2.0_Quick_Start_Guide.pdf

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation