TERM
Transit Economic Requirements Model

User's Guide

Prepared for

Federal Transit Administration
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CHAPTER 1 - INTRODUCTION

The FTA Transit Economic Requirements Model (TERM) is a PC based computer application designed to estimate the nation's transit capital investment needs over an extended time horizon. The model estimates the total amount of annual capital expenditures required over a twenty-year period to maintain or improve the physical condition and performance of the nation's transit infrastructure. These annual expenditure estimates are provided for each of three major capital investment categories — (1) asset rehabilitation and replacement, (2) asset expansion, and (3) performance improvements — and are further subdivided by transit mode, asset type (e.g., vehicles, stations, structures, etc.) and urbanized area characteristics (e.g., size, FTA region). The model output also includes estimates of the physical condition of the nation's transit asset base — both for the current year and for a 20-year forecast period. Asset condition forecasts are directly impacted by the asset condition replacement policies applied by the user. Finally, TERM also estimates both the current and projected future changes in deferred investment or "state-of-good-repair" (SGR) backlog. The latter represents the level of investment required to bring the nation's transit assets to SGR by replacing all assets that have exceeded their useful life and also by addressing all rehabilitation activities known to be past due.

TERM's design allows the user to control a wide range of model input parameters (e.g., asset replacement and rehabilitation assumptions, financial assumptions and benefit–cost parameters) to facilitate the analysis of a wide range of investment scenarios.

BASIC MODEL FEATURES

The current TERM application consists of the following model features and characteristics:

PC Based Application: TERM was developed using Microsoft Access software and is designed to run on a standard personal computer.

Menu Driven User Interface: The model features a menu driven user interface. This interface allows the user to easily adjust all model parameters, edit model input files (data tables), run scenarios, print reports, and conduct user-defined query analyses.

Model Database: TERM includes a detailed database documenting a wide range of transit related data required to perform model computations. The model includes the following data tables:

- *UZA Demographics* — population and employment levels and growth rates for over 300 of the nation's largest urbanized areas
- *Agency–Mode Statistics* — current service levels (revenue miles), ridership, operations and maintenance (O&M) costs
- *National Asset Inventory* — a listing of all the transit assets (e.g., vehicles, stations, facilities, etc.) owned and operated by the nation's transit operators,

including each asset's type, acquisition date, purchase cost, mode and rehabilitation history (if available)

- *Asset Types* – a list of transit assets by type as well as the replacement cost and decay rate for each
- *Transit Cost–Benefit Parameters* — benefits of transit investment on a trip mile basis.
- *Transit Mode Characteristics* — average speeds, headways, fares, capital costs
- *New Starts Development Periods and Costs* (by mode)

User Defined Investment Scenarios: TERM allows the user to create a wide range of capital investment scenarios and analyses. For example, the user can evaluate the impacts of variations in asset rehabilitation and replacement polices, budget constraints, inflation rates, discount rates, and other input parameters on annual expenditure levels and future asset conditions. Model outputs can be disaggregated according to mode, asset type, population strata, UZA code, state or FTA region.

Pre-Defined Output Reports: TERM features a number of pre-defined output reports, including:

- *Average Annual Expenditures by Mode (20 years)*
- *Average Annual Expenditures by Asset Category (20 years)*
- *Average Annual Expenditures by Urban Area Population (20 years)*
- *Current and Forecast Physical Conditions by Mode (20 years)*
- *Current and Forecast Physical Conditions by Asset Category (20 years)*

All pre-defined reports are easily accessed from the model's Main Menu. Special reports can also be created as required.

TERM: BACKGROUND AND PURPOSE

TERM is used by the FTA Office of Budget and Policy to estimate transit asset conditions and the dollar value amount of transit capital investment requirements for the transit sections of the "*Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance,*" a biennial report to Congress. This report provides Congress with information on the current state of the Nation's surface transportation system and estimates of the level of investment required to maintain and improve the conditions of transit assets and performance (or to attain a state-of-good-repair) over a 20-year forecast period. TERM's estimates are generated using data obtained from a variety of sources including the National Transit Database (NTD), FTA Grant documents, Metropolitan Planning Organizations (MPOs), FTA research projects, and special data requests to the nation's local transit operators.

FTA commissioned the development of TERM to improve the quality of its (and DOT's) estimates of future transit capital funding needs. FTA specifically requested a PC-based application (similar to the Highway Economic Requirements System (HERS) model used by FHWA) capable of estimating the following information:

- Current SGR Backlog, Asset Conditions and Service Performance of the Nation's Existing Transit Asset Base
- Level of Investment Required to attain specific investment objectives (e.g., maintain or improve that condition/performance; attain SGR).
- Impact of Varying Levels and Types of Investment on Future Condition, SGR Backlog and Performance
- Cost Effectiveness of transit investments based on Benefit–Cost analyses.

TERM meets each of these specifications.

INVESTMENT NEEDS MODULES

TERM uses six different analytical modules to estimate the nation's transit capital needs for the 20-year predictive period. The following briefly describes each of these modules. More detailed descriptions, including supporting calculations and data sources, are in subsequent chapters of this User's Guide.

1. ***Rehab–Replacement Module (Preservation):*** The Rehab-Replacement Module estimates the total investment required for ongoing rehabilitation and replacement of the nation's existing transit assets over a 20-year forecast horizon, including reinvestment in existing fleet vehicles, maintenance facilities, stations, guideway and trackwork, and train control and traction power systems. This module combines a detailed inventory of all US transit assets with a set of asset-specific decay curves to determine when individual transit assets in the inventory will require rehabilitation or replacement over the 20-year forecast period. The model then records these expenditures in a tally of national transit capital needs.

   Users can manipulate module inputs – including budget constraints and replacement condition thresholds (i.e., the condition rating at which assets are replaced) to assess the level of investment required to attain specific reinvestment objects (e.g., including modeling of the long-term impacts of current levels of transit capital reinvestment) This module's asset decay relationships also permit analyses both of the current condition of the nation's transit assets and how that condition can be expected to change in the future as determined by alternate replacement strategies and funding scenarios.

2. ***Asset Expansion Module (Maintain Performance):*** The asset expansion module estimates the level of investment in new, expansion assets that will be required to maintain the quality of existing transit services given projected growth in travel demand. This module first estimates the rate of growth in transit vehicle fleets required

to maintain current vehicle occupancy rates given a projected growth rate in unlinked passenger trips (UPT) by mode, FTA region and population stratum. This module also invests in the expansion of other assets needed to support projected fleet growth. These latter investments include maintenance facilities, and, in the case of rail systems, additional route miles made up of guideway, trackwork, stations, train control and traction power systems. Asset expansion investment needs are assessed for all agencies reporting to NTD by mode. Note that TERM does not invest in asset expansion for those agency-modes whose current ridership is well below the national average (specifically, where riders per peak vehicle is more than one standard deviation below the national average).

3. ***Reduce Crowding Module (Improve Performance):*** The Reduce Crowding Module is one of two modules designed to estimate the level of investment required to improve transit service standards to a target level. The module identifies local agency-modes with a high vehicle occupancy or "crowding," i.e., high ridership per peak vehicle relative to the national average for that mode. This module invests in additional fleet capacity as needed to reduce peak vehicle crowding in these agency- modes to an acceptable level of service standard defined as the national average of riders per peak vehicle plus one standard deviation. If the increase in fleet size is sufficiently large, this module will also invest in additional expansion assets such as maintenance facilities and, for rail systems, additional route miles (including guideway, trackwork, stations, train control and traction power systems).

4. ***Increase Average Speed Module (Improve Performance):*** The Increase Average Speed Module is the second of the two improve performance modules. This module is designed to identify urban areas with average transit operating speeds that are well below the national average. This module then estimates the minimum required investment in a high-speed transit mode (i.e., HRT, LRT, or BRT) required to reach a minimum performance standard, defined as the national average operating speed less one standard deviation. The determination of which high-speed mode to invest in is based on (1) which high-speed mode(s) already exists in the UZA or (2) if there is currently no high-speed mode in the UZA, TERM selects a preferred mode of investment based on UZA size (e.g., UZA's under one million get BRT while larger UZA's get LRT). Finally, as with the asset expansion module, TERM does not undertake speed-improving investments in UZA's with low ridership.

5. ***Benefit-Cost Module 1 (Asset Preservation and Expansion to Maintain Performance):*** This module assesses the cost-effectiveness of investments proposed by the Rehab-Replacement and Asset Expansion Modules. More precisely, it compares the discounted stream of costs associated with the ongoing operations of each local agency-mode identified in NTD (including costs for rehab-replace, asset expansion and agency O&M costs) with the discounted stream of projected benefits to riders and society from the continued operation of that mode. If the projected benefits exceed the projected costs, then TERM includes the rehab-replacement and expansion needs estimates for that agency-mode in the tally of national investment

needs. If the projected costs exceed the projected benefits, TERM gives the agency-mode a "second chance" by removing the costs and benefits of asset expansion and retesting to see if the agency-mode is cost-effective on the basis of the rehab-replacement investments only. Once again, if the projected benefits exceed the projected costs, TERM includes these rehab-replacement needs (but not the asset expansion investments) in its tally of national investment needs. If both benefit-cost tests are failed, TERM enters a third and final stage of analysis called a "partial" benefit cost test. Under this test, a proportion of the reinvestment needs for agency-modes that fail the benefit-cost test are forced to pass the test (i.e., assigned a B/C ratio of 1.0), with that passing proportion determined by the initial B/C ratio. Hence, agency-modes with B/C ratios less than but close to 1.0 will still have most of their reinvestment needs met (or at least assigned a B/C value of 1.0). In contrast, agency-modes with B/C ratios close to zero would have little or none of their reinvestment needs added to TERM's national tally of reinvestment needs. Note that agency-mode assets assigned a finally B/C ratio of less than 1.0 are still assumed to be operated into the future, they are not, however, assumed to be replaced.

6. ***Benefit-Cost Module 2 (Improve Performance***): This module assesses the cost-effectiveness of investments proposed by TERM's two performance improvement modules (i.e., reduce crowding and increase average speed). Benefit-Cost Module 2 assesses the cost-effectiveness of "improve" performance investments as single, stand-alone projects, without reference to the overall cost effectiveness of the local agency-mode likely to operate that investment. This in contrast to Benefit-Cost Module 1, which assesses the cost-effectiveness of continued investment in and operation of an existing local agency-mode. (Alternatively, Module 1 is focused on rehab-replacement and modest expansions of existing agency-modes while Module 2 focuses on major "New Starts" investments.)

CURRENT AND FORECAST PHYSICAL CONDITIONS

TERM's database includes a set of over fifty different statistically estimated decay curves, each designed to estimate the current (and future) physical condition of a different asset type based on its age, utilization and maintenance history[1]. As previously noted, TERM uses these decay curves to determine those points in the asset life cycle (i.e., condition ratings) at which assets will require rehabilitation and ultimately replacement within the Rehab-Replacement Module.

Beyond merely determining *when* the individual assets recorded in TERM's asset inventory will require replacement, these asset decay curves are also used to evaluate the *current physical condition* of the nation's transit assets. Given that each of TERM's decay curves use the same condition rating scale (see **Exhibit 1-1**), the condition ratings

[1] Note: While all decay curves include age as a condition determinate, utilization and maintenance history were not found to be statistically significant for all asset types. Here utilization is captured by such measures as passenger boardings, vehicle miles and service hours while maintenance history is captured by either maintenance costs or maintenance staffing hours.

assigned to each individual asset type can be aggregated across broad groupings of assets regardless of type. This allows TERM to generate overall measures of average asset condition for whole asset categories (e.g., vehicles or facilities), for individual transit agencies, FTA regions, and all transit assets nationwide.

Finally, in addition to providing estimates of the *current* physical condition of the nation's transit infrastructure, TERM also provides *forecasts* of how these conditions can be expected to change over a twenty-year forecast period. It is this capability that allows TERM to run the "maintain" and "improve" conditions scenarios. Under the "maintain" conditions scenario, TERM estimates the current physical condition of the Nation's transit assets. The user then iteratively (by trial and error) adjusts the replacement thresholds for five asset categories (guideway, facilities, systems, stations and vehicles) until the aggregate condition for these categories at the end of the model run is equal to their starting condition thus, on average, "maintaining conditions". Under the improve conditions scenario, the user adjusts the replacement thresholds for the five asset categories until it attains an overall condition rating of "good" (or 4.0). This process is described in Chapter 7 of this User's Guide. The replacement threshold is the condition level, chosen by user, below which aging assets are retired and replaced.

Exhibit 1-1
Asset Condition Rating Scale

Rating	Condition	Description
5.0 to 4.8	Excellent	No visible defects, near new condition
4.0 to 4.7	Good	Some (slightly) defective or deteriorated component(s)
3.0 to 3.9	Adequate	Moderately defective or deteriorated component(s)
2.0 to 2.9	Marginal	Defective or deteriorated component(s) in need of replacement
1.0 to 1.9	Poor	Critically damaged component(s) or in need of immediate repair

The asset decay curves that support these condition estimates were developed using data from three primary sources. Asset decay curves for bus and rail vehicles, maintenance facilities, and stations are based on data from on-site asset condition assessments performed at a statistically valid sample of transit agencies across the country, collected specifically to support the estimation of transit asset conditions by TERM. Decay curves for all other asset types except trackwork were obtained from a detailed, Engineering Condition Assessment (ECA) study completed for the Chicago Transit Authority (CTA) in the early nineteen nineties. Decay curves for trackwork assets were estimated using information gleaned from a 2008 workshop with a number of track engineers from the Nation's largest transit agencies.

FTA is working to replace the older CTA ECA data with data collected specifically for TERM with statistically valid on-site surveys. *Both the data sources and the process used to estimate the decay curves used by TERM are considered in detail in the chapter on the Rehab-Replacement Module.*

CONSTRAINED AND UN-CONSTRAINED MODEL RUNS

TERM was initially intended to be run to yield "unconstrained" estimates of national transit investment needs, i.e., where expenditures are unconstrained by existing funding capacity. However, it has also been designed to estimate transit investment backlogs, conditions, performance under the assumption that capital expenditures in future years are constrained to reflect funding realities. Specifically, a "constraint" feature allows the user to limit the annual level of funding available for rehabilitation and replacement activities.

The primary benefit of the constraint feature is to allow the user to compare and evaluate the likely impact of different capital funding scenarios on the future investment backlog and asset conditions. This capability allows the user to determine, for example, whether a continuation of recent transit capital reinvestment rates will likely lead to either an improvement or worsening the investment backlog or overall asset conditions. When funding is constrained, asset replacement is delayed, average asset ages increase, and aggregate asset conditions will likely be lower than if conditions were maintained or improved.

To constrain investment expenditures for expansion activities to "maintain or improve performance," the user must manipulate the input parameters for the related investment modules, as discussed in Chapter 2).

TERM DATABASE

TERM's asset investment needs modules rely on a broad range of input data. These data are stored in data tables and housed in a common relational database. The following is a brief summary of the more important data tables used by TERM. More detailed descriptions of all TERM data tables are provided in later chapters as they relate to the analyses they support.

Static Input Tables: TERM's static input tables are the foundation of all of the model's investment needs analysis. These tables are "static" in the sense that the user does not alter their contents from one model run to the next. Key static input tables include:

- <u>Asset Inventory:</u> This table contains detailed asset inventory records documenting all assets used by the nation's transit operators. These records contain each asset's type, mode, owner/agency, age, date of fabrication, acquisition cost, and quantity. These inventory data are derived from NTD data, from agency submissions to FTA asset inventory data requests and from special FTA studies (e.g. FTA Light and Heavy Rail Costs Studies (2004) and the FTA Rail Modernization and Bus Facilities studies (1991)). This table is the primary data source for the data used by TERM's Rehab and Replacement Module.

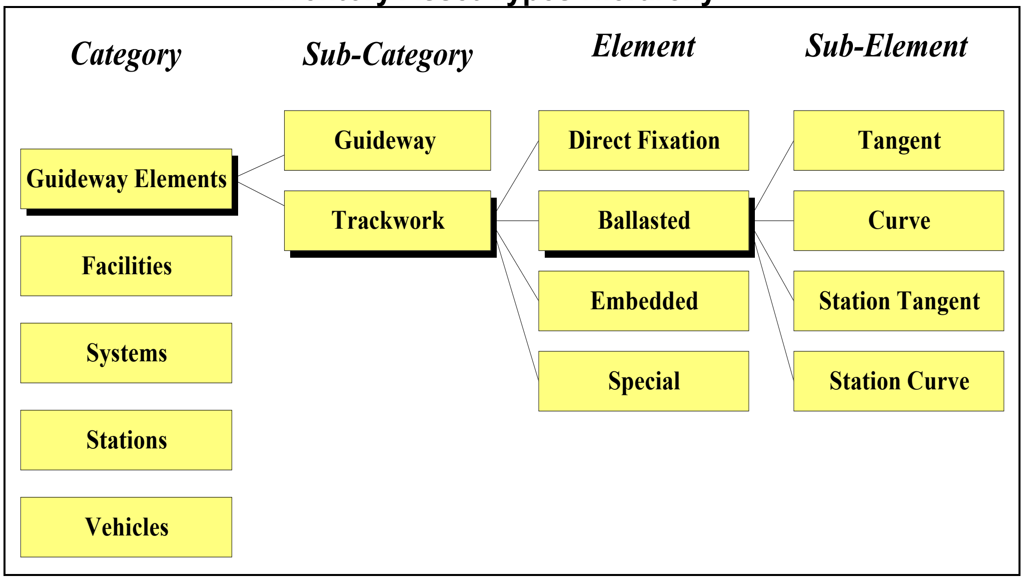
- UZA Demographics: This table contains demographic data for over three hundred of the nation's largest urbanized areas. For each urban area, the table includes the UZA Code, local MPO(s), population level and growth rate, employment level and growth rate, state(s) in which the UZA is located, the population stratum of the UZA, area served (in square miles), current levels of vehicle miles traveled (VMT) levels and projected growth rates, and current levels of transit passenger miles traveled (TPM) in each UZA and the projected TPM growth rates. The TPM growth projections are the primary input used to estimate transit asset expansion investment needs.

- Agencies: This table documents basic characteristics of all public transit systems identified in NTD, including their name, FTA identification code, location (city, state, UZA, and FTA region), and the population strata to which they belong. Data in this table are obtained from NTD.

- Agency-Mode Statistics: This table contains detailed agency operations and maintenance statistics by agency-mode. Specific table fields document the level of transit service consumed and supplied in recent years (more specific), and the level of maintenance applied to each agency's asset base (by mode). This table provides crucial input data to (1) estimate which transit agency-modes are candidates for performance improvement investments and (2) support the cost and benefit analysis of future investments in agency-modes (i.e., rehab-replace, expansion and performance improvement). The data in this table come from NTD.

- Asset Types Files: This table identifies all the types of assets owned and operated by the Nation's public transit systems with one record for each type of asset (see Exhibit 1-2). For each asset type, the table includes data fields for asset unit replacement cost, rehabilitation cost, rehabilitation life expectancy, and acquisition cost inflation factors used to convert asset replacement values to year preceding the twenty-year forecast period. This table also documents some of the asset decay relationships used to estimate asset condition on the basis of age, maintenance, and usage. The table is constructed in a hierarchical format (**Exhibit 1-2**) so that asset inventory data collected from agencies can be assigned the most accurate asset type code.

Exhibit 1-2
Inventory Asset Types Hierarchy



- Benefit-Cost Measures: This table documents the benefits (or cost reductions) associated with increased transit investment. These measures include transit rider values (e.g., value of time and links per trip), auto costs per VMT (congestion delay, emissions costs, and roadway wear), and auto user costs (auto depreciation, insurance, fuel, maintenance and daily parking costs). This table is presented in Appendix B.

- Mode Types: This table provides data on transit operations (average speed, average headway, and average fare) and estimates of typical ridership fare elasticities (i.e., the responsiveness of riders to changes in fares, by transit mode). Similar data are included for non-transit modes (e.g., private auto and taxi costs). (An artificial mode designation "SY" is used to identify system or agency assets — such as office furniture and computers — utilized by multiple transit modes. This table is presented in Appendix B.

- New Starts Modes: This table provides estimates of the average length of each New Starts project development phase, the share of total costs devoted to each phase, the average unit costs by investment category (e.g., vehicles, guideway, stations, soft costs, etc.), and O&M costs on a "per mile invested" basis. These data are used by TERM to estimate the costs and benefits associated with performance improvement investments (on a mode-by-mode basis). Estimates of the average length of each development phase and share of total costs devoted to each phase are based on the project development schedules as documented in the New Starts submissions for a sample of US transit capital investments completed over the past fifteen years. Capital cost data for this analysis were obtained from FTA's Light and Heavy Rail Capital Cost Study Updates. Operating cost and related data were derived from NTD.

Tables with User Defined Input Parameters: The following tables contain parameter data that can be modified by the user between model runs to develop and evaluate alternate investment scenarios.

- Investment Policy: This data table contains the physical condition ratings used as thresholds to determine when assets will be replaced. (Unique thresholds may be chosen for each of the following asset categories: guideway elements, facilities, systems, stations, and vehicles).

- Financial Assumptions: This data table contains user's choice of inflation assumptions (real or nominal dollars) and discount rate.

Output Tables: The following tables provide the model output generated by TERM:

- Investment Needs Forecast: This data table provides TERM's estimates of all projected investment needs disaggregated according to investment type, i.e., rehabilitation and replacement, asset expansion to maintain and asset expansion performance improvement. The table includes one record for each asset documented in TERM's asset inventory. The table also includes TERM's estimates of the physical conditions for all assets identified in the Asset Inventory table for the base year and for each year of the twenty-year forecast period. It also provides the benefit-cost ratios associated with each investment type. Finally, this table also includes a projected value of the SGR backlog for each asset record included in the forecast.

- Asset Expansion Investment Forecast: This table provides TERM's estimates of the asset expansion needs for each year of the twenty-year forecast period. Output is segmented according to agency, mode, and year of investment. The output from this table is transferred to the Investment Needs Forecast table and included in the twenty-year investment needs forecast.

- Performance Needs Forecast: This table provides estimates of the projected capital investment needs that will be required to meet performance improvement objectives. These forecasts are derived from TERM's Performance Enhancement modules. This information is ultimately transferred to the Investment Needs Forecast table.

- Cost–Benefit Replace: This table provides the results of TERM's cost-benefit analyses of the continued operation of each individual transit agency-mode. The output from this table is transferred to the Investment Needs Forecast table.

THE USER'S GUIDE

The purpose of the User's Guide is to provide a comprehensive understanding of TERM, including the theoretical underpinnings of the model, its structure, its data requirements and step-by-step instructions on how to use and maintain it.

To achieve these objectives, the guide is divided into 7 chapters. This first chapter is intended to provide a general overview of the model's purpose and design. Chapter 2 describes the Rehab-Replacement Module and its methodology for modeling the asset utilization, decay, retirement and replacement problem. This chapter also describes the data sources used to support this process, including primary research conducted specifically to support TERM. Chapter 3 describes the Asset Expansion Module, the model component used to assess investment requirements for fleet and facilities expansion to meet projected transit passenger growth. This includes discussion of projection techniques and growth forecast data sources. Chapter 4 describes the Performance Improvement Modules used to identify specific rail and bus investments that would serve to mitigate existing constraints on service performance for specific agencies and urban areas. Chapter 5 fully describes the benefit-cost tests used by TERM to assess the cost effectiveness of all investments proposed by the Rehab-Replacement, Asset Expansion and Performance Improvement modules. Chapter 6 describes the flow of calculations performed by TERM as it passes sequentially through each investment module and then evaluates investments using the Benefit-Cost Modules. Finally, Chapter 7 documents how to use the TERM model including update requirements and how to navigate the user interface.

CHAPTER 2 - REHAB-REPLACEMENT MODULE (PRESERVATION)

INTRODUCTION

TERM's Asset Rehab-Replacement Module is designed to estimate annual funding needs for ongoing rehabilitation and replacement of the Nation's existing transit assets. Specifically, these needs include:

- Elimination of any investment backlog ("deferred investment")
- Normal replacement of assets reaching the end of their useful life
- Mid-life rehabilitations
- Annual capital expenditures (covering all smaller capital costs)

TERM estimates these needs for each year of a twenty-year forecast period (investment backlog is provided as the estimate of capital needs as of January 1 of the starting year of each model run). TERM is then capable of reporting these needs by mode, asset type, local agency, UZA, state and/or FTA region.

ASSET DECAY SIMULATION: OVERVIEW

TERM's estimates of capital needs for asset rehabilitation and replacement are generated by simulating the future asset life cycle needs of all existing US transit assets — including each asset's use, maintenance, rehabilitation, decay and eventual retirement. The foundation of this analysis is a detailed inventory of all assets currently owned and operated by the nation's urban transit agencies. TERM also houses a set of mathematical decay curves, each constructed to predict the physical condition of a different transit asset type based on that asset's age, maintenance and utilization. Putting together the asset inventory and the asset decay relationships, TERM can estimate the current physical condition of all US transit assets and predict which assets will require rehabilitation and/or replacement (and at what point in time) over the next twenty years. Finally, by tallying these rehab and replacement needs across all assets recorded in the asset inventory, TERM can generate a year-by-year, national level forecast of transit capital re-investment needs.

The following sections provide more detailed descriptions of TERM's national inventory of transit assets and of the decay curves used to simulate life cycle costs for those assets (including their supporting data sources). The text then goes on to provide a detailed description of the specific algorithms used to simulate asset decay and to generate TERM's rehab-replacement needs estimates.

ASSET INVENTORY

TERM's relational database includes an asset inventory designed to document all capital assets owned and operated by the nation's 600 plus urban transit operators and more than 1,000 rural operators. Each inventory record provides descriptive data for a specific transit asset (e.g., vehicle, station, track segment), including that asset's type, acquisition date, purchase cost, quantity, owner agency and mode. Depending on the level of detail provided to FTA by the owner agency, the asset record may also include data on the asset's physical location (e.g., garage or rail line) or other asset description data. The asset inventory also documents the data source for each asset record and the year the data were obtained. Finally, each inventory record is assigned a unique asset ID number. As of January 2019, TERM's asset inventory included more than 50 thousand asset records[2]. The data structure of TERM's asset inventory records is presented below in **Exhibit 2-1**.

Exhibit 2-1
Asset Inventory: Data Structure (tbl06AssetInventory)

Field Name	Data Type	Description
Asset ID Number	Numeric	Unique Asset ID Code
Agency ID Code	Numeric	FTA Transit System ID Code
Agency	Text	Agency Name
Garage/Segment/Line	Text	Asset Location
Mode Code	Text	Two letter FTA abbreviation
Description	Text	Asset Description
Asset Type Code	Numeric	Identifies Asset Type
Category	Text	Guideway, Facilities, Systems, Stations or Vehicles
Sub-Category	Text	Descriptive Data (e.g., track)
Element	Text	Descriptive Data (e.g., ballasted)
Sub-Element	Text	Descriptive Data (e.g., curve)
Quantity	Numeric	Quantity Owned and Operated
Units	Text	Unit of Measure
Date Built	Numeric	Date Asset Was Built/Acquired
Rehabilitated	Yes/No	Has Asset Been Rehabilitated?
Unit Replacement Cost	Numeric	Unit Cost to Replace Asset
Total Replacement Cost	Numeric	Total Cost to Replace Asset
Data Date	Date	Year Data Were Obtained
Data Source	Text	Data Source

[2] TERM's inventory records have been grouped both to reduce model file size (conserve memory) and, more importantly, to reduce model run times. Specifically, asset records have been grouped such that all records of the same asset type, age, mode and owner (local agency) have been consolidated as a single asset record (note that this grouping sums unit quantities and replacement costs across all "like" records). In the absence of such grouping, TERM's asset inventory would include more than 150,000 records and model run times would more than triple.

Inventory Development and Maintenance — Data Sources

As of January 2019, FTA is in the process of implementing the Asset Inventory Module (AIM) of NTD, a new reporting requirement that is expected to become the source of most, if not all, asset inventory data for TERM going forward. However, while urban and rural operators have now provided their initial submissions to AIM (as of October 2018), this remains a new reporting requirement and the reported data are not yet of sufficient quality to support investment needs analysis within TERM. That said, FTA has developed a process to pull and modify data directly from AIM for use in TERM (as described in detail below).

Until such time as AIM data are deemed ready to support analysis within TERM, FTA will continue to conduct analysis using asset inventory data from the three primary data sources:

- Inventory data requests to large operators
- NTD fleet vehicle data
- FTA research studies

Each of these sources is considered in detail:

Inventory Data Requests (large agencies only): Operators of the nation's larger transit agencies, including all major rail agencies, are periodically requested to submit an electronic inventory of all physical assets currently used in support of revenue service (excluding revenue vehicles, which are obtained from NTD)[3]. These agency submissions constitute the largest, most important source of non-vehicle asset data included in the inventory. Agency submissions are initiated via a letter from FTA headquarters requesting an electronic inventory of all non-revenue vehicle assets. Upon receipt of this data, each agency submission is first checked for completeness and data quality. To be complete, individual submission record must include each asset's type, date built and one of either the replacement cost or number of units (e.g., track feet). To be comprehensive, a submission must document all asset types, in sufficient quantity, as required to support agency-mode operations. Submission comprehensiveness can be checked using basic NTD metrics that help define agency size; including station counts, total track miles and number of maintenance facilities). The inventory data are converted from the data structure used by the submitting agency to the one used by TERM. This step requires matching and assigning each asset record submitted by an agency to one of the 400 plus asset type codes recognized by TERM (see Asset Types File below). The final step is to substitute this new data in place of the old asset inventory data for that agency. In some instances, some portion of the older asset records for that agency may need to be retained

[3] On average, agency submitted asset inventory data should be updated roughly every five years. More frequent updates do not provide sufficient improvement or change to TERM's needs predictions to warrant their expense.

(e.g., if the new submission is not comprehensive of all agency assets: for example, if investment in train control systems is missing).

National Transit Database Revenue Vehicle Data: All urban and rural transit operators receiving federal funding assistance are required to submit a current listing on their revenue vehicle fleets as part of their annual submission to the National Transit Database (NTD). This fleet data (provided on Form 408) identifies all of the agency's revenue vehicles including their type, mode, acquisition date, quantity, seating capacity, model number and manufacturer. Given the high quality and annual frequency of this data, NTD data represent the only source of revenue vehicle inventory data used by TERM. In addition, TERM's asset inventory records include all revenue vehicles reported to NTD including those in directly operated service and contracted service, as well as those currently undergoing long-term repairs or rehabilitation. It is important that TERM's needs estimates be inclusive of all vehicle investment needs, not just those currently available for revenue service.

- *Classification of Bus Vehicle Types:* Prior to 2002, NTD vehicle data for buses were reported based on seating capacity and NTD's bus vehicle codes reflected this practice (AB for articulated bus, BA for buses with more than 35 seats, BB for buses with 25-35 seats and BC for buses with less than 25 seats). TERM used these four classifications to report bus conditions and replacement needs (with differing unit costs for each). Beginning in 2002, NTD consolidated all non-articulated buses into a single bus type, "BU" but also began to report the size (length) of all bus vehicles. TERM now uses the reported length data to group bus vehicles into five length categories (60 foot for articulated or AB, 40 ft = BA, 35 ft = BB, 30 ft = BC and 25 ft or less = BD). These new length groupings conform more closely to the available data on bus vehicle costs and hence represent an improvement in TERM's needs estimates for buses.

FTA Research Studies: In addition to data supplied directly from owner agencies or indirectly through NTD, asset inventory data for TERM have also been obtained from FTA research studies. Over the past decade or more, FTA has completed several studies that have yielded transit asset inventory listings as a study product (typically for a small sample of agencies or asset types). These studies represent a valuable source of inventory data for those agencies that have not responded to direct requests for data or where the data submitted have proven incomplete or of insufficient quality. As a general rule, TERM development staff have taken the position that it is preferable to rely first on data obtained from direct agency submissions over that provided from these one-time studies. Following are descriptions of those FTA studies used to support creation and maintenance of TERM's transit asset inventory.

- *NTD Asset Condition Module (ACM):* Over the period 2000 through 2002, FTA ran a beta test (i.e., pilot or test run) of the Asset Condition Module. The aim of project was to test the feasibility of asking urban transit agencies to report their asset inventory data (including asset condition data) as part of their NTD submission. The beta test of the ACM provided asset inventory data for a broad sample of US transit operators, including numerous smaller, bus only operators. This data proved valuable in filling holes in agency submitted data and in understanding the size, age and replacement costs of non-vehicle assets operated by the nation's smaller agencies (the latter being too small and numerous for direct requests for inventory data).

- *Light and Heavy Rail Capital Cost Studies:* In 2004 FTA's Office of Program Management updated two-decade old studies of the capital costs of light and heavy rail transit projects completed since 1970. These data document the unit quantities, purchase costs, asset types and date-built values for over twenty different light rail projects and close to thirty different heavy rail investments. These data are available in a data format close to that used by TERM.

- *FTA Rail Modernization Study (rail only):* This source provides high level descriptive data on the nation's rail transit assets as they existed in the late nineteen eighties. This source was used both to back-up and confirm the quality and content of data obtained from other data sources. This source also provided data on initial service dates of most rail systems. The data from this study continues to be used by TERM to generate asset records for those rail agencies for which TERM staff have been unable to acquire inventory data or where the agency's data are incomplete (see Generation of Inventory Records for Missing Asset below).

- *FTA Bus Facilities Study (bus only):* This study has been used as a primary source for documenting the existence and age of the Nation's transit bus facilities. Data from this study have been supplemented and validated using data derived from the NTD and from the other FTA studies described above.

- *FTA Transit State of Good Repair Study:* This report, completed in December of 2009, provides a discussion of the condition and capital reinvestment needs of most of the Nation's twenty largest transit operators.

Pulling Data from NTD AIM for Use in TERM

In January 2019, TERM was modified to include a GUI-driven process to pull raw data from AIM directly into TERM. This process includes a detailed set of business rules (shown below) designed to convert AIM asset records into TERM asset records (as documented in tbl06AssetInventory). This data pull and conversion process is completed as follows.

- Step 1: The user must first obtain the most recently available AIM data from NTD. The data must be obtained in CSV format (stored in an Excel file).

- Step 2: From TERM's Main Menu, click the "AIM Import" button located in the "Run Model" section of the form.

- Step 3: Select an AIM template to pull data from. AIM currently consists of four templates, each housing asset data for different asset types, each with its own business rules for conversion to the TERM inventory format (A15 – Facilities and Stations; A20 – Guideway and Systems; A30 – Revenue Vehicles; and A35 – Non-Revenue Vehicles). Upon selection of an AIM template, TERM will open the document library on your computer. You must next select the Excel file housing the data for your selected template and click OK. TERM will inform you when the import process is complete. If the import code determines there are any issues with individual records (e.g., key fields are not populated), TERM will exclude these records from the import process and document their exclusion in an AIM template specific data table. Complete the import process for all 4 AIM templates.

AIM to TERM Record Conversion: Business Rules for Template A20

While conversion of asset records from the NTD AIM to TERM-compatible format is fairly straightforward for most AIM templates (A15, A30 and A35), the process is complicated for data stored in template A20 (guideway and systems asset types). For example, the AIM records for tunnels and bridges in A20 represent many individual assets of varying ages – data which need to be converted to multiple individual asset records for use within TERM. To address this issue, FTA has developed clear business rules to convert A20 asset records into inventory records that can be processed by TERM. These business rules are documented in **Exhibit 2-2** below.

Exhibit 2-2
Business Rules for AIM Template A20 to TERM Record Conversion

ElementName	Group	Number of Records	Date Built (Start year is NTD data yea	Unit Quantity
At-Grade/Ballast (including expressway)	A	1) Convert decade built distribution to year built records (ten records per decade)	1) For Pre-1930 records, set start year to [Service Inauguration Year] in tbl03AgencyMode	0) First convert values recorded in "Percent" units to track miles (will need data from either tbl03AgencyMode or NTD "Track and Roaway" table) 1) Unit quantity for each record = total linear miles / number of records
At-Grade/In-Street/Embedded				
Elevated/Retained Fill				
Elevated/Concrete				
Elevated/Steel Viaduct or Bridge				
Below-Grade/Retained Cut				
Below-Grade/Cut-and-Cover Tunnel				
Below-Grade/Bored or Blasted Tunnel				
Below-Grade/Submerged Tube				
Substation Building	B	2) One record for each asset substation count (e.g., if count = 15, then generate 15 asset records)	2) Assume mid-point of decade built	2) Unit quantity = count
Substation Equipment	C		2a) Assume mid-point of decade built for subsation	3) Unit quantity = number of substations
Third Rail/Power Distribution	D	3) One record for each year from age = 0 to age = 1.25*[Age250] years (divisable as quantity based on track miles)	3) Uniform distribution of ages across the records for age = 0 to age = 1.25*[Age250] years (divisable as quantity based on track miles) i) Date built cannot be less than the [Service Inauguration Year] in tbl03AgencyMode	4) Unit quantity = total track miles (from 15 Tangent, 16 Curve, 17 non-revenue service track and 18 Revenye Track - No Capital respnsibility)
Overhead Contact System/Power Distributio				
Train Control & Signaling				
Tangent --Revenue Service	E			5) Reported track miles / number of records
Curve -- Revenue Service				
Non-Revenue Service				
Revenue Track - No Capital Replacement Res				
Double Diamond Crossover	F	2) One record for each asset count (e.g., if count = 15, then generate 15 asset records)	4) Random age/date built for each asset record (assume assets are from 0 to 1.25*[Age250] years of age i) Date built cannot be less than the [Service Inauguration Year] in tbl03AgencyMode	2) Unit quantity = count
Single Crossover				
Half Grand Union				
Single Turnout				
Grade Crossings				

Generation of Inventory Records for Missing Assets (Pre-AIM)

While the pre-ND AIM sources of asset inventory data outlined above represent the then best available, they did not provide a comprehensive listing of all US transit assets. For example, there were many instances where larger agencies were unable to respond to FTA requests for a detailed asset inventory or where the inventory data submitted were either incomplete or of insufficient quality. Similarly, with the exception of NTD vehicle data, the pre-AIM data sources described above only provided data for a nation's larger transit operators. Hence these sources did not cover the more than 400 small urban transit agencies operating nationwide (given their small size and large number, the nation's small size transit operators have not been requested to submit asset inventory data for use in TERM)[4].

Given these limitations, there was a measurable proportion of US transit assets that remained un-documented within TERM using the pre-AIM primary data collections sources identified above. As of August 2019, AIM data are still preliminary and hence current TERM analyses are still dependent on these pre-AIM sources of inventory data. It has been estimated that these undocumented assets represent roughly one-quarter of all US transit assets by replacement value. It is obvious then that a failure to somehow

[4] Small operators typically consist of a small bus fleet of thirty vehicles or less and a single maintenance facility. Most small agencies locate their administrative offices within an existing maintenance facility.

account for these "missing" assets would yield rehab and replacement needs estimates that are significantly below the nation's actual replacement needs.

To address this issue, TERM includes a module that generates artificial asset records for each U.S. agency that lacks a complete inventory listing. Specifically, this module is designed to generate asset records for all non-vehicle assets for which data have not been provided by the owner agency (either directly or through an FTA study) or where the inventory data provided were incomplete (do not cover all asset types) or of poor quality.

The asset record generation process works as follows:

First, a list of "minimum" assets are generated for each agency mode identified in NTD, founded on the principle that each transit mode must include a core set of asset types without which mode operations would be infeasible (e.g., a rail system must have trackwork, train control, stations, etc.). Having identified the minimum asset types for each agency mode, the user must use secondary data sources to quantity these generated assets. Here, the best data source is NTD, which currently provides the number of route miles, track miles, crossings, maintenance facilities and stations for all US transit agencies by mode. The specific NTD data table used to scale the number of generated assets by asset category is presented in **Exhibit 2-3** below.

Exhibit 2-3
NTD Data Used to Scale Holdings of Missing, Non-Vehicle Assets

Asset Category	NTD Table
Guideway Elements - Rail Guideway - Bus Guideway - Grade Crossings - Trackwork	Transit Way Mileage (by grade type) - Directional route miles - Lane miles - Number of Crossings - Track mileage
Facilities - Administration - Maintenance	Maintenance Facilities - Assume 1 per rail system - Maintenance facility count by size
Systems - Train Control, Electrification, Communications - Control Center	Transit Way Mileage - Track Mileage - Assume 1 per rail system
Stations - Stations - Elevators / escalators	Passenger Stations - Total Stations (by grade type for rail systems) - Total elevators / total escalators

Trackwork and guideway assets are generated down to the grade type level based on the track mileage by grade type data provided in NTD (At-grade Exclusive, At-Grade Crossings, At-Grade Mixed Traffic, Elevated Structure, Elevated Fill, Open Cut and Subway). Trackwork is assumed to be ballasted for all at-grade, elevated fill and open cut, and be direct-fix for all elevated structures and subway.

Rail stations are also generated down to the grade type level (at-grade, elevated and underground) based on the proportion of track mileage by grade type for each agency rail mode. Elevated track mileage is the sum of elevated structure and elevated fill track mileage, while underground track mileage is the sum of open cut and subway track mileage.

The units furnished by NTD for each asset category (e.g., route miles, number of stations, number of maintenance facilities, etc.) conform to those used by TERM's Asset Types File (tbl05AssetTypeData). This allows TERM to use the latter source to assign a replacement cost to each missing asset.

The second step involves comparing the list of generated assets for each agency mode and the current asset inventory list (tbl06AssetInventory). The asset lists are grouped at the [Sub-Category] level and compared based on the total replacement cost of each asset grouping[5]. Asset types missing from the asset inventory list are identified as those with no corresponding match in TERM's asset inventory (NULL inventory quantity and inventory cost value).

The final step in generating asset records is to assign date-built values to the missing asset quantities. This is accomplished by three different processes based on the asset type and whether the agency mode's service inauguration year is known.

The first process assigns date-built years to all guideway element asset types. The distribution of asset ages is determined by a uniform distribution over a number of years. The asset is distributed over the span determined by the lowest of: a) the expected replacement life of the asset, or b) the number of years the agency mode has been in service. Based on judgment of known assets and their current life spans, the expected replacement life for this evaluation is increased by 25% as a rule of thumb.

The second process assigns date-built years to facility and station elements where the agency mode service inauguration year is known. Each unit quantity of the asset is distributed based on the total quantity of assets and the span determined by the lowest of: a) the expected replacement life of the asset, or b) the number of years the agency mode has been in service. The expected replacement life used is increased by 25%.

The third process assigns date-built values to facility and station assets of agency modes where their service inauguration year is unknown. Asset records are generated for each unit quantity of the asset and the built date is assigned as a random year generated within either: a) the adjusted expected life of the asset, or b) a span of 50 years. This process

[5] The query must be designed with a directional join to identify all non-vehicle asset categories and sub-categories in the generated assets list and only those in the asset inventory list (tbl06AssetInventory) where the joined fields match.

applies a nearly uniform distribution to the generated asset records and avoids bias towards any existing distribution of asset ages.

Upon completion of this asset generation process, all newly created records for "missing" assets are entered into a separate data table within TERM, the Generated Assets data table (tbl10MissingAssetsQuantitiesTotal). Upon initiating the next TERM model run, any generated assets documented in TERM's asset inventory (from a prior model run) are deleted and replaced by the current asset listing in the Generated Assets data table.

ASSET TYPES FILE

The Asset Types File (tbl05AssetTypeData) provides a detailed listing of all asset types recognized by TERM. The current file lists over 400 different transit asset types, all grouped into a hierarchy of categories (including guideway, facilities, systems, stations and vehicles), sub-categories, elements and sub-elements (see **Exhibit 2-4**). For each asset type, the Asset Types File provides a unique asset type code, unit replacement cost, number and timing of life cycle rehabilitations, rehabilitation cost(s), unit of measure (e.g., track feet) and cost data source. In addition, this file houses the equation parameters for many (but not all) of the asset decay relationships used to generate estimates of asset conditions and replacement needs. Finally, this file also includes a variety of cost data that have rarely or never been used by TERM but are maintained in the model as a record of past work or in case the data should be required in future. These cost data include: unit cost data used in prior year TERM analyses; a percentage breakout of unit costs into their labor, material and equipment components for each asset; and actual and projected price index values for the period 1993-2030 (from FTA's 1995 Price Index Study). The data structure of the Asset Types File is presented below in **Exhibit 2-5**.

Exhibit 2-4
TERM Asset Types File: Hierarchy Sample

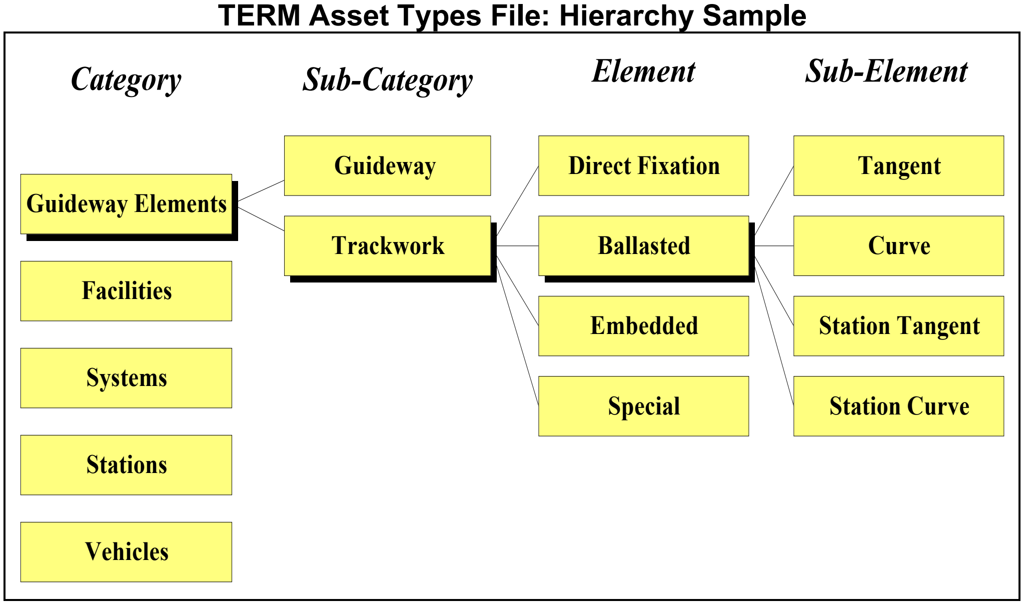


Exhibit 2-5
Asset Types Table (tbl05AssetTypes): Data Structure (Used Fields Only)

Field Name	Data Type	Description
Type Code	Numeric	Unique Asset Type Code
AIMTemplate	Text	Source of AIM Data
AIM_Legacy	Text	AIM or legacy TERM asset type?
Mode	Text	Mode Type ("all" if not specific)
Asset Description	Text	Descriptive Information
Category	Text	Guideway, Facilities, Systems, Stations or Vehicles
Sub-Category	Text	Descriptive Data
Element	Text	Descriptive Data
Sub-Element	Text	Descriptive Data
Units	Text	Unit of Measure
Unit Cost	Currency	Cost per unit
Unit Cost Year	Numeric	Year of the unit cost (e.g., $2003)
Unit Cost Source	Text	Source of the unit cost estimate
Total Replacement Cost	Numeric	Total Cost to Replace Asset
DecayCurveType	Text	Type of decay curve (functional form)
AssetCurveName	Text	Decay curve name
Logit_Constant	Numeric	Decay curve parameter: Logit function
Logit_Age	Numeric	Decay curve parameter: Logit function
Logit_Usage	Numeric	Decay curve parameter: Logit function
Logit_Maint	Numeric	Decay curve parameter: Logit function
SplineBreakPoint	Numeric	Decay curve parameter: Spline function
SplineConstant	Numeric	Decay curve parameter: Spline function
SplineSlope	Numeric	Decay curve parameter: Spline function
SplineDummy	Numeric	Decay curve parameter: Spline function
LinearLogConstant	Numeric	Decay curve parameter: LinearLog function
LinearLogSlope	Numeric	Decay curve parameter: LinearLog function
LinearLogDummy	Numeric	Decay curve parameter: LinearLog function
Rehabs Allowed	Numeric	Number of life cycle rehabs permitted (up to 5)
Rehab1Cost	Numeric	Cost of first rehab
Rehab1Cond	Numeric	Condition value when first rehab occurs
Rehab2Cost	Numeric	Cost of second rehab
Rehab2Cond	Numeric	Condition value when second rehab occurs
Rehab3Cost	Numeric	Cost of third rehab
Rehab3Cond	Numeric	Condition value when third rehab occurs
Rehab4Cost	Numeric	Cost of fourth rehab
Rehab4Cond	Numeric	Condition value when fourth rehab occurs
Rehab5Cost	Numeric	Cost of fifth rehab
Rehab5Cond	Numeric	Condition value when fifth rehab occurs
ReliabilityPriorityScore	Numeric	Reliability Priority Score
SafetyPriorityScore	Numeric	Safety Priority Score

Field Name	Data Type	Description
O&MCostPriorityScore	Numeric	O&M CostPriority Score

Asset Types File: Function

The Asset Types File performs five primary functions. First, it provides a consistent definition of asset types (names and codes) across all data stored in TERM's Asset Inventory File. Note here that each asset record in the Asset Inventory has been assigned one of the asset type codes recorded in the Asset Types File (these two tables are joined together using this data field in a one-to-many relationship). This assignment of a unique type code to each inventory asset permits analysis and reporting of transit needs and conditions within the asset type's hierarchy designed for TERM.

The second function of the file is to store unit cost value of each asset type recorded in the asset types table (e.g., the cost of a standard 40 ft bus), as well as the year that cost was valid for (to adjust costs for inflation) and finally the source of that unit cost value. In general, TERM relies on replacement cost data as provided by local agencies in their asset inventory submissions. However, if an asset inventory record does not include the replacement cost of that asset (i.e., this costs data was not provided by the owner agency, or if the record was obtained from NTD AIM), TERM will estimate the asset's replacement value by multiplying the asset's unit quantity (e.g., track feet, from the inventory) by its unit cost as documented in the Asset Types File (e.g., cost per track foot).

The third function of the Asset Types File is to house the asset decay relationships used to project current and future physical conditions for each inventory asset. This includes the name of the decay curve being applied to each asset type, the curve's functional form and the curve parameters values used by that functional form.

The fourth function is to house the life cycle cost profile parameters. These parameters determine the number of rehabilitation actions each asset type will undergo over its full life cycle (up to 5), ages at which these rehab actions occur, and the cost of each action (expressed as percent of useful life and replacement cost, respectively).

Finally, the Asset Types File houses the asset type level ("fixed") priority scores used by TERM to determine the order in which asset reinvestment needs are addressed when funding is constrained (insufficient to address all needs). Specifically, the Asset Types File records these fixed scores for three priority criteria: reliability, safety and O&M cost impacts (see discussion of Investment Prioritization).

Updating of Asset Types File: Cost Data

The unit cost values documented in the Asset Types File should be reviewed and updated on a periodic basis (e.g., every two to five years depending on asset type) to reflect changes in the actual unit costs for each asset type. Historically, these data have been updated using two primary sources.

- *FTA TEAM Database:* The TEAM (Transportation Electronic Award and Management) system is used by FTA to manage and track the grant process. As such, it contains a great deal of information on the costs and number of units of transit capital assets purchased with FTA grants. While TEAM is a reliable source for unit cost data for most rail and bus vehicle types, it has not historically provided reliable unit cost data for other asset types. The TEAM database is maintained on an ongoing basis, hence new unit cost data can be obtained from TEAM on an annual or more frequent basis.

- *FTA Light and Heavy Rail Capital Cost Studies*: Special FTA studies, such as the Light and Heavy Rail Cost Update Studies outlined above, frequently provide reliable sources of as-built unit cost data for transit capital projects. While these studies represent good sources of unit cost data, they are conducted infrequently at intervals of five or more years.

ASSET DECAY CURVES

TERM's Rehab-Replacement Module uses over 100 different decay curves to simulate the ongoing physical decline and to determine the timing of eventual asset replacement. While TERM Federal is designed to establish different asset replacement threshold conditions for each of the five asset categories (guideway, facilities, systems, stations and vehicles), it has long been common practice to use a common condition rating replacement threshold across all of the five categories (the replacement threshold is commonly set to condition 2.5). Throughout each model run, TERM uses these curves to record the ongoing decline in asset condition as assets age, the improvement in condition when assets are replaced, and the timing and cost of all rehabilitation and replacement events.

In addition to determining when individual assets recorded in TERM's asset inventory will require rehabilitation or replacement, the decay curves are also used to evaluate the current physical condition of each asset and to *forecast* how those conditions are expected to change under alternate replacement strategies or funding constraints over each twenty-year model run. Finally, the condition ratings forecasts of individual assets are also aggregated across broad groupings of assets, regardless of type, yielding overall measures of average transit asset conditions for whole asset categories (e.g., vehicles, facilities, stations, etc.), modes, FTA regions or for all transit assets nationwide.

Asset Condition Rating Scale

TERM's asset decay curves rate the physical condition of all assets on a numeric scale of five (excellent, in like-new condition) through one (poor, in need of immediate repair). While the actual decay curves provide these condition ratings on a continuous, real number scale (i.e., decimal values are permitted), the underlying condition rating scale is integer based. The definition for each integer point in this scale is provided below in **Exhibit 2-6**[6].

Exhibit 2-6
Asset Condition Rating Scale

Rating	Condition	Description
5.0 to 4.80	Excellent	No visible defects, like-new condition
4.0 to 4.7	Good	Some (slightly) defective or deteriorated component(s)
3.0 to 3.9	Adequate	Moderately defective or deteriorated component(s)
2.0 to 2.9	Marginal	Defective or deteriorated component(s) in need of replacement
1.0 to 1.9	Poor	Critically damaged component(s) or in need of immediate repair

To estimate physical condition and to make the asset decay concept operational it is first necessary to develop specific mathematical formulations of the asset decay process (which can and do differ by asset type). As of February 2019, TERM uses a range of decay curves developed using the sources and methods described next.

Decay Curve Source Data: CTA Engineering Condition Assessment (1992)

Prior to 1995, all of TERM's asset decay curves were estimated using a single primary data source, the Chicago Transit Authority's (CTA) 1992 Engineering Condition Assessment. This $20 million study employed multiple consultant teams to assess the physical condition of all of CTA's fixed assets including guideway, facilities, systems and stations. The end product was a highly detailed data set recording the physical condition, age and asset types for a large sample of transit assets. The reported condition values utilized the five-point, integer scale presented above in Exhibit 2-5.

In 1995, FTA used these detailed condition data to estimate a set of preliminary asset decay relationships covering all fixed asset types. The results of this analysis are documented in the 1996 report *The Estimation of Asset Decay Ratings*. These decay relationships formed the preliminary basis for the construction of TERM and, as of June 2005, many of these relationships are still used by the model (including those for guideway and systems).

Each of the asset decay curves estimated using the ECA data used the "reverse logit" functional form (the form providing the best statistical fit to the ECA data). Within each curve, condition was found to be determined by the following three variables:

[6] The choice of this five point integer scale was based on the anticipated widespread adoption of similar scales in the mid-nineteen ninties by all US states in response to the then Federal requirement to develop statewide Public Transportation Management Systems (PTMS). While this requirement was ultimately dropped by the Federal government, some states and local agencies have adopted and continued to utilize a five point, integer condition rating system.

- ***Age:*** Individual assets decay over time through use and exposure to the elements — younger assets are generally in better condition than older assets of the same type

- ***Utilization Rate:*** Assets with high utilization rates will deteriorate more quickly than assets used with less frequency.

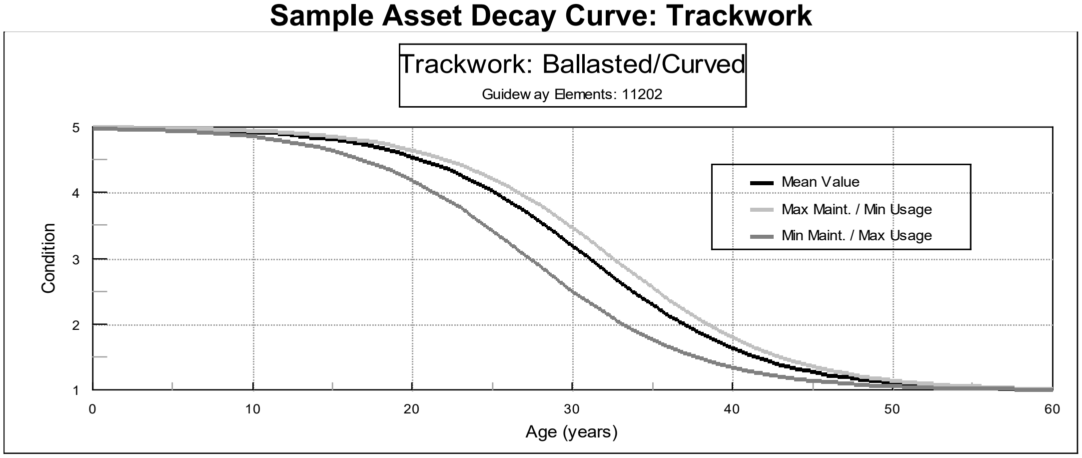
- ***Maintenance Rate:*** For many asset types, increased maintenance yields improved asset conditions[7].

The mathematical formulation for these decay curves is as follows:

$$Condition = 1 + 4 * \left\{ \frac{e^{(\alpha + \beta * Age + \gamma * Utilization\ Rate + \delta * Ma\text{int}\ Rate)}}{1 + e^{(\alpha + \beta * Age + \gamma * Utilization\ Rate + \delta * Ma\text{int}\ Rate)}} \right\} \quad (2\text{-}1)$$

Examples of these ECA based decay curves are found below in **Exhibit 2-7, Exhibit 2-8, and Exhibit 2-9.** The original decay curve parameters for all fixed asset types have been retained in TERM's Asset Types File (tbl05AssetTypeData).

Exhibit 2-7
Sample Asset Decay Curve: Trackwork



[7] Counter intuitively, asset conditions frequently appear to *decline* with increased maintenance rates. This finding confuses cause and effect. A negative statistical relationship between condition and maintenance highlights the increased cost of maintaining lower condition assets.

Exhibit 2-8
Sample Asset Decay Curve: Train Control

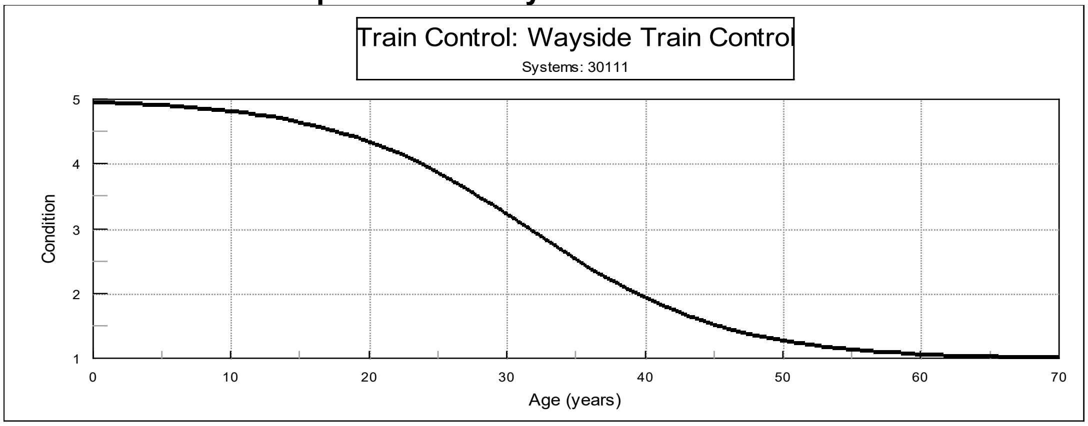
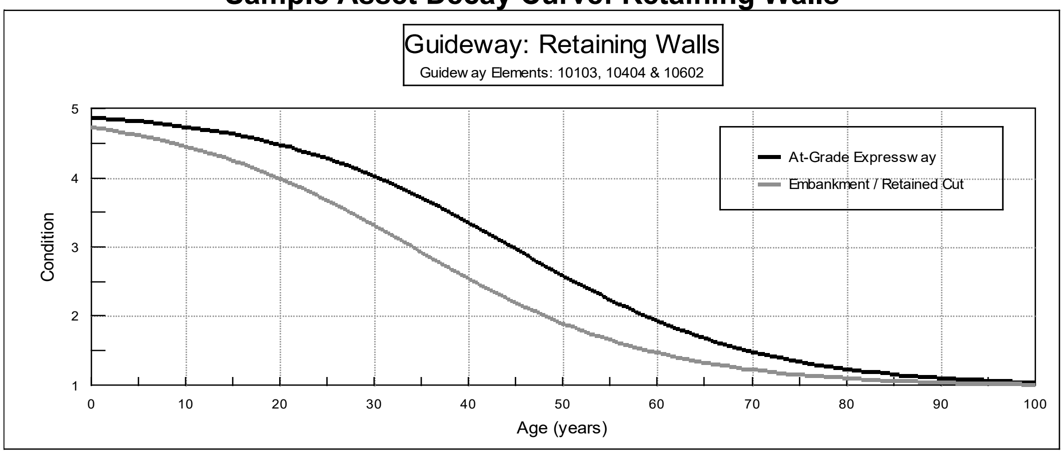


Exhibit 2-9
Sample Asset Decay Curve: Retaining Walls



Decay Curve Source Data: National Asset Condition Assessments for TERM (1999-2004)

While CTA's Engineering Condition Assessment (ECA) data provided a valuable starting point for the estimation of asset decay relationships, these data reflect the fixed-asset decay experience of a single US transit operator. Moreover, the original data sets for transit vehicles were not only limited to a single operator but were only for small vehicle samples.

Given these concerns, the decision was made in 1998 to initiate a program to assess the physical condition of all transit asset types on a nationwide basis with the ultimate goal of developing a full set of nationally-based asset condition decay curves for TERM. To date these national physical condition inspections have covered a broad sample of transit assets including the nation's bus fleets (1999, 2002), rail vehicle fleets (1999, 2002 for light and heavy rail, and 2003 for commuter rail), bus and rail maintenance facilities (1999, 2002) and rail stations (2004). These inspections yielded large sample data sets for each asset type inspected. The sample data then provided the basis for the estimation of statistically significant decay relationships for each of these asset types.

Unlike the reverse logit decay curves obtained from CTA's ECA dataset, the decay relationships estimated using data obtained through the national condition assessment program for TERM are best represented using spline regression models. Spline models provide a means to segment the life cycle of each asset type into different regimes, with each regime representing a different age group (e.g., 0-5 years, 5-15 years and 16 years and older) Here, each age regime is represented by a different linear regression equation with each of these individual regressions for each regime linked together. Spline models better capture variations in the rate of decline in an asset's condition throughout its asset life-cycle: typically accelerated early on when the asset is most heavily used and then more slowly in later years, frequently reflecting the age-retarding impact of rehabilitations. The mathematical form of the spline function and graphic examples of spline models used by TERM are provided below.

Spline Model Functional Form

$$Cond = 1 + 4 * e^{(\beta_1 + \beta_2 Dum3 + \beta_3 Dum16 + Age*(\alpha_1 Age + \alpha_2 Dum3 + \alpha_3 Dum16 + \lambda Ma\,int\,Cost))} \quad (2\text{-}2)$$

Exhibit 2-10
Bus Spline Function

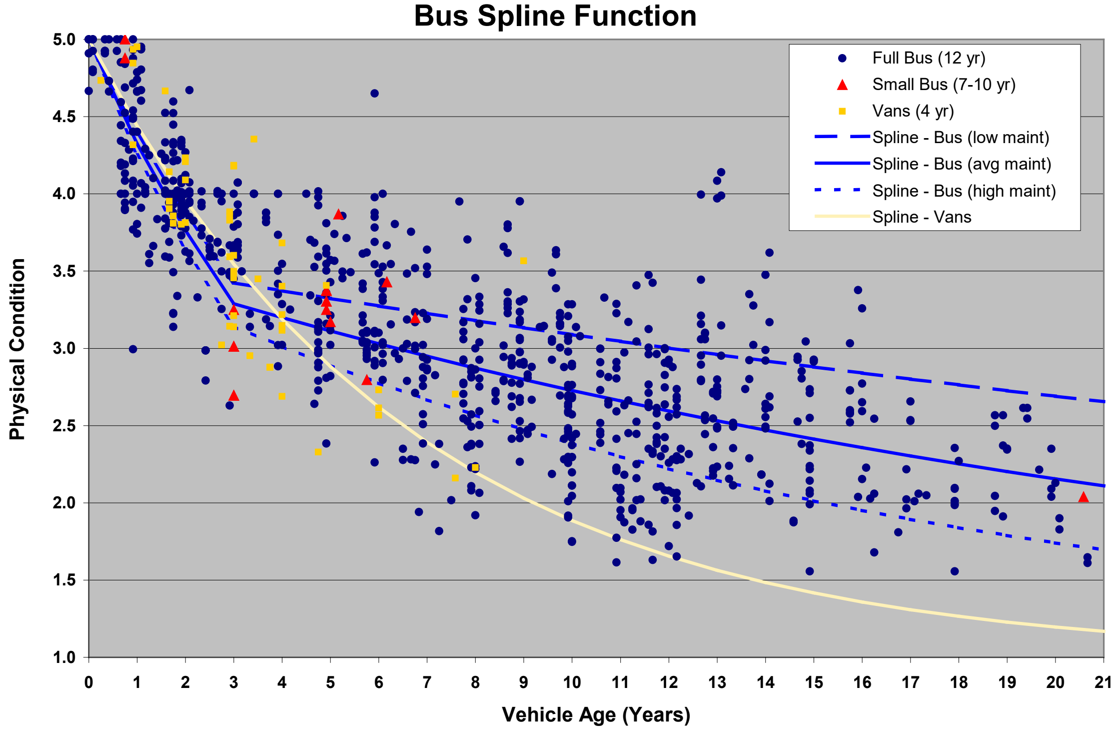
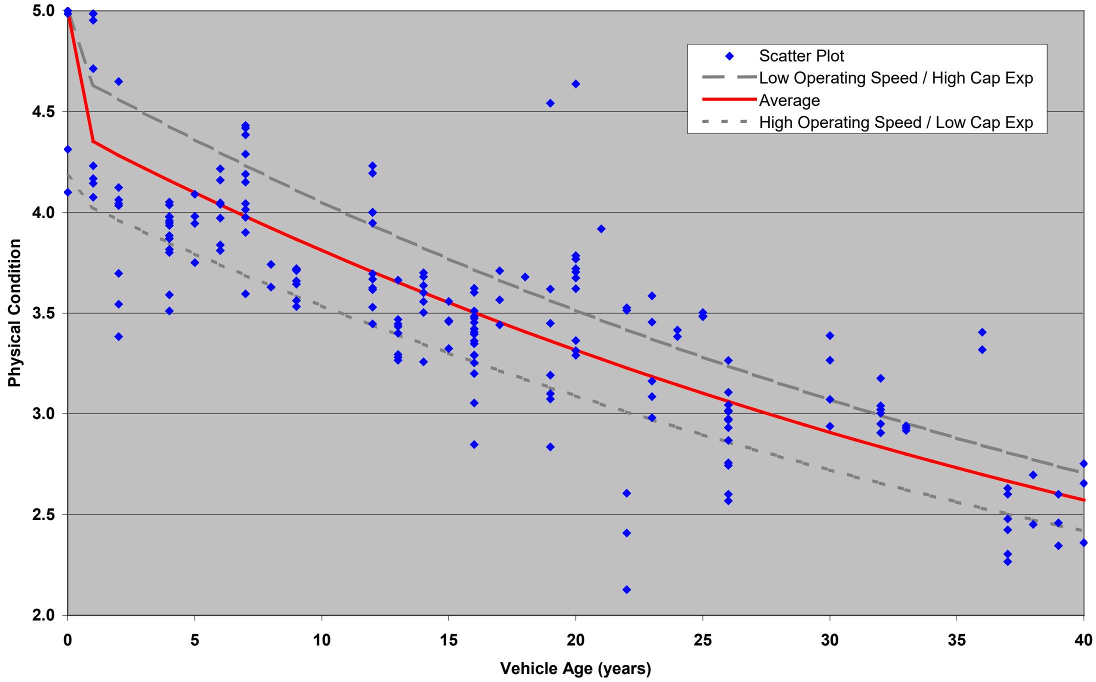


Exhibit 2-11
Light and Heavy Rail Vehicle Spline Function



Given differences in the number of equation terms across these newly estimated relationships and slight differences in functional form (the timing of the spline break-points or "knots") it has proven impractical to record the parameter values of the spline models within TERM's Asset Types File. Rather, these relationships are directly embedded in TERM's model code.

Decay Curve Source Data: Decay Curve Project (2018)

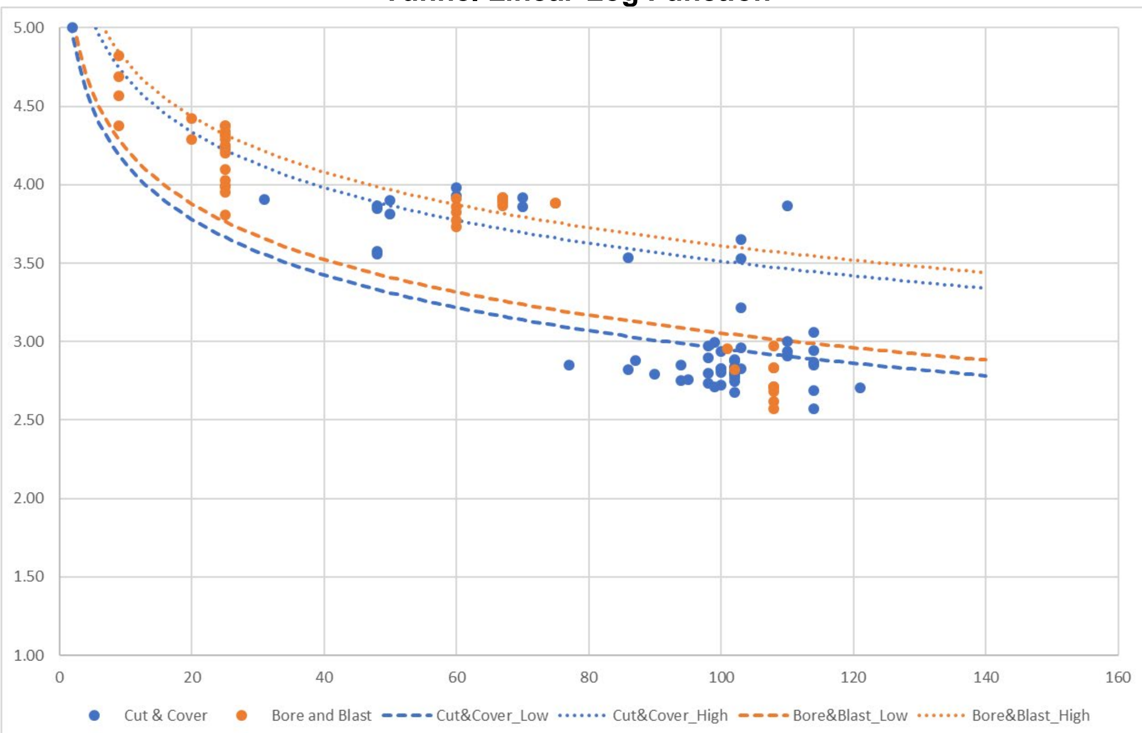
In 2017, FTA initiated a follow-up study to the assessments performed over 1999-2004, with the intention of modernizing some decay curves (e.g., motor bus curves) and also expending the study to cover additional asset types not covered by prior work (e.g., tunnels, bridges and LRT stations). In addition, this update was also intended to address the need for new decay curves applicable to the many new asset types to be reported following the introduction of NTD AIM. As with work conducted over 1999-2004, the new curves would primarily be developed using empirical condition data obtained through field inspections. The actual inspections were completed over the period of April through December 2018, which resulted in the collection of 1,160 new condition observations (including data on bridges, tunnels, stations, buses and vans, and a wide range of facility types) obtained at 43 agencies and from 8 NTD transit modes. The new curves were implemented within TERM in early 2019.

While the 2018 update resulted in the estimation of 71 new asset decay curves (based on empirical field data) and revisions to 28 additional, age-based curves (based on improved understanding of asset life expectancies). A key development of this work was the development and implementation of a third functional form: Linear-Log (2-3). An example Linear-Log function for tunnels is presented below in **Exhibit 2-12**.

Linear-Log Functional Form

$$Y = \alpha + \beta * \ln(Age) + \gamma * Dummy_{Variable1} + \delta * Dummy_{Variable2} + \ldots \quad (2\text{-}3)$$

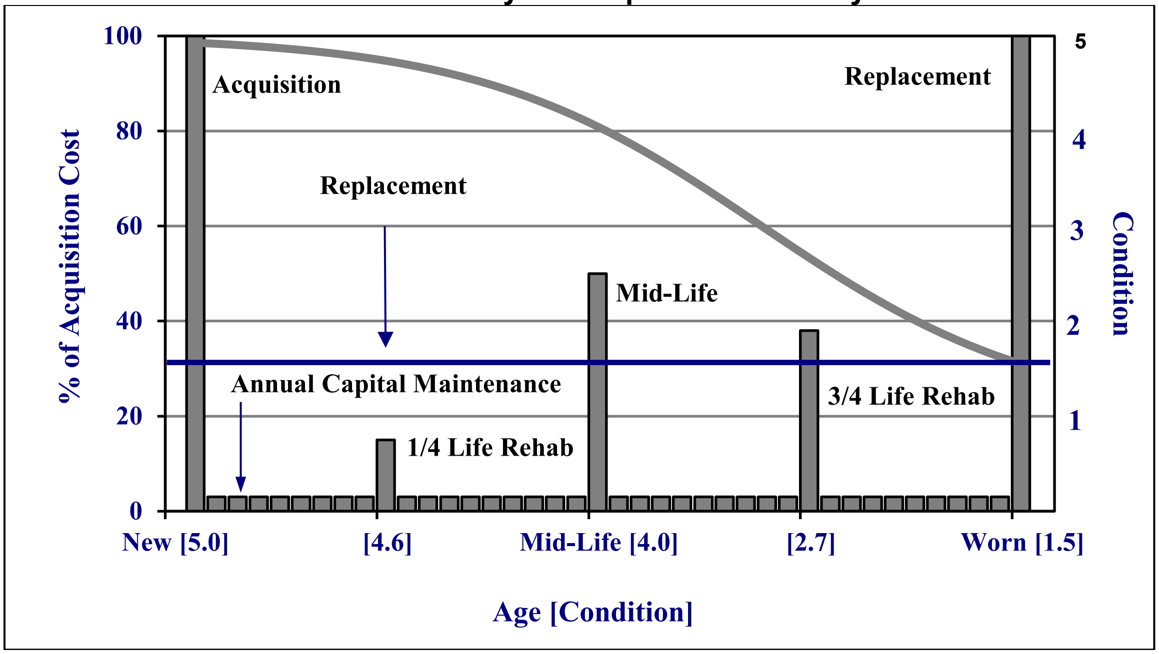
Exhibit 2-12
Tunnel Linear-Log Function



ESTIMATION OF REHAB AND REPLACEMENT NEEDS: THE ASSET DECAY ALGORITHM

Together, the transit asset inventory and asset decay curves provide the data and relationships required to simulate the ongoing use, maintenance, decay and eventual replacement of the nation's existing stock of transit capital assets. This process is represented conceptually for a generic asset in Exhibit 2-13. Here, asset age is represented on the horizontal axis, the cost of life-cycle capital investments on the left-vertical axis (as a percent of acquisition cost) and asset condition on the right-vertical axis. At age = 0 each asset is assigned an initial condition of 5.0 (i.e., excellent) while the asset's initial purchase cost is represented by the tall vertical bar on the left of the chart. Over time, the asset's condition begins to decline in response to aging and use, requiring periodic life-cycle improvements including annual capital maintenance and periodic rehabilitation projects. Finally, the asset reaches the end of its useful life (defined in this example as a physical condition of 1.5), at which point the asset is retired and replaced.

Exhibit 2-13
TERM Asset Decay and Capital Cost Life-Cycle



Rehabilitation and Replacement Condition Thresholds

The timing of asset rehabilitations and replacement is driven by asset condition. Specifically, the model user inputs the specific condition values at which asset rehabilitations and replacement take place. These values are referred to as "condition thresholds". The horizontal axis in Exhibit 2-11 calls out the rehabilitation and replacement condition thresholds for this hypothetical asset type (e.g., [4.6] for ¼ life rehab; [4.0] for mid-life rehab; [2.7] for ¾ life rehab and [1.5] for replacement). The replacement condition threshold is also called out explicitly as a horizontal line in the chart.

Rehabilitation Condition Thresholds: The condition thresholds for rehabilitation activities are input individually for each asset type identified in the Asset Types File (see above). As discussed earlier, TERM permits up to five different rehabilitations for each asset type; the number, cost and condition thresholds for which are all recorded in the Asset Types File. Specification of rehabilitation activities at this level allows TERM to better represent the diverse types of rehab activities performed for each asset type.

Replacement Condition Threshold: In contrast, the condition thresholds for asset replacement are set at the asset category level. As discussed above, TERM's hierarchy of asset types groups all assets into five broad categories of asset types including Guideway Elements, Facilities, Systems, Stations and Vehicles. Assigning replacement condition thresholds at the category level ensures that all asset types within each category are treated equitably within the asset replacement process. Hence, while the asset types within each asset category may represent a broad range of life-spans and retirement ages, each asset type will be retired at the same condition value, providing consistency to the retirement decision process.

Condition Versus Age Based Replacement

Within TERM, the timing of asset rehabilitations and replacement is driven by asset condition and not asset age. There are two reasons for using condition versus age-based replacement. First, the asset decay relationships used by TERM determine asset condition as a function of up to three variables, including age, maintenance and usage. These multi-variable based condition assessments provide TERM with a better overall measure of asset's service quality and reliability throughout its life-cycle than is possible with an age only assessment.

Second, use of condition versus age-based replacement thresholds allows TERM to define the end of useful life using condition values that are consistent across broad groupings of transit asset types, representing a wide range of useful lives. For example, the useful life of transit buses is roughly 15 years while the useful life of rail vehicles is more than 25 years. Replacing both vehicle types at a predetermined condition threshold (e.g., condition = 2.2) avoids the problem of assigning specific retirement ages to each asset type and also ensures that all vehicle types are evaluated equally using a common replacement standard.

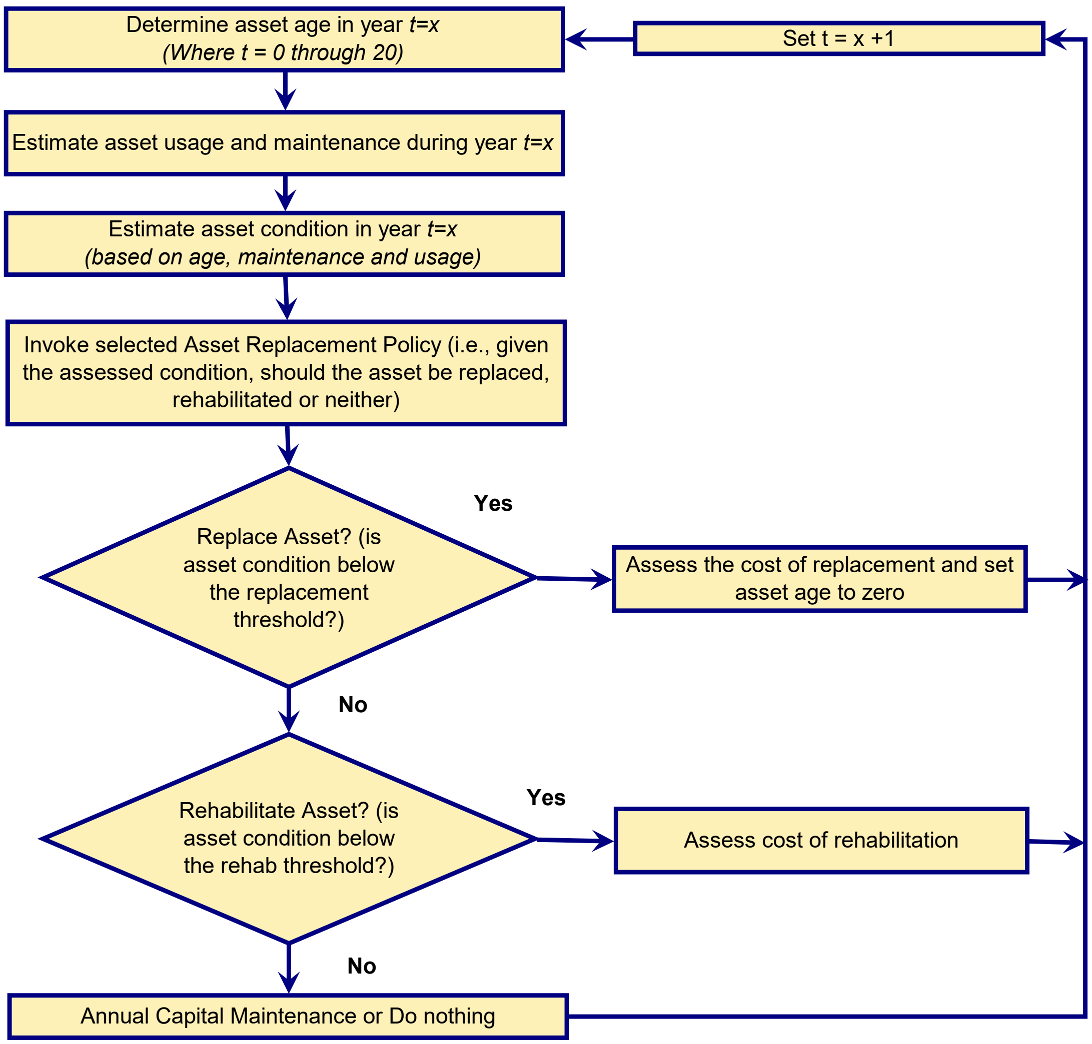
Model Decision Flow: Unconstrained Rehab and Replacement

To model the decay and financially unconstrained reinvestment processes depicted in Exhibit 2-13, the Rehab-Replacement Module must evaluate asset condition and reinvestment needs for each year of a standard model run and then determine the reinvestment needs for that year. This includes the start-year (where starting year needs represent investment backlog) followed by twenty-years of subsequent condition and needs assessment (i.e., for $t = 0$ to $t = 20$). The Module completes this process for all assets identified in TERM's Asset Inventory. A flow chart of this unconstrained annual rehab and replacement evaluation is provided below in **Exhibit 2-14**.

For each analysis year ($t = x$), the Rehab-Replacement Module evaluates each asset's projected age (based on its date-built value as recorded in the asset inventory), use and maintenance levels (based on data from NTD). The model next estimates the asset's expected condition based on these data and using the asset decay curve specific to the asset type under evaluation. This condition estimate is then recorded in TERM's Investment Needs output file (this output file includes 21 different condition fields, one for the start year and one for each of the twenty projection years).

The Rehab-Replacement Module next determines what capital reinvestment activities are required for the current year, if any. The module first determines whether the asset's estimated condition is below the minimum replacement threshold for assets of that type. If true, the module "replaces" the asset by (1) re-setting its date-built value to the current projection year, (2) setting the asset's condition rating to 5 (new or excellent) and (3) entering the asset's replacement cost in the investment needs field for that projection year.

Exhibit 2-14
Annual Condition and Investment Needs Evaluation Algorthim*



If the asset's current condition is not below the replacement minimum, the module would next determine whether the asset had crossed a rehabilitation threshold. As discussed above, TERM allows each asset type to undergo up to five different rehabilitations over the asset's life-cycle. The number of rehabilitations permitted for each asset type (and the cost of each) is recorded in the Asset Types file. Each of these five potential rehabilitations is triggered by condition thresholds similar to that used for asset replacement (i.e., assets are rehabbed as their condition drops below each rehab condition threshold). If the asset's condition has triggered a rehabilitation activity, then (1) the cost of that rehab is recorded in the investment needs field for that year and (2) TERM records the specific rehab activity as having been completed (so that specific rehab is not repeated in future years).

If the asset's current condition has not triggered any rehab or replacement activities, the Module determines whether there is any annual capital maintenance expense for this asset type. If so, this cost is entered into the capital in the investment needs field for the current analysis year, otherwise a value of $0.00 is entered.

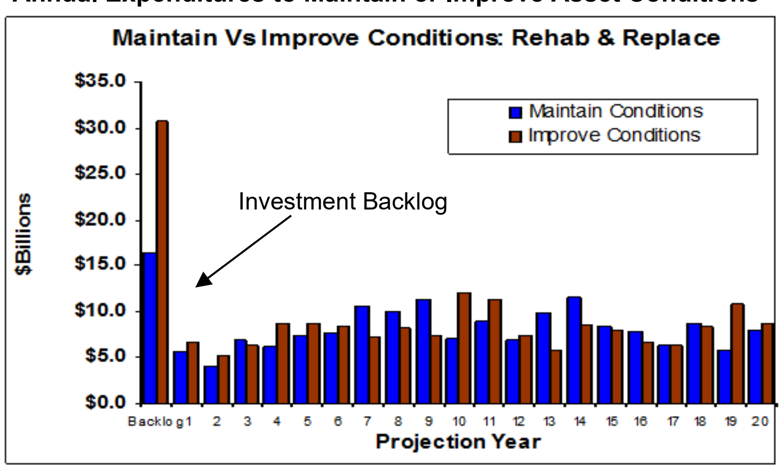
Finally, regardless of the need for capital investment or not, the Module moves to the next year of analysis ($t = x + 1$) and repeats the asset condition and investment needs evaluation process for a new year. The process is completed when the model completes the analysis for year $t = 20$.

Asset Rehabilitation Does Not Impact TERM's Condition Estimates: It is important to note that the Rehab-Replacement Module does not increase its estimate of an asset's physical condition rating following a rehabilitation activity. This is of course contrary to expectation as the physical condition of real-world transit assets do improve following any rehabilitation activity. There are two primary reasons for not modeling this condition improvement. First, TERM's asset decay curves provide expected condition values at each asset age based on the experience of many assets and agencies. At each asset age, the data underlying decay curve estimation represents assets with a range of rehabilitation experiences—including major rehabs, minor rehabs and no rehabs—with no consistent program of life-cycle rehabilitations pursued across the agencies sampled. Therefore, the impact to asset condition from periodic rehabilitations has already been factored into (i.e., is implicit) in the decay curves themselves and hence asset conditions should not be adjusted to reflect these activities. Second, there is no way of knowing what specific rehabilitation activities assets included in the asset inventory have undergone to be able to realistically adjust the conditions of these assets to reflect their individual rehab experiences.

Constrained Reinvestment Needs and the SGR Backlog (or Deferred Investment)

Exhibit 2-15

Annual Expenditures to Maintain or Improve Asset Conditions

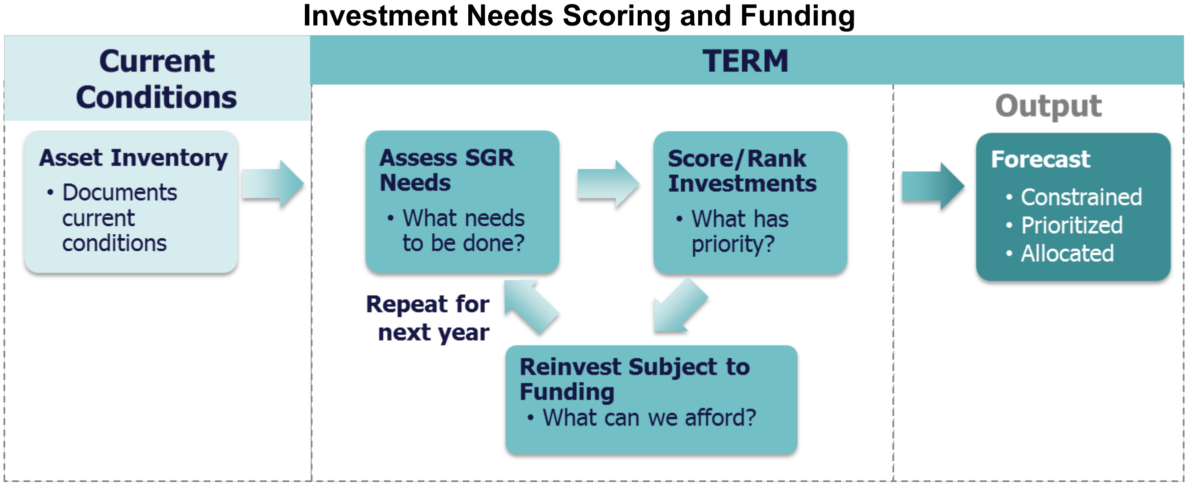


The description of the Rehab-Replacement Module as provided above assumes that the availability of unlimited reinvestment funds (i.e., funding is unconstrained). Under these circumstances, all deferred reinvestment needs (i.e., the state-of-good repair backlog) are entirely eliminated at the start of the model run, and sufficient funding is available to address all subsequent reinvestment needs as they arise. In reality, existing funding capacity is not usually sufficient to address all outstanding needs, either now or in the future, resulting in the ongoing presence of an SGR backlog (see **Exhibit 2-15**). To model this situation, TERM is equipped with a budget constraint that allows the user to specify the expected level of national capital funding capacity for transit for each year of the 20-year model run. Given this constraint, TERM will seek to expend the total funding capacity assigned to each budget year (which is typically the case). However, should funding be sufficient to reduce the SGR backlog to zero in any given year, TERM will hold any unused funds for that year in for use in future periods. In addition, as of 2010, TERM has been modified to track the investment backlog over all twenty years of the investment forecast and not just the initial backlog amount as in earlier versions of the model.

Investment Prioritization within TERM

TERM requires rules to determine the order in which reinvestment needs are addressed when funding is constrained. This includes decisions regarding the relative investment priority (ranking) of each reinvestment need, the actual allocation of limited investment funding to outstanding investment needs and the treatment of investment needs that cannot be addressed given the available funding capacity. These decisions are primarily controlled by TERM's investment prioritization module. Specifically, the prioritization module is designed to support the following TERM analyses *for each year of analysis* (as outlined below in **Exhibit 2-16**):

Exhibit 2-16
Investment Needs Scoring and Funding



- For each year of analysis, TERM first identifies which assets are not in SGR at the start of the year, and hence in need of a reinvestment action. Initial asset conditions (for year 0) are assessed based on the asset data as recorded in the asset inventory
- The prioritization routine then scores and ranks the needs for each year subject to a set of reinvestment criteria (described in detail below)

- Next, TERM sorts the ranked reinvestment needs – from highest to lowest – and then seeks to address these needs subject to the available funding capacity for that year. When funding is fully consumed for a given year, TERM then effectively moves on to the next year of analysis.
- Finally, TERM records all the completed reinvestment actions for each year (i.e., the "funded needs") as "expenditures". In contrast, all unaddressed needs are added (or returned) to the SGR backlog.

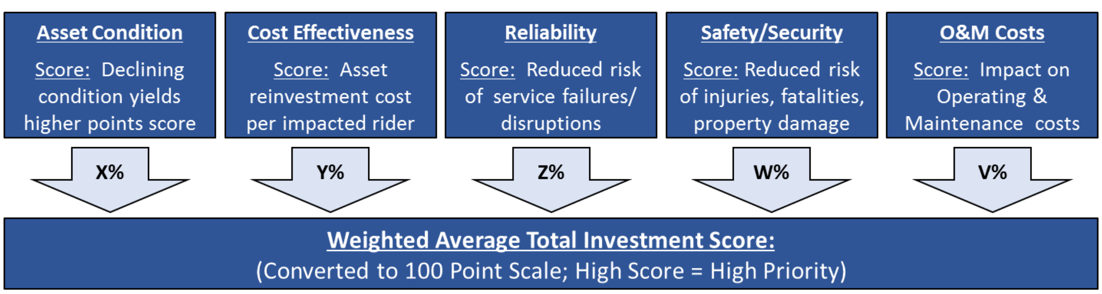
Prioritization Module Development

TERM Federal's prioritization routine is derived from a comparable routine from TERM Lite, which was in turn developed based on research conducted by the Chicago Regional Transportation Authority (RTA). That work sought to devise a method of prioritizing transit reinvestment needs for the Chicago region based on a set of pre-determined set of criteria and related criteria scoring rules. The following subsections describe the RTA's prioritization approach and its implementation within TERM Federal. In addition to the overall approach, it is important to note that many of the prioritization parameter settings utilized by TERM Federal were also adopted from RTA's default values (as these were based on extensive research, testing and review).

Prioritization Criteria

TERM's prioritization routine uses five criteria to score and rank all reinvestment needs. These five criteria are presented below in **Exhibit 2-17** and include the following:

Exhibit 2-17
TERM Investment Needs Criteria and Scoring



- Asset Condition: Declining condition is an indicator of declining performance, declining useful life, and higher likelihood of failure – all pointing to higher prioritization for replacement.

- Cost Effectiveness: This criterion – which represents asset reinvestment cost per impacted rider – is a proxy benefit cost measure. Specifically, it is intended to help prioritize reinvestment dollars towards those needs that benefit the most riders at the least cost.

- Reliability: This criterion is designed to focus reinvestment dollars towards those investments that contribute most to maintaining or improving transit service reliability.

- Safety & Security: This criterion is designed to focus reinvestment dollars towards those investments that contribute most to maintaining or improving the safety and security of transit riders and local transit agency staff.

- O&M Costs: This criterion is designed to focus reinvestment dollars towards those investments that contribute most to reducing operating and maintenance costs. For example, fleet maintenance costs tend to increase measurably with fleet age and hence the replacement of fleet vehicles provides a benefit in the form of reduced O&M costs. In contrast, the replacement of an aging radio system provides little or no impact to O&M costs as these systems require little or no maintenance.

Individual Criteria Scoring

TERM's prioritization routine is designed to assess the performance of each reinvestment need against each of the five criteria and then rank those investments relative to one another. This section describes the specific methodology used to score the individual reinvestment needs against each of the five criteria.

General Scoring Approach: Each of the five criteria are scored on a common, continuous (non-integer) scale running from 1 to 5. Here, a value of 1 indicates the lowest possible investment priority score for a given criterion and 5 the highest.

Asset Condition: The condition prioritization scores for each asset are calculated directly off of TERM's estimated condition values for that asset. Note here that assets in poor condition (1) are assigned a high priority score for reinvestment (5) (as they need replacement) while new assets in excellent condition (5) receive the lowest possible prioritization score (1). In other words, the condition rating and condition prioritization scores both run on the same 1-5 scale but in opposite directions. For this reason, the prioritization scores are simply assigned as the "mirror image" of the estimated physical condition score. This approach is presented in **Exhibit 2-18**.

Cost Effectiveness: This criterion is a proxy benefit-cost measure intended to prioritize reinvestment dollars towards those needs that benefit the most riders at the least cost. Specifically, investment cost effectiveness is calculated as asset reinvestment cost divided by the number of annual riders for the owning agency-mode. These values are then converted to 1-to-5 priority scores based on threshold values (controlled as parameters in TERM). Here, very low values – implying lower cost investments tending to benefit large numbers of riders – translate into a priority score of "5". In contrast, very high values – implying higher cost investments tending to benefit fewer riders – translate into a priority score of "1". If benefiting rider data were available on a more granular level (i.e., within the agency-mode level of detail), it would likely be preferable to assign these scores on number of benefiting riders alone, as investment cost is not an indicator of investment benefit.

Exhibit 2-18
TERM Investment Needs Criteria and Scoring

FTA Condition Ratings and RTA Prioritization SGR Scores			
Condition	**FTA Rating**	**Condition Score**	**Description**
Excellent	5	1	➢ New asset
Good	4	2	➢ Minimal signs of wear
Adequate	3	3	➢ Asset has reached its mid-life
Marginal	2	4	➢ Asset reaching or just past its useful life
Poor	1	5	➢ Asset past its useful life/in need of immediate repair or replacement

<u>Reliability, Safety & Security and O&M Costs</u>: Each of these measures are scored using a common methodology, but with differing parameters. Conceptually, this approach segments the priority scoring for each criterion into two separate components – one static and one dynamic (changing with time) – and then combines these two components to derive an overall criterion score. These static and dynamic scoring components capture the following:

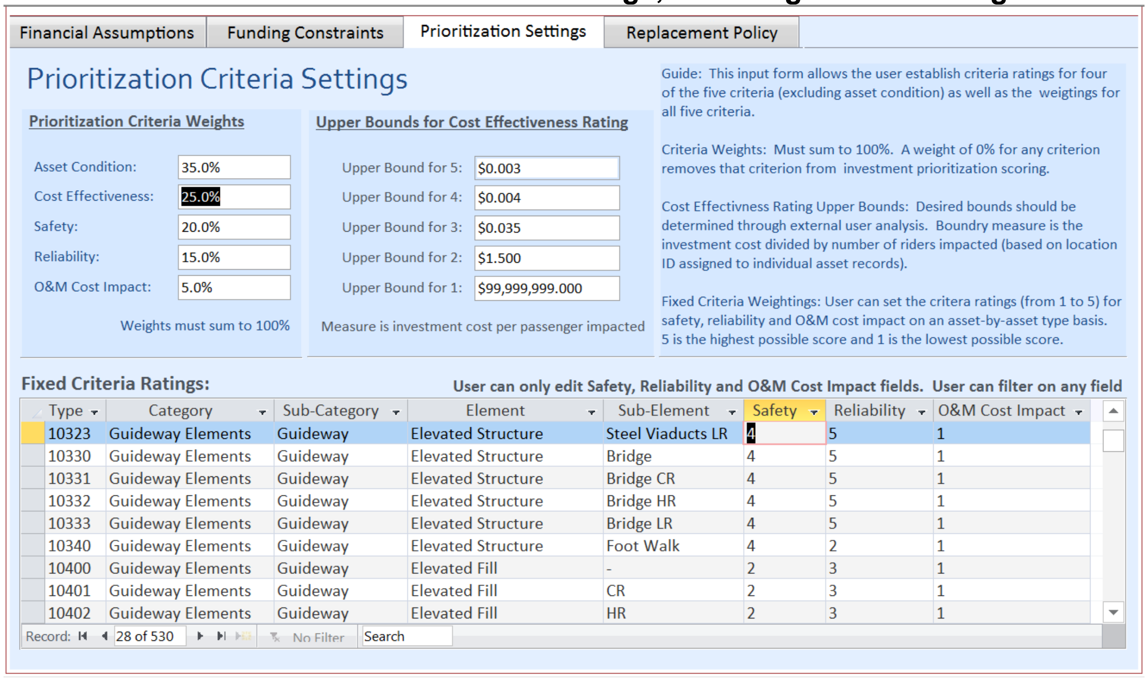
- <u>Asset Type - Static Component:</u> While some asset types are critical to service reliability (or safety), others are less so or not at all. For example, well-functioning vehicles are critical to service reliability (and to safety and low operating costs). In contrast, good quality bus parking areas provide minimal if any contribution to service reliability or safety). Similarly, some asset types have maintenance cost requirements that are both significantly higher than other asset types *and* are subject to change (increase) as the asset ages. In short, an asset's importance to service reliability, safety or maintenance cost impacts varies significantly by asset type.

- <u>Asset Condition - Dynamic Component:</u> In addition, asset reliability (safety and O&M cost impact upon replacement) is also determined by asset condition. Here, assets in poorer condition will be more likely to fail, potentially be less safe, or have higher maintenance requirements than newer assets in good or excellent condition.

To summarize, TERM's scoring for the reliability, safety and O&M cost criteria is determined based on both an asset's type and its condition – thus reflecting the asset type's importance to each criterion (e.g., service reliability) and its ability to support that role as determined by its current condition. Given this approach, TERM's prioritization module scores the asset type and condition attributes for these three criteria as follows:

- Asset Type – Static Scoring: For each of the three criteria, each asset type identified in TERM was assigned a fixed score from 1 to 5 based on whether reinvestment in that asset type would yield negligible (1) through significant (5) impacts on the criterion in question. As noted above, these assignments were based on research conducted by Chicago RTA. For example, for revenue vehicles RTA assigned a "5" for each of these three criteria as replacement of aging fleet vehicles can be expected to provide good returns on service reliability, reduced likelihood of safety problems, and reductions to maintenance costs. In contrast, replacement of aging bus shelters received "1"s for reliability and O&M cost impacts and a "2" for safety & security as it is not anticipated that these replacements provide much or any return with respect to these criteria. While current static score settings are based on RTA research, these scores can be easily altered within TERM. Example static scoring of these three criteria for elevated structure and elevated fill are presented below in **Exhibit 2-19** (lower panel of screenshot showing "Fixed Criteria Scoring"). This exhibit also displays the current criteria weights as well as the current thresholds for the cost effectiveness ratings.

Exhibit 2-19
TERM Prioritization Criteria Settings, Including Static Scoring


Financial Assumptions | Funding Constraints | Prioritization Settings | Replacement Policy

Prioritization Criteria Settings

Prioritization Criteria Weights

Asset Condition: 35.0%
Cost Effectiveness: 25.0%
Safety: 20.0%
Reliability: 15.0%
O&M Cost Impact: 5.0%

Weights must sum to 100%

Upper Bounds for Cost Effectiveness Rating

Upper Bound for 5: $0.003
Upper Bound for 4: $0.004
Upper Bound for 3: $0.035
Upper Bound for 2: $1.500
Upper Bound for 1: $99,999,999.000

Measure is investment cost per passenger impacted

Guide: This input form allows the user establish criteria ratings for four of the five criteria (excluding asset condition) as well as the weigtings for all five criteria.

Criteria Weights: Must sum to 100%. A weight of 0% for any criterion removes that criterion from investment prioritization scoring.

Cost Effectivness Rating Upper Bounds: Desired bounds should be determined through external user analysis. Boundry measure is the investment cost divided by number of riders impacted (based on location ID assigned to individual asset records).

Fixed Criteria Weightings: User can set the critera ratings (from 1 to 5) for safety, reliability and O&M cost impact on an asset-by-asset type basis. 5 is the highest possible score and 1 is the lowest possible score.

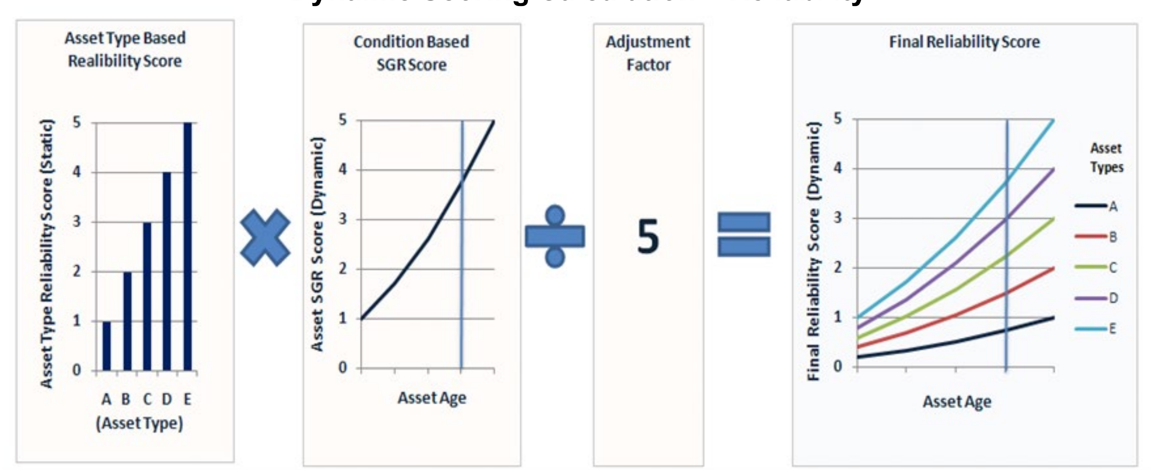
Fixed Criteria Ratings: User can only edit Safety, Reliability and O&M Cost Impact fields. User can filter on any field

Type	Category	Sub-Category	Element	Sub-Element	Safety	Reliability	O&M Cost Impact
10323	Guideway Elements	Guideway	Elevated Structure	Steel Viaducts LR	4	5	1
10330	Guideway Elements	Guideway	Elevated Structure	Bridge	4	5	1
10331	Guideway Elements	Guideway	Elevated Structure	Bridge CR	4	5	1
10332	Guideway Elements	Guideway	Elevated Structure	Bridge HR	4	5	1
10333	Guideway Elements	Guideway	Elevated Structure	Bridge LR	4	5	1
10340	Guideway Elements	Guideway	Elevated Structure	Foot Walk	4	2	1
10400	Guideway Elements	Guideway	Elevated Fill	-	2	3	1
10401	Guideway Elements	Guideway	Elevated Fill	CR	2	3	1
10402	Guideway Elements	Guideway	Elevated Fill	HR	2	3	1

Record: 28 of 530 | No Filter | Search

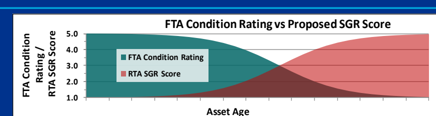
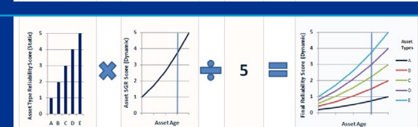
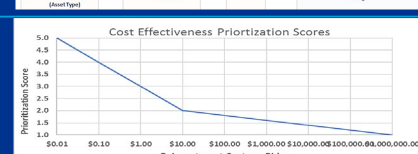
- Asset Condition – Dynamic Scoring: In addition to the static scoring based on asset type, scores for the three criteria are also driven by estimated asset condition. Specifically, it is assumed that as asset condition declines, the likelihood of reliability, safety and increased maintenance cost issues tends to increase. To capture this effect, the fixed scores are multiplied by each individual asset's current condition score (not condition rating) to come up with a combined prioritization score that considers both asset type and asset condition (as depicted below in **Exhibit 2-20**). Given that the static and condition scoring are each on five-point scales, their product is divided by 5 to yield reliability, safety and O&M cost impact scores that are also on five-point scales. In contrast to the "static" asset type score, these condition-based scores are "dynamic" as asset condition ratings change continuously over the 20-years of the forecast.

Exhibit 2-20
Dynamic Scoring Calculation – Reliability



Finally, the individual approaches used to score the five investment criteria are summarized below in **Exhibit 2-21**.

Exhibit 2-21
Criteria Scoring Summary

Criterion	Definition	Scoring Approach
Condition	• Asset physical condition • The lower the condition rating, the higher the prioritization score • Dynamic Scoring: Asset condition	
Reliability	• Degree to which reinvestment impacts service reliability (reduces service failures) • Dynamic Scoring: Asset type and condition	
Safety & Security	• Degree to which reinvestment impacts the safety and security of passengers / employees • Dynamic Scoring: Asset type and condition	
O&M Cost Impact	• Degree to which reinvestment reduces operating costs • Dynamic Scoring: Asset type and condition	
Rider Impact	• Cost of reinvestment divided by number or riders (for agency mode) • Crude benefit-cost metric intended to favor investments that benefit more riders	

Total Prioritization Score

Having generated prioritization scores for each of the five investment criteria based on the approaches described above (all on a common 1 to 5 scale), TERM's prioritization routine next combines these values into an overall prioritization score. This is a simple, two-step process. First, TERM calculates a weighted average value across all five criteria scores. The weights used for this calculation were developed by Chicago RTA with the support of their three service boards, CTA, Metra and Pace. These weights are controllable parameters within TERM and the default values are displayed above in the upper-left-hand corner of **Exhibit 2-19**. Second, the weighted average value for each scored asset is converted from the 1-5 scale to a 100-point scale. The transformation helps "spread out" the prioritization scores, making it easier to view, rank, compare and understand relative scores across a range of assets. An example calculation demonstrating this two-step process is provided below in **Exhibit 2-22**.

Exhibit 2-22
Calculation of Total Prioritization Score

Criteria	Score (1 to 5)		Criteria Weight		Convert to Base 100		Base 100 Score
SGR / Condition	3.75	x	20%	x	20	=	15.00
Reliability	2.62	x	20%	x	20	=	10.48
Safety	3.11	x	20%	x	20	=	12.44
Riders Impacted	4	x	20%	x	20	=	16.00
O&M Cost Impact	1	x	20%	x	20	=	4.00
Total			**100%**			=	**57.92**

User input (shaded cells: Criteria Weight)

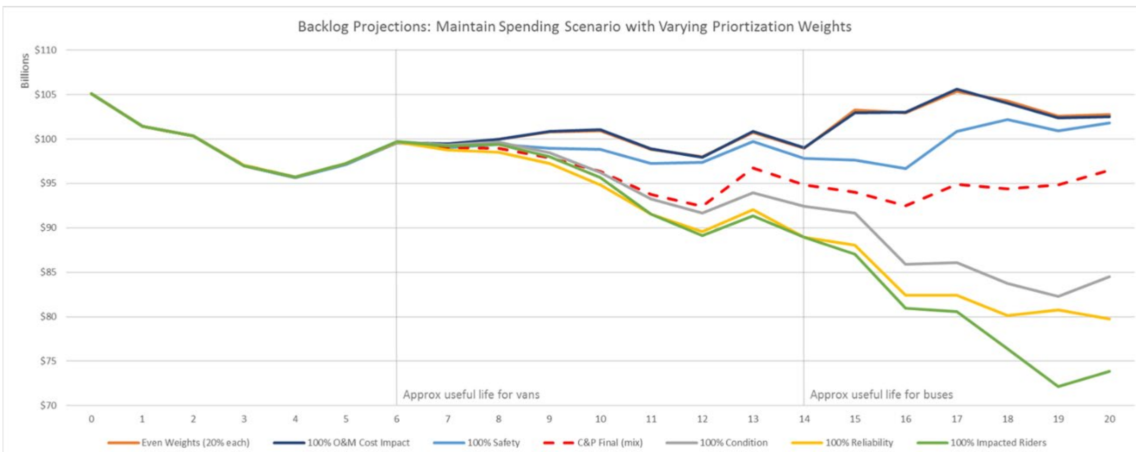
Sensitivity of Backlog to Prioritization Settings

As discussed earlier, TERM is designed to project the size of the SGR backlog for each year of the 20-year forecast period (e.g., as a means of assessing the impact of funding levels on backlog growth). It is important to note here that the size and composition of those backlog projections are sensitive to TERM prioritization settings.

- Backlog Composition: First, by determining which investments to address when funding is constrained, the prioritization routine therefore also determines which needs are not addressed, and hence which reinvestment needs enter (or remain in) the SGR backlog. If the user changes either the criteria weights or the static scoring settings (for the reliability, safety and O&M cost criteria), the user will directly impact prioritization scoring and in turn the selection of which assets to fund (and which to send to the backlog). Changes in the composition of the backlog become most evident by year 20 of the projection, when the impact of changes in prioritized investment selection accumulates over this extended time period.

- Backlog Size: Similarly, prioritization settings, in particular the criteria weights, can also impact the projected size of the SGR backlog (see **Exhibit 2-23**). As with backlog composition, the impact of changes in criteria weights is most evident in the later years of the projections, when the impact of changes in investment prioritization have accumulated over time. Note that the backlog estimates can vary by as much as 30 percent by year-20 of the projection, depending on the criteria weights used.

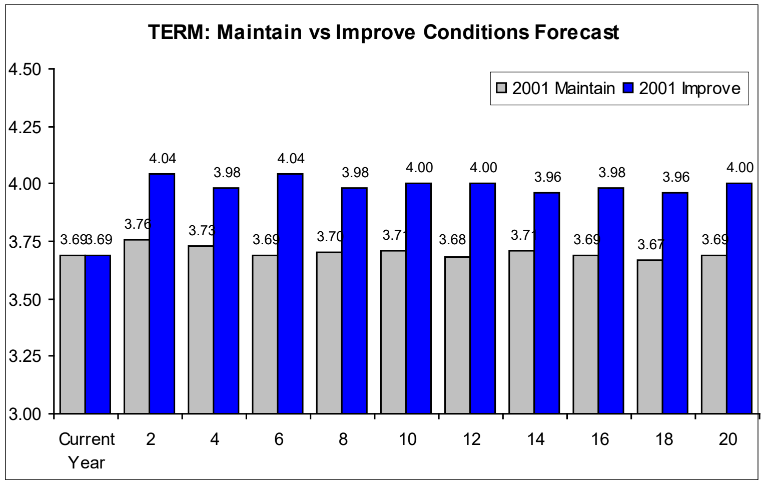
Exhibit 2-23
Impact of Criteria Weights on Projected Backlog Size



MODELING PRESERVATION NEEDS

Prior to the 2010 C&P Report, TERM's rehab-replacement module was primarily used to determine the level of capital re-investment required to maintain national average physical conditions at their current level (i.e., at t=0) or to improve average conditions to an overall level of "good" (to the extent possible without replacing assets prior to the end of a reasonable amount of useful life). The maintain and improve investment targets were modeled by adjusting the minimum condition replacement thresholds for TERM's five asset categories until the desired maintain and improve conditions targets are met. Specifically, these two investment scenarios are modeled as follows:

Exhibit 2-24
Condition Forecast: 2001 C&P Report



<u>Maintain Conditions:</u> Under the maintain conditions scenario, TERM's five replacement condition thresholds are adjusted until the condition values for each asset category at the *end* of the model run (t = 20) equal their condition values at the *start* (t = 0). In practice this requires multiple TERM runs aimed at achieving this scenario / modeling objective. Also, between the start and end points condition values are not constrained to equal the starting value. Rather conditions typically increase significantly following the initial year of the model run (after the investment backlog has been addressed) and then decline slowly to the target starting condition by the end of the model run. This behavior is depicted in **Exhibit 2-24**, which presents the maintain conditions scenario analysis for the 2001 C&P report. Finally, if an asset category's initial condition is greater than 4.0 (or "good"), the asset's condition is not maintained at this high level, but is, rather, allowed to decline to 4.0 such that the maintain conditions needs for this asset type do not exceed its improve asset conditions needs.

<u>Improve Conditions:</u> Under the improve conditions scenario, TERM's five replacement condition thresholds are adjusted until the condition values for each asset category at the *end* of the model run (t = 20) are equal to 4.00 or "good". In practice it is not always possible to attain a value of 4.00 for all asset categories. For example, some cases attaining a category condition rating of 4.00 may require asset replacement at an unreasonably early point in the asset life-cycle. Conversely, if the category asset condition rating already exceeds 4.00 for later years of a model run, it may not be possible to postpone asset replacement sufficiently (i.e., use a low enough replacement threshold) to attain a final condition value of 4.00. Finally, given that the distribution of asset ages for some asset categories is <u>not</u> uniformly distributed (i.e., asset age distributions are "lumpy"), it often not possible to attain the desired ending asset condition precisely (or even closely in some cases). This is true for both the maintain and improve conditions scenarios.

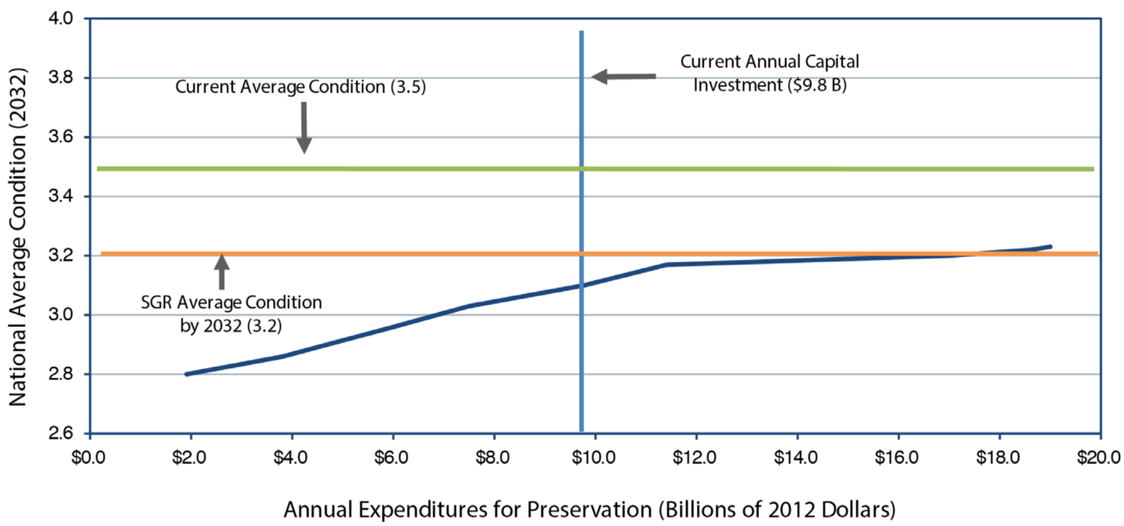
<u>SGR Needs:</u> Beginning with the 2009 Rail Modernization Study and continuing on to the 2010 National State of Good Repair Assessment and the 2010 C&P Report, the Maintain and Improve Scenarios have been increasingly superseded by the single state-of-good-repair (SGR) scenario. Under this scenario, TERM is run unconstrained (as with the Maintain and Improve Conditions Scenarios) with the replacement condition threshold set

to 2.50 for all asset types. This scenario is considered to be both easier to understand and more realistic than the prior Maintain and Improve Conditions Scenarios.

Aggregating Condition Values

Implicit in the above discussion is the concept of aggregating asset condition values across various groupings of transit assets or even all transit assets. For example, the impact of varying levels of preservation investments on asset conditions (as shown Exhibit 2-25), presents the average conditon across all US transit assets. Within TERM, average condition values are calculated as the weighted average condition across all assets in an asset category (or other asset grouping), where assets are weighted by their replacement value. This weighting ensures that more expensive assets (e.g., subway tunnels) receive a greater condition weighting than less “important” items such as fencing. Note that average asset condition ratings are not limited to asset categories but can be averaged across any database dimension desired including modes, agencies, cities, urban population strata and regions.

Exhibit 2-25
Impact of Preservation Investment on 2032 Transit Conditions in All Urbanized and Rural Areas: 2015 C&P Report



INVESTMENT NEEDS FORECAST TABLE

Investment needs projections produced by the Rehab-Replacement Module and all other investment needs modules (including asset expansion and performance improvement needs) are recorded in TERM’s Investment Needs Forecast table (see **Exhibit 2-26**). Table contents include both the actual dollar needs estimates and the related condition value estimates for each year of a twenty-year model run[8]. The Investment Needs Forecast Table also records other data relevant to the asset decay and replacement process including the asset's type, original date built, replacement date built (if replaced during the model run), and rehabilitation history. Finally, this table includes data useful in grouping and analyzing this including mode, owner agency, urban area and state location, asset inventory ID and initial replacement value.

Exhibit 2-26
Investment Needs Forecast Table

Field Name	Data Type	Description
Asset ID	Numeric	Unique Asset ID (Maps to Asset Inventory)
Transit System	Text	Name of Asset Owner
Mode Code	Text	Asset Mode
Agency ID Code	Text	Agency FTA ID Code
Agency Mode ID	Text	Combination Agency FTA ID and Mode Code (maps to agency mode table)
UZA Code	Numeric	UZA Code (maps to urban demographics table)
State	Text	State abbreviation
Population Stratum	Text	Population Stratum of UZA
FTA Region	Text	FTA Region
Asset Type Code	Numeric	Asset Type Code (maps to Asset Types File)
Original Date Built	Numeric	Original Date Built
New Date Built	Numeric	New Date Built value if asset replaced during model run
Quantity	Numeric	Asset Quantity (number of feet, vehicles, stations, etc.)
Units	Numeric	Feet, vehicles, stations, etc.
Unit Cost	Numeric	Cost per unit
Valuation	Numeric	Initial replacement value of asset
Current Year Invest Cost	Numeric	Investment cost in year 0 (i.e., backlog)
Year "T" Invest Cost	Numeric	Investment cost in year T (twenty different fields where t = 1 through 20)
Start Year Invest Condition	Numeric	Asset condition in year 0 (pre-backlog investment)
Total Cost	Numeric	Total investment needs for years t = 0 through t = 20
Discounted Cap Cost	Numeric	Discounted investment needs for years t = 0 through t = 20
Current Year Invest Condition	Numeric	Asset condition in year 0 (post-backlog investment)
Year "T" Invest Condition	Numeric	Asset condition in year T (twenty different fields where t = 1 through 20)
Ben-Cost Ratio	Numeric	Benefit Cost Ratio for the proposed investment
Data Source	Text	Source of asset inventory data
Rehab4Cost	Numeric	Cost of fourth rehab

[8] For conditions this includes the initial at the start of the model run, conditions immediately after all backlog investment needs have been addressed and then condition estimates for all remaining years of the model run.

Field Name	Data Type	Description
Rehab4Cond	Numeric	Condition value when fourth rehab occurs
Rehab5Cost	Numeric	Cost of fifth rehab
Rehab5Cond	Numeric	Condition value when fifth rehab occurs

CHAPTER 3 - ASSET EXPANSION MODULE (MAINTAIN PERFORMANCE)

INTRODUCTION

In addition to the ongoing rehabilitation and replacement of existing assets, agencies also devote a portion of their capital budgets to the purchase of "expansion" assets — including purchases of additional vehicles, stations, new rail guideway and facilities beyond that already in service. Conceptually, investments in expansion assets can be thought of as serving two distinct purposes. First, the demand for transit services continues to grow over time in line with population and employment. To maintain current service standards in the face of this expanding demand, transit operators must similarly expand their service capacity. Failure to do so would result in increased vehicle crowding, increasing dwell times and decreased operating speeds for existing services. Second, transit operators also invest in expansion projects with the aim of improving current service standards. Such improvements include capital expansion projects to reduce vehicle crowding or increase average operating speeds.

TERM's Asset Expansion Module is designed to address the first of these issues, investment to maintain current service standards. *By doing so, investments proposed by the Asset Expansion Module are said to "maintain performance" of the nation's existing transit services.* The second investment type, expansion to improve service quality or "improve performance", is addressed in the Chapter 4.

ASSET EXPANSION BY ASSET TYPE

Fleet Expansion

The Asset Expansion Module is designed to estimate the level of investment in new vehicles, facilities and guideway as required to maintain current service standards on an agency-mode basis. Specifically, this module assumes that each agency-mode has the objective of maintaining the ratio of passenger miles per peak vehicle constant over time. To do so agencies must continuously invest in additional fleet capacity at a rate equal to the growth in unlinked passenger (UPT) trips for the FTA region, mode and urban stratum size that they serve. The Asset Expansion Module models this rate of investment for each agency-mode reporting to NTD using equation (3-1):

$$\Delta FleetSize_{t=x} = \text{int}\{FleetSize_{t=x} - FleetSize_{t=x-1}\} \quad (3\text{-}1)$$

$$= int\{Fleet\ Size_{t=0} * (1 + UPTGrowth_{UZA})^{x} - Fleet\ Size_{t=0} * (1 + UPTGrowth_{UZA})^{x-1}\}$$

$$= int\left\{Fleet\ Size_{t=0} * (1 + UPTGrowth_{UZA})^{x} * \left(1 - \frac{1}{(1 + UPTGrowth_{UZA})}\right)\right\}$$

Where *t=0* is the current date (i.e., the model start date), *t=x* is the forecast date and "int" represents conversion of the expression calculation to integer terms to ensure vehicles are purchased in integer quantities. The cost of this investment for is given by:

$$FleetExpansionNeeds \quad = \Delta Fleet\ Size_{t=x} * CostPerVehcile \qquad (3\text{-}2)$$

Here, the cost per vehicle is obtained from TERM's Asset Types file.

Expansion of Supporting Assets

After forecasting the number of new vehicle purchases required to maintain existing passenger miles per vehicle ratios (equation 3-1), the Module next estimates the related investment in all other asset categories — including facilities, stations, new guideway, and other assets — required to support those new vehicles. Investment quantities for these non-vehicle asset categories are estimated on a per route mile basis based on the historical relationships between the number of route miles invested per peak vehicle (on a modal basis). For example, investment in new guideway route miles for mode y is determined using the following relationship:

$$\Delta Guideway\ Investment_{t=x, Mode\ y} = Route\ Miles\ Per\ Peak\ Vehicle_{Mode\ y} * \Delta Fleet\ Size_{t=x} \qquad (3\text{-}3)$$

Here, the historical ratio of $Route\ Miles\ Per\ Peak\ Vehicle$ for mode y is based on the modal average route miles per peak vehicle for that mode as calculated using the most recently published NTD data. Moreover, the proposed investment in additional guideway represents a mix of at-grade, elevated and subway alignments reflecting the nation's current investment in these alignment types by mode (as reported to NTD). It is important to note that TERM imposes minimum levels of guideway investment (e.g., 5 miles) to avoid investment in very small, uneconomical projects. In doing so, the mode keeps track of fleet expansion totals from one projection year to the next and only invests in additional guideway once the minimum threshold has been attained.

The cost of this investment for mode y is:

$$GuidewayExpansionNeeds_{Modey} = \Delta GuidewayInvestment_{t=x,Modey} * CostPerRouteMile_{Modey} \qquad (3\text{-}4)$$

The cost per route mile of guideway invested is derived from the cost data contained in TERM's Asset Types File.

In addition to the investment in guideway as presented in equation (3-2), the Asset Expansion Module utilizes similar equations to predict other fleet expansion support investments including those for trackwork, facilities, systems (train control, traction power, communications), and stations (at-grade, elevated and subway).

In the case of systems assets, the equation is essentially the same:

$$SystemsExpansionNeeds_{Modey} = \Delta GuidewayInvestment_{t=x,Modey} * Systems\ CostPerRouteMile_{Modey} \quad (3\text{-}5)$$

Where *Systems Cost per Route Mile*$_{Modey}$ is a combined unit cost per mile for train control, electrification (if needed), and communications for the specific rail mode in question (where the cost values are derived from as-built costs for New Starts projects for each rail mode type).

In the case of systems assets, the equation is essentially the same:

$$StationExpan_{Modey} = \Delta GuidewayInvestment_{t=x,Modey} * StationsPerRouteMile_{Modey} * CostPerStation_{Modey}$$

(3-6)

Where *Stations Per Route Mile*$_{Modey}$ is the national average number of stations per route mile (calculated by mode using NTD data) and the value *Cost Per Station*$_{Modey}$ is again derived from as-built costs for New Starts projects for each rail mode type.

Finally, in the case of facilities, the equation is as follows:

$$FacilityExpan_{Modey} = \Delta Fleet\ Size_{t=x} * FacilityCostPerVehicle_{Modey}$$

(3-7)

Here $\Delta FleetSize_{t=x}$ is the change in fleet size in period *x* and *Faciliity Cost Per Vehcile*$_{Modey}$ is derived from as built costs for New Starts projects for each mode type. Also included are estimated investment requirements for site preparation, environmental mitigation and project soft-costs. These latter costs are also applied on a per mile basis based on the as-built cost experience of an over fifty different light and heavy rail transit investments completed in the US since 1975[9].

UNLINKED PASSENGER TRIP (UPT) FORECASTS

The asset expansion forecasts in equation (3-1) through (3-3) are driven by the trend rate of increase in unlinked passenger trips (UPT). As of 2014, TERM currently estimates future UPT growth based on the trend rate of growth (compound average growth rate or CAGR) over the preceding 15-year period. Moreover, this rate is determined at the Mode-FTA Region-Population Stratum level of detail. This stratification of growth rates was developed to explicitly recognize differences in UPT growth rates by mode, by region of the nation, and by urban area population size. Given the number and location of transit modes combined with ten FTA regions and 4 urban population strata, this approach results in a listing of growth rates for over 250 separate mode-FTA region-stratum size combinations (note: stratum 1 is > 1 million; stratum 2 is < 1 million and > 500,000; stratum 3 is < 500,000 and > 250,000; and stratum 4 is < 250,000).

[9] For further information, please refer to the Light Rail Capital Cost Study Update (2003) and Heavy Rail Capital Cost Study Update (2004).

The table of growth rates is updated in preparation for the development of a new C&P report. Note, however, that a 2-step rate review and adjustment rules are applied to the 15-year trend growth rates prior to their use on TERM. Adjustments include the following:

- Step 1: Mode-Region-Strata with Less Than 15-Years of Service: There are typically many instances where a mode-region-stratum combination has been in service for less than 15-years (and hence 15-year growth rate cannot be calculated). In this case, TERM determines the longest period of time for which UPT growth can be calculated from the following time period options 10-years, 5-years, 4-years, 3-years, 2-years, 1-year. This time period then becomes the "selected" rate to project future UPT growth for that mode-region-stratum combination.

- Step 2: Negative Growth Rates Not Permitted: TERM's expansion module only works with non-negative growth rates (as it is not possible to generate "negative fleet growth"). Hence, if the selected growth rate for a mode-region-stratum combination is less than zero, the growth rate is set to zero, and hence TERM will not invest in fleet expansion for any agencies operating within that mode-region-stratum combination.

RELATIONSHIP BETWEEN EXPANSION AND REHAB-REPLACE MODULES

In 2018, the expansion module was modified to greatly improve consistency between it and the Rehab-Replacement Module (primarily to ensure the reinvestment needs for existing and expansion modeled on the same basis). Given these changes, the Expansion Module now functions as follows:

- Expansion Module Precedes the Rehab-Replace Module: The revised expansion module now runs before (vs after) the Rehab-Replace Module. Specifically, at the start of each model run, TERM first checks to determine if expansion assets are present in TERM asset inventory and then deletes these. Next, TERM determines if the current run includes expansion assets as part of the analysis. If "yes", the expansion modules will generate complete TERM asset records for the full listing of required expansion assets (based on the logic described below). These expansion records are then added to TERM's inventory of existing assets. At this point, the expansion module run is complete, with all needs analysis for existing and expansion assets now controlled by the Rehab-Replace Module.

- Expansion Asset Acquisition: By definition, expansion asset records all have "date built" values that fall after the start year of analysis and which can fall anywhere from year-1 to year-20 of the period of analysis. Given this, TERM's Rehab-Replacement Module treats expansion assets as "non-existent" up to the year of acquisition. At the year of acquisition, the Module then documents the cost of that acquisition – and this activity is recorded as an acquisition cost (i.e., separately from rehab or replacement cost).

- Common Assessment of Reinvestment Needs: Following the year of acquisition, expansion assets are subject to exactly the same rules as existing assets (within the Rehab-Replace Module). Therefore, once acquired, expansion assets are treated as "existing" assets and hence are subject to exactly the same decay curves, life-cycle cost profiles, prioritization rules and reinvestment budget constraint.

RESTRICTIONS TO ASSET EXPANSION INVESTMENTS

The Asset Expansion Module imposes three basic restrictions to expansion investments. These include:

- Minimum ridership requirements for investment eligibility
- Minimum and maximum constraints on rail miles built
- Investment expenditure scheduling

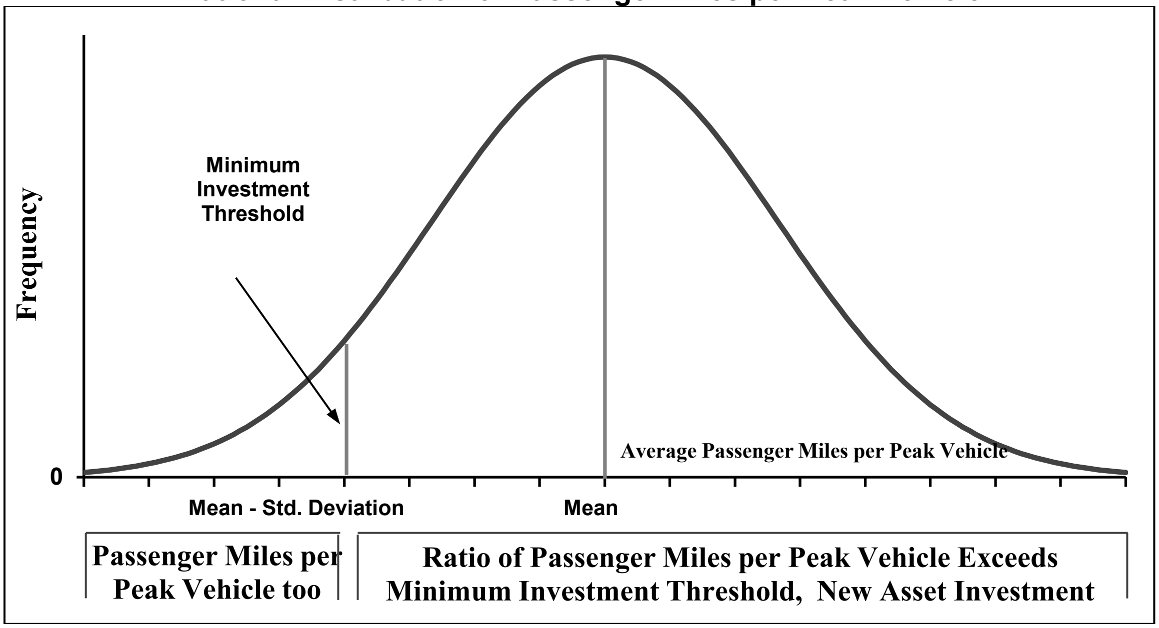
Each of these are described below.

Minimum Investment Threshold

To avoid investing in new expansion assets for those transit systems with low passenger miles per peak vehicle, the Expansion Asset Module requires that each agency–mode pass a minimum passenger mile per peak vehicle threshold before investment in that agency–mode is allowed[10]. While the user sets this threshold, this value is based on the national distribution of passenger miles per peak vehicles for each modal type as outlined in **Exhibit 3-1**.

[10] It is considered unreasonable to invest in asset expansion and maintain the ratio of passenger miles per peak vehicle if the value of this ratio is well below the national average.

Exhibit 3-1
National Distribution of Passenger Miles per Peak Vehicle



Specifically, the following relationship is used:

$$Minimum\ Investment\ Threshold_{Mode\ i} = (\mu_{Mode\ i} - \sigma * \delta) \quad (3\text{-}8)$$

Where $\overline{\mu}$ and σ are the mean and standard deviation of the national distribution of agency passenger miles per peak vehicle ratios (by mode) and δ is an input parameter set by the user. For initial module development, δ was set equal to unity. Agencies that fall below the minimum investment threshold in the early years of a model run can rise above that level in later years if the model predicts sufficient growth in agency ridership.

Investment Ceilings and Floors

In the real world, the rate of expansion in new rail investment is limited by the capacity of the operating agency to finance the investment and by the capacity of construction industry to build additional miles of guideway. The Asset Expansion Module explicitly recognizes these capacity limitations by setting a maximum investment ceiling of five miles per year for all modes (including expansion to any existing bus guideway investments). The Asset Expansion Module also imposes a minimum investment restriction of three miles per year on guideway investment for all modes to ensure that the Module does include investments in guideway segments that would be too short to justify high, fixed-project planning costs and construction workforce mobilization costs. These investment choices are intuitively reasonable but have been arbitrarily set. An empirical analysis of actual guideway investment practices represents an opportunity for further work.

The Asset Expansion Module keeps a running tally of the amounts that are not invested in any given investment period (year) due to the minimum and maximum investment constrains (i.e., both minimums not invested in and excess amounts beyond the annual maximum). These amounts are carried over investment calculations in a future period(s) when a maximum investment ceiling is not binding (i.e., when these is excess capacity for investment and more than sufficient investment to exceed the minimum).

EXPANSION ASSET MODULE OUTPUT

Rehabilitation and Replacement of Expansion Assets

Following its estimated date of "purchase", each expansion asset is decayed, rehabilitated, and replaced as needed using the same replacement and rehabilitation algorithms as used in the Rehabilitation and Replacement Module described above. All asset expansion expenditures — including purchase, rehabilitation, and replacement costs — are added to TERM's investment needs tally. Furthermore, all asset expansion investment costs are included in the model's capital investment cost–benefit analysis.

Recording of Asset Expansion Needs

The Asset Expansion Module calculates the asset expansion requirements of all agency-modes identified in the most current year of NTD data. The module then records these annual expansion needs estimates within TERM's Investment Needs Forecast Table, with investment records for each major asset category: including guideway, trackwork, facilities, systems, stations and facilities. As with other Investment Needs Forecast Table records the asset expansion investments record the related agency, mode, asset type, units invested, initial acquisition costs and ongoing rehab and replacement needs.

CHAPTER 4 - PERFORMANCE IMPROVEMENT MODULES

INTRODUCTION

While the Asset Expansion Module is designed to estimate the level of capital investment required to maintain existing transit service performance given projected growth in transit travel demand, the Performance Enhancement Modules estimate the level of investment required to improve service performance. Specifically, TERM includes two performance enhancement modules which estimate investment needs to meet the following performance improvement objectives:

- Increase average operating speeds of the lowest performing transit agencies
- Reduce vehicle occupancy rates for agencies with the highest passenger trips per peak vehicles ratios

Each of these modules is considered below.

OPERATING SPEED PERFORMANCE ENHANCEMENT MODULE

The Operating Speed Performance Enhancement Module identifies those US urbanized areas (UZA's) with average operating speeds well below the national average and seeks to raise those speeds to a minimum operating speed standard through the introduction of new transit investment. This module operates on the premise that average operating speeds for rail and bus rapid transit (BRT) are higher than for "regular" bus. Hence, the substitution of rail transit capacity in place of existing bus capacity in large urbanized areas or the substitution of BRT for bus in smaller urbanized areas is made to boost the average operating speed for the urbanized area as a whole.

The module defines average UZA transit operating speed as the weighted average speeds for all rail and bus modes, weighted by vehicle miles. Hence, the average transit operating speed for UZA x is given by the following expression:

$$AvgTransitSpeed_x = \frac{VehicleMiles_{Bus,x} * AvgSpeed_{Bus,x} + VehicleMiles_{Rail,x} * AvgSpeed_{Rail,x}}{VehicleMiles_{Bus,x} + VehicleMiles_{Rail,x}} \quad (4\text{-}1)$$

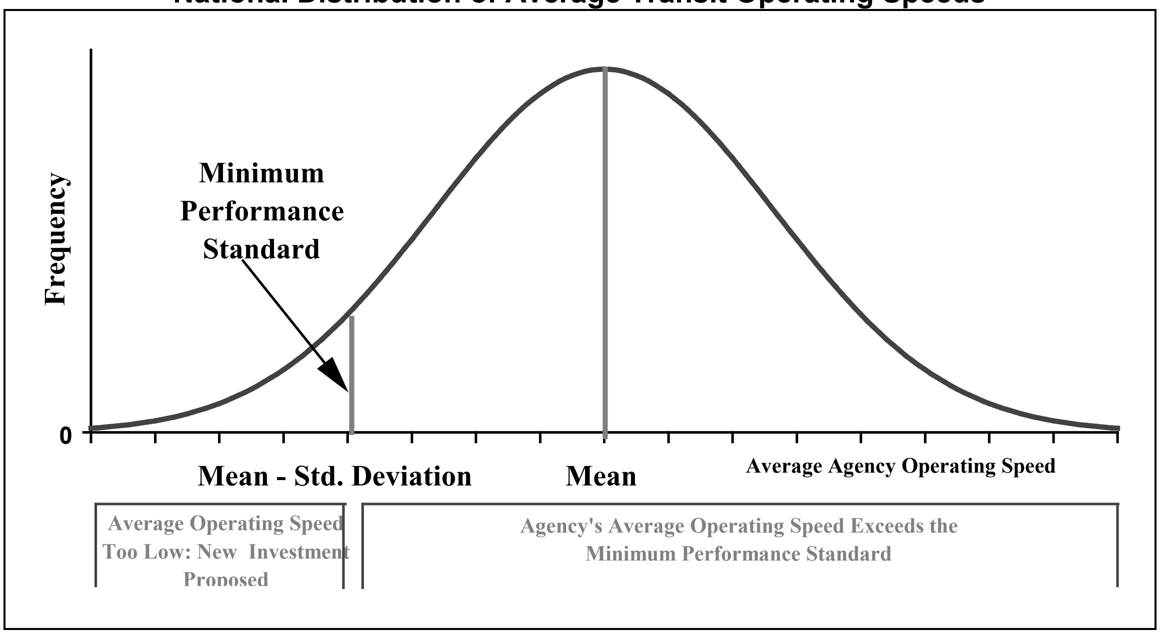
Minimum Operating Speed Performance Threshold

The primary challenge in using this module is to establish a credible minimum national performance threshold for average operating speeds. Once established, UZA's falling below this performance minimum would be considered candidates for performance improving capital investments while UZA's at or above the threshold would be considered "good performers" not requiring such investment. To meet this need, the minimum performance threshold, Φ, is defined as a function of the mean, $\overline{\mu}$, and standard deviation, σ , of the national distribution of average UZA transit operating speeds. Specifically,

$$\Phi = \overline{\mu} - \lambda\sigma \qquad (4\text{-}2)$$

Where λ >0 and is defined by the user in TERM. Hence, the performance investment criteria requires investment in new rail capacity and the substitution of rail service for bus service for those UZA's where *Avg. Transit Speed* $_x$ < Φ (see Exhibit 4-1). Under these conditions, investment in new rail facilities and the substitution of rail for bus service continues (thus raising the average UZA transit operating speed) until *Avg. Transit Speed* $_x$ = Φ. (Note: λ has been assumed to equal 1, see "Establishing the Minimum and Maximum Performance Threshold Values" below.)

Exhibit 4-1
National Distribution of Average Transit Operating Speeds



Investment Needs Estimation: Conversion Rates

In practice, the module operates by substituting new rail or BRT investments in place of existing bus investments until each agency's average operating speed is equal to Φ. First it estimates the rate at which bus passenger miles can be converted to rail or BRT passenger miles on a per vehicle mile basis on a UZA-by-UZA basis. It next estimates the rate at which rail or BRT vehicle miles can be converted to guideway miles of investment (assuming each guideway mile produces a set number of annual vehicle miles of service on average). Once again, this value is estimated on a UZA-by-UZA basis. Given these conversion rates, it is a simple matter to estimate — using the average transit speed formula — the level of new rail or BRT investment required to attain the minimum performance threshold. Calculation of these conversion rates and derivation of the investment needs formula is considered next. The formulas are specified as if an investment is being made for *Rail*.

1. Passenger Miles per Vehicle Mile $_{Bus}$ to Passenger Miles per Vehicle Mile $_{Rail}$: In general, rail is observed to produce more passenger miles on a per vehicle mile basis than does bus. Hence, for this analysis, we assume the following relationship:

$$\alpha_x = \left\{ \frac{\left(\frac{PaxMiles}{VehicleMiles}\right)_{Rail,x}}{\left(\frac{PaxMiles}{VehicleMiles}\right)_{Bus,x}} \right\} \tag{4-3}$$

Where $\alpha_x > 1$ and x is the UZA (TERM estimates the parameter α_x for each UZA).

2. Vehicle Miles per Track Mile $_{Rail}$: Each track mile is assumed to produce a positive number of vehicle miles of service on an annual basis. Here we assume the following relationship:

$$\beta_x = \left(\frac{VehicleMiles}{TrackMiles}\right)_{Rail,x} \tag{4-4}$$

Where $\beta_x > 1$ and x is the UZA (TERM estimates the parameter β_x for each UZA).

3. Vehicle Miles $_{Bus}$ to Track Miles $_{Rail}$: Given the conversion rates above, a one-mile reduction in bus vehicle miles in UZA x requires an investment of $\frac{\beta_x}{\alpha_x}$ track miles of rail guideway.

Guideway Investment Formula

Finally, attaining the minimum performance standard implies investing in rail or BRT guideway and substituting rail or BRT vehicle miles for bus vehicle miles until the performance threshold is attained. Under these conditions, the following will hold true.

$$\Phi = \frac{\overline{VehicleMiles}_{Bus,x} * AvgSpeed_{Bus,x} + \overline{VehicleMiles}_{Rail,x} * AvgSpeed_{Rail,x}}{\overline{VehicleMiles}_{Bus,x} + \overline{VehicleMiles}_{Rail,x}} \tag{4-5}$$

Where $\overline{VehicleMiles}_{y,x}$ is the level of vehicle miles required to attain performance standard Φ for mode y in UZA x. For rail, this represents an increase in vehicle miles while for bus it represents a decrease. Specifically, for rail there is the following relationship between current vehicle miles and the level required to meet the performance standard Φ.

$$\overline{VehicleMiles_{Rail,x}} = \Delta VehicleMiles_{Rail,x} + VehicleMiles_{Rail,x} \qquad (4\text{-}6)$$

Where, $\Delta VehicleMiles_{Rail,x} = \beta_x \, \Delta TrackMiles_{Rail,x}$ > 0 (from equation 4-4).

Similarly, for bus we can define the following relationships using the conversion rates developed above.

$$\overline{VehicleMiles_{Bus,x}} = \Delta VehicleMiles_{Bus,x} + VehicleMiles_{Bus,x}$$

Where, $\Delta VehicleMiles_{Rail,x} = \beta_x \, \Delta TrackMiles_{Rail,x}$ > 0 (see equation 4-3 and 4-4).

Substituting these relationships into the expression for Φ and solving for $\Delta TrackMiles_{Rail,x}$ yields the desired expression:

$$\Delta TrackMiles_{Rail,x} = \frac{\Delta AvgTransitSpeed_x * \left(VehicleMiles_{Bus,x} + VehicleMiles_{Rail,x}\right)}{\beta_x * \left(AvgSpeed_{Rail,x} - \left(\frac{1}{\alpha_x}\right) * AvgSpeed_{Bus,x}\right)} \qquad (4\text{-}7)$$

This expression provides the estimated increase in track miles to raise transit-operating speeds up to the performance minimum for those UZA's currently falling below that threshold. Note that all values in this expression are calculable using data series currently available from NTD.

VEHICLE OCCUPANCY PERFORMANCE ENHANCEMENT MODULE

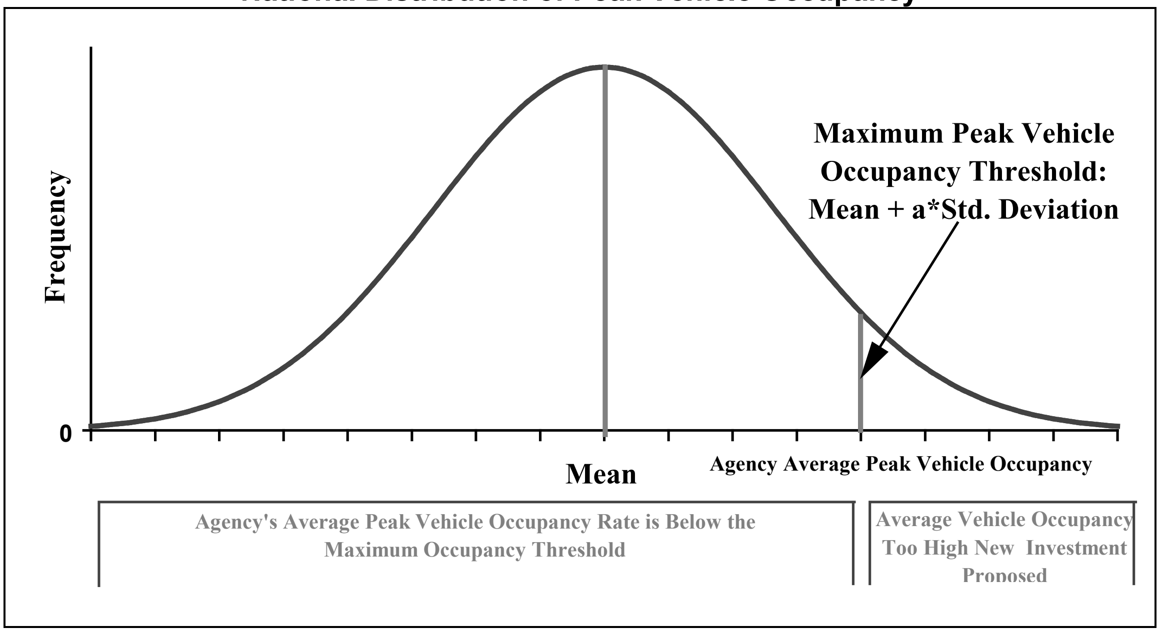
The goal of the Vehicle Occupancy Performance Enhancement Module is to identify those US transit agency-modes with vehicle occupancy rates that are well above the national average. The module then seeks to reduce crowding for these high occupancy agency-modes below some maximum occupancy threshold by investing in new vehicles and related support assets. TERM performs these investments on an agency-mode basis (i.e., individual transit modes are treated separately for each transit agency identified in NTD).

Similar to the Operating Speed Performance Improvement Module, the maximum peak vehicle occupancy threshold for the Vehicle Occupancy Performance Enhancement Module, Ω, is defined as a function of the mean, $\overline{\mu}$, and standard deviation, σ, of the national distribution of agency vehicle occupancy rates (by mode). Specifically,

$$\Omega = \overline{\mu} + \lambda\sigma \qquad (4\text{-}8)$$

Where λ >0 and is defined by the user in TERM. Hence, the performance investment criteria requires investment in new transit vehicles and related assets when *Avg. Vehicle Occupancy* $_x$ > Ω (see **Exhibit 4-2**). Under these conditions, the module invests in new vehicles (thus lowering vehicle occupancy rates) and related assets (including guideway, trackwork, facilities, systems and stations) until *Avg. Vehicle Occupancy* $_x$ = Ω.

Exhibit 4-2
National Distribution of Peak Vehicle Occupancy



Specifically, if mode y of agency x is currently operating at vehicle occupancy rate in excess of Ω, TERM invests in new mode y vehicles until the following condition holds true:

$$\Omega = \frac{Riders_{x,y}}{Vehicles_{x,y} + \Delta Vehicles_{x,y}} \qquad (4\text{-}9)$$

Hence the required investment in new transit vehicles for mode *y* is equal to:

$$\Delta Vehicles_{x,y} = \frac{Riders_{x,y}}{\Omega} - Vehicles_{x,y} \qquad (4\text{-}10)$$

INVESTMENT IN SUPPORTING ASSETS: PERFORMANCE IMPROVEMENT MODULES

After forecasting the number of track miles of rail to attain the minimum speed performance standard (equation 4-7) and the number of additional vehicles required to attain the desired maximum passengers per peak vehicle ratio (equation 4-10), the Improve Average Speed and Improve Vehicle Occupancy Performance Modules next estimate the related investment requirements for all other asset categories — including facilities, stations, guideway, and systems. The investment quantities for these remaining asset categories are estimated in exactly the same manner as was described in Chapter 3 for the Asset Expansion Module. Specifically, asset quantities for these additional asset categories are determined on a per track mile basis based on the historical relationships between the number of track miles invested per peak vehicle (by mode). For example, investment in new guideway route miles by the Improve Average Speed Module for mode y is determined using the following relationship:

$$\Delta Guideway\ Investment_{t=x,Mode\ y} = Route\ Miles\ Per\ Peak\ Vehicle_{Mode\ y} * \Delta Fleet\ Size_{t=x} \qquad (4\text{-}11)$$

Here, the historical ratio of $Route\ Miles\ Per\ Peak\ Vehicle$ for mode y is based on the modal average route miles per peak vehicle for that mode as calculated using the most recently published NTD data. Moreover, the proposed investment in additional guideway represents a mix of at-grade, elevated and subway alignments reflecting the nation's current investment in these alignment types by mode (as reported to NTD).

The cost of this investment for mode y is:

$$Guideway\ Expansion\ Needs_{Mode\ y} = \Delta Guideway\ Investment_{t=x,Mode\ y} Cost\ Per\ Route\ Mile_{Mode\ y} \qquad (4\text{-}12)$$

The Module utilizes similar equations to predict other fleet expansion support investments including those for trackwork, facilities, systems (train control, traction power, communications), and stations (at-grade, elevated and subway). Also included are estimated investment requirements for new guideway and facilities expansion including expenditures for right-of-way purchases, site preparation, environmental mitigation and project soft-costs.

ESTABLISHING THE MINIMUM AND MAXIMUM PERFORMANCE THRESHOLD VALUES

All the data used by the Improve Average Speed Module (equations 4-1 through 4-7) and Improve Vehicle Occupancy Module (equations 4-8 through 4-10) comes from the NTD, with the exception of λ which is input by the user. Note that the value of λ is input and controlled separately for each module. To date λ has been set equal to one (unity) for both modules, hence, establishing the minimum operating speed standard as the mean of the average operating speed less one standard deviation. Similarly, the maximum vehicle occupancy standard has been established as the mean of the average peak vehicle occupancy plus one standard deviation.

RESTRICTIONS TO PERFORMANCE IMPROVEMENT INVESTMENTS

Performance Improvement Module investments are subject to two of the three investment restrictions imposed on investments proposed by the Asset Expansion Module (Chapter 3). Specifically, restrictions imposed here include:

- Minimum and maximum constraints on rail miles built
- Investment expenditure scheduling

Detailed descriptions of these investment restrictions are provided in Chapter 3.

Performance investments to increase speeds are not subject to a crowding threshold (e.g., passenger miles per peak vehicle) as in the case of asset expansion investments to meet ridership increases. The fact that TERM makes investments in rail and BRT as replacements to existing bus services, means that the occupancy rates of remaining bus services are assumed to be the same as they were before the speed enhancing investments were made.

Performance enhancing investments to reduce occupancy rates are implicitly subject to a minimum passenger miles per peak vehicle threshold, since these investments are only made by TERM in areas with above average occupancy rates.

CHAPTER 5 - BENEFIT–COST ANALYSIS

INTRODUCTION

This chapter provides a detailed description of TERM's benefit-costs analysis. TERM can be run with or without the benefit-cost module but, when implemented, all of the investments identified in TERM's capital investment requirements estimates must successfully pass the model's benefit-cost analysis. If an investment "fails" the benefit-cost test (i.e., if B/C < 1), it is rejected, and its costs are not added to the model's tally of national transit investment needs. If the investment passes the benefit-cost test, the investment needs tally is updated to include the investment costs. All of TERM's benefit-cost tests evaluate proposed investments over a 20-year time period.

BENEFIT–COST RATIOS: AGENCY/MODE VS PROJECT-BASED EVALUATIONS

TERM uses two separate modules to estimate the benefit-cost ratios of the transit capital investments it proposes. Benefit-Cost Module 1 evaluates the effectiveness of all investments to "maintain or improve conditions" proposed by TERM's Rehab-Replacement Module and all investments to "maintain performance" as proposed by the Fleet Expansion Module. Benefit-Cost Module 2 evaluates investments proposed to improve performance in terms of average speed and occupancy levels as proposed by TERM's Performance Improvement Modules).

Benefit–Cost Module 1: Rehab/Replace and Asset Expansion

Benefit-Cost Module 1 evaluates the overall cost-effectiveness of capital investments by each agency-mode identified in NTD (e.g., "MBTA Bus"). **Specifically, this module compares the discounted stream of capital investment costs (rehab, replacement and expansion) and operating costs for each agency-mode with the discounted stream of benefits anticipated from continued agency-mode operations over a twenty-year period.** If the projected benefits exceed projected capital and operating costs, TERM includes its rehab-replacement and asset expansion needs estimates for this agency-mode in its tally of national transit investment needs. Otherwise, this agency-mode fails the "full" Module 1 benefit-cost test and must then undergo a "partial" benefit-cost test to determine whether some portion of that agency-mode's assets should be permitted to pass the test. Those assets that ultimately do not pass either the full or partial benefit-cost tests will have their projected rehab/replacement and asset expansion needs are omitted from TERM's capital needs projections.

Full Benefit-Cost Test – Step-1: The benefit/cost ratio calculation performed by Module 1 is shown in equation (5-1) below; i is the discount rate, j is the agency-mode and t is time measured in years (from 1 to 20). Benefits here include those benefits accruing to current riders from continued agency-mode operations plus those benefits to new riders from ongoing fleet expansion as required to serve the projected growth in ridership (i.e., maintain performance).

Benefit-Cost Module 1: Step 1 – Evaluate All Proposed Investments

$$Benefit/Cost\ \ Ratio_{agency-mode\ j} = \tag{5-1}$$

$$\left\{\frac{\sum_{t=1}^{20}\left\{\left(\left(User,\ Agency\ \&Social\ Benefits_{j,t=0}\right)*\left(1+TMP\ Growth_{j}\right)^{t}\right)/\left(1+i\right)^{t}\right\}}{\sum_{t=1}^{20}\left\{\left(Replace\,Cost_{j,t}+Expansion\ Cost_{j,t}+\left(O\ \&\ M\,Costs_{j,t}*\left(1+TPM\ Growth_{j}\right)^{t}\right)\right)/\left(1+i\right)^{t}\right\}}\right\}$$

Note that this expression evaluates the discounted streams of all agency-mode benefits and costs (i.e., the sum for existing operations and for proposed capital improvements) within the context of a single benefit-cost calculation. This means that the cost-effectiveness of all the capital investment necessary to maintain an agency's ongoing operations, holding asset conditions and performance levels constant, is evaluated in its entirety rather than the cost effectiveness of individual replacement needs such as adding single track segments or bus vehicles.

Full Benefit-Cost Test – Step-2: If the dollar amount of the projected discounted benefits (numerator) exceeds or is equal to the dollar amount of projected capital and O&M expenditures (denominator), the B/C ratio is greater than or equal to 1, and the estimated twenty-year capital investment needs for that agency-mode are included in TERM's estimate of total US transit capital investment needs. If, in contrast, the agency-mode fails the benefit-cost test by generating a B/C ratio less than 1, TERM conducts a second-tier analysis to determine if the agency-mode will pass the benefit-cost test if TERM's proposed maintain performance investments and benefits are excluded from the analysis. In this second-tier analysis, Benefit-Cost Module 1 recalculates the B/C ratio after removing all proposed investment costs and benefits associated with performance improvement (i.e., capacity utilization reduction and fleet expansion investment removed. See equation 5-2 below. Note that both benefits in the numerator and operating costs in the denominator decline as investments are removed.

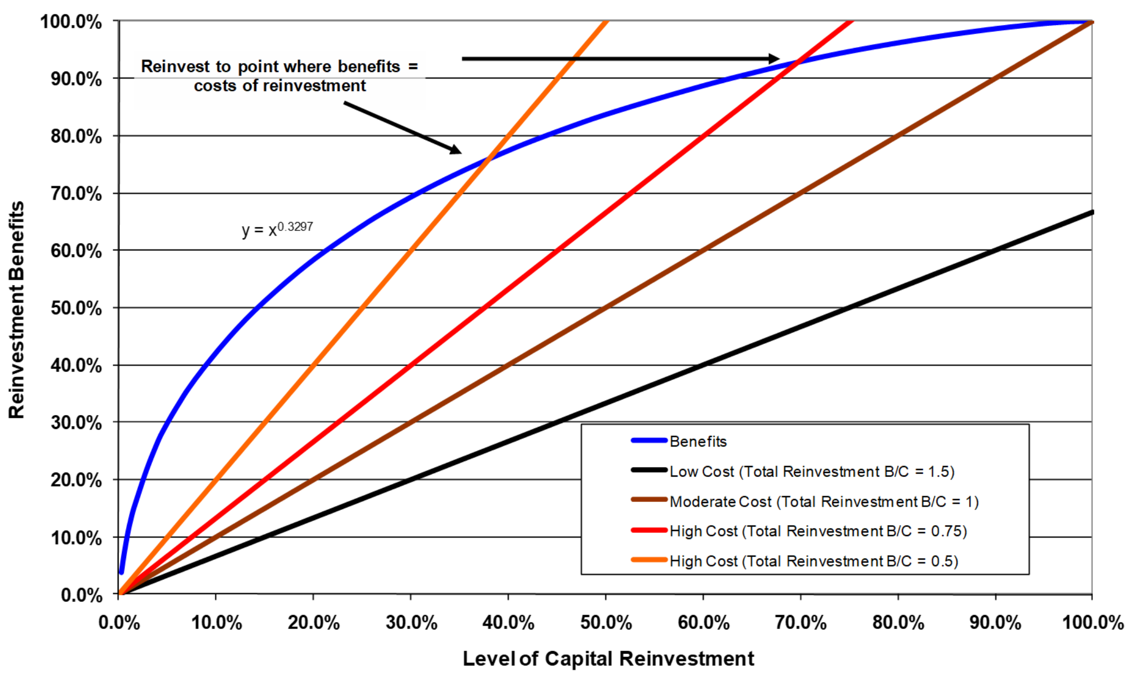
Benefit-Cost Module 1: Step 2 – Remove Fleet Expansion Investments

$$Benefit/Cost\ \ Ratio_{agency-mode\,j} = \tag{5-2}$$

$$\left\{\frac{\sum_{t=1}^{20}\left\{\left(\left(User,\ Agency\ \&\ Social\,Benefits_{j,t=0}\right)*\left(1+TPM\ Growth_{j}\right)^{t}\right)/\left(1+i\right)^{t}\right\}}{\sum_{t=1}^{20}\left\{\left(Replace\,Cost_{j,t}+O\ \&\ M\,Costs_{j,t}\right)/\left(1+i\right)^{t}\right\}}\right\}$$

Partial Benefit-Cost Test – Step-3: If the agency-mode now passes the benefit-cost test with only the rehab and replacement investments, these remaining capital investment needs are added to the national investment needs tally. If not, then the agency-mode must be evaluated using the "Partial" benefit cost test. The partial test operates under the assumption that there are diminishing returns to transit investment such that if less productive (i.e., lower benefit generating) assets are removed from benefit-cost consideration, then the overall benefit-cost ratio for the agency mode will improve (increase) and if enough of the lowest benefit-producing assets are removed, the overall benefit/cost ratio for the remaining assets will attain a passing value of 1.0. This partial benefit-cost test is displayed conceptually below (**Exhibit 5-1**). The relationship used to model diminishing returns was estimated using actual station level (rail) and route level (bus) data to assess the range of benefits to productivity across transit assets at a single operator (in this case both data sets were obtained from NYCT).

Exhibit 5-1
Rail Investment Benefits vs Costs
(Indicies Relative to Today's Service Levels)



*Based on station boardings data from NYCT

To determine which assets pass and which assets fail the partial benefit-cost test, TERM does the following. First, all agency-mode assets are ranked from lowest- to highest-used based on the product of the asset's estimated condition (at the start of the model run) multiplied by its expected useful life (see **Exhibit 5-2**). This has the effect of providing low values (high rankings) to assets (1) with lower condition ratings and (2) with short lives (such that multiple replacements may be required over the 20-year model run). The needs of better-condition assets with longer expected lives are addressed last. After all agency-mode assets have been ranked using this approach, TERM uses the diminishing returns relationship depicted in the chart above to determine what proportion of agency-mode assets (by value) will be permitted to pass the benefit cost test (such that the aggregate

B/C ratio across all passed assets equals 1.0. TERM then orders the ranked assets (lowest to highest) and assigns a B/C ratio of 1.0 until the total value of passing assets has been attained. Those assets not assigned a B/C ratio of 1.0 retain their initial (failing) B/C ratio and hence are not included in TERM's national investment needs for the balance of the model run. Note that this action assumes that the service provided by these agency-modes is continued, but that capital reinvestment in these assets is suspended for the remaining time period covered by the model run.

Exhibit 5-2
Partial Benefit-Cost Test Ranking

	Life Expectancy									
Condition	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
5	50	100	150	200	250	300	350	400	450	500
4	40	80	120	160	200	240	280	320	360	400
3	30	60	90	120	150	180	210	240	270	300
2	20	40	60	80	100	120	140	160	180	200
1	10	20	30	40	50	60	70	80	90	100

Note that the partial benefit-cost test ranking procedure represents a simple and preliminary solution to this issue. FTA should investigate more sophisticated approaches to this problem in future years.

Future Improvement Opportunity: Recognize Increasing Benefits of Transit Re-Investment as Physical Conditions Decline Benefit-Cost Module 1 does not recognize the possibility that as the condition of the assets of an agency-mode that has failed to pass the benefit-cost test continues to decline, it is likely that the agency-mode could eventually pass a more comprehensive benefit-cost test at some point over TERM's twenty-year time horizon if the overall decline in condition and the increasing benefits of investing in a declining system were recognized by the benefit-cost module.

Benefit–Cost Module 2: Performance Improvement Investments

Benefit-Cost Module 2 assesses the effectiveness of investments proposed by TERM's two improve performance sub-modules: (1) to improve (increase) average speed and (2) to improve (reduce) average occupancy modules. As described in earlier sections of this manual, these sub-modules estimate the amounts of investment required by agencies operating either well below national average operating speeds or well above national average occupancy rates per peak vehicle to reach acceptable speed and occupancy levels. As shown below, Benefit-Cost Module 2 compares the expected stream of benefits from a performance improving investment with the expected stream of capital and ongoing operating costs from the investment.

For these investments, the benefit-cost ratio is calculated as follows:

Benefit-Cost Module 2: Performance Investments

$$Benefit - Cost\ \ Ratio_{Performance\ Improving\ \ Investments\ for\ j} = \quad (5\text{-}3)$$

$$\left\{ \frac{\sum_{t=1}^{20} \left\{ \left(\left(Project\ User, Agency\ \&\ Social\ Benefits_{j,t=0} \right) * \left(1 + TPM\ Growth_j \right)^t \right) / (1+i)^t \right\}}{\sum_{t=1}^{20} \left\{ \left(Project\ Capital\ Costs_{j,t} + O\ \&\ M\ Costs_{j,t} \right) / (1+i)^t \right\}} \right\}$$

Where *i* is the discount rate, *t* is the year, and *j* is the proposed project for either a specific agency-mode (sub-module 1, to improve occupancy) or a specific UZA (sub-module 2, to improve speed).

As in the case of Module 1, investments with a B/C ratio ≥ 1 are included in TERM's estimated total National performance improvement investment needs estimate while those with a B/C of less than one, i.e., failing the test, are omitted from this estimate. The cost and benefit calculations are based on actual local operating costs, local transit fares (as reported to the NTD) and local ridership projections (as reported by MPOs). A more detailed account of this analysis is provided in Chapter 4.

Note that Benefit-Cost Module 2 analyzes the cost effectiveness of performance improving investments on an agency-mode basis for occupancy improvements and on an urbanized area (UZA) basis for average speed improvements rather than at a corridor-specific level.[11] This analysis is not undertaken at the corridor specific level because consistent and comprehensive corridor-specific data (e.g., ridership, emissions, noise, current transit investment, road network configuration, mode-split data, etc.) are not currently available.

IDENTIFICATION AND CALCULATION OF INVESTMENT BENEFITS

This section provides an overview of the general benefits evaluated by the Benefit-Cost calculations discussed in the previous section. Subsequent sections will provide a more detailed discussion of the precise calculations used to provide quantitative estimates of the benefits to transit riders, agencies and society and the sources of data used for these calculations.

Transit Benefits Recognized by TERM

Exhibit 5-3 provides a list of the transit investment benefits currently recognized by TERM. For analytical purposes, benefits are first categorized by the stakeholder impacted by the investment (e.g., transit riders, local agencies and society) and second by the type of

[11] This in contrast to the "real world" New Starts planning process where projects are developed based on the travel needs and conditions within specific "priority" corridors. TERM currently does not perform corridor analysis because transit agency data is not available and would difficult to collect on this basis.

investment made (rehab-replace, expansion, or performance improvement). Detailed descriptions of the calculations and supporting data sources for each type of benefit, according to the stakeholder group impacted, are provided below.

BENEFITS TO TRANSIT RIDERS

Most of the benefits from transit investment in existing and new assets accrue to existing and new transit riders. The main benefits enjoyed by these transit riders include:

Exhibit 5-3
Transit Benefits Recognized by TERM

Group Impacted	Investment Type	Benefit	Investment Mode	Alternative Mode
Transit Riders	Rehab-Replace / Expansion	Maintaining the condition and performance of an existing mode ensures that current users of that mode continue to enjoy lower trip costs (fare + travel time + wait time) relative to the next-best modal alternative	Rail Bus	Bus/Auto Auto/Taxi
	Reduce Vehicle Occupancy	Reduced wait times on existing routes through higher capacity/increased service frequency (There is no modal alternative here, just an improvement to an existing mode by adding additional fleet vehicles and supporting assets)	Rail Bus	Rail Bus
	Increase Average Speed	Reduced travel times on existing routes through higher capacity/increased frequency	Rail Bus	Bus/Auto Auto/Taxi
Local Transit Agency	Rehab/Replace	Reduced O&M costs: <u>This benefit not currently included in TERM</u>	All	
Society	All	Reduced Auto VMT's leading to reductions in: - Congestion delay - Emissions (Air) - Emissions (Noise) - Roadway wear - Accidents - Highway admin costs	All	

- Travel Time Savings
- Reduced Auto Costs
- Improved Mobility
- Improved Quality of Service

TERM's analysis is limited to benefits that are readily quantifiable using available data sources (e.g., NTD, FHWA *Final Report on the Federal Highway Cost Allocation Study*). TERM's analysis compares the sum of user costs for a trip when transit investments have been made with the sum of these costs for a trip when no transit investments have been made. In most instances, this means comparing the rider's costs on the selected transit mode with the rider's cost on the mode which is the next-best alternative. The user cost of a transit trip is assumed to equal the sum of the user's out-of-pocket fare for the trip and cost of the user's time for making the trip. The cost of the user's time includes the cost of "in-vehicle" travel time and the "out-of-vehicle" time spent waiting for the transit vehicle to arrive. Recognizing that riders consider the opportunity cost of time spent waiting to be double the opportunity cost of the time spent "in motion", a transit rider's total trip cost is given (for a rail trip) by (5-4): (Wait time is calculated as average headway divided by 2. See Exhibit 5-3.)

$$Total\,Trip\,Cost_{Rail} = Fare_{Rail} + \left(Veh\,Time_{Rail} + 2 * Wait\,Time_{Rail}\right) * Value\,of\,Time \qquad (5\text{-}4)$$

Within TERM's Benefit-Cost modules, the total trip cost for a rail trip is compared to the next-best modal alternative available to the rider if (re-) investment in rail is not made. This assumes that the rider would choose his or her next-best mode to rail if there were no investment in rail. For many riders (e.g., transit-dependent riders) the next-best option to rail is bus. For these riders, the net benefit of the investment in rail is given by equation (5-5), which measures the change in trip cost resulting from a switch from rail to bus. If the value of time saved by the investment exceeds any additional out-of-pocket fare cost resulting from the change, the net benefit to the rider will increase and the total user cost of the trip will go down.

$$\Delta Trip\ Cost_{Rail\,vs\,Bus} = \qquad (5\text{-}5)$$
$$\left(Fare_{Rail} - Fare_{Bus}\right) + \left[(Veh\,Time_{Rail} - Veh\,Time_{Bus}) + 2 * (Wait\,Time_{Rail} - Wait\,Time_{Bus})\right] * Value\ of\ Time$$

Alternatively, for those users for which auto is the next-best-mode of travel, the difference in shifting from auto to rail is given by:

$$\Delta Trip\ Cost_{Rail\,vs\,Auto} = \qquad (5\text{-}6)$$
$$\left(Fare_{Rail} - Auto\,Trip\,Cost\right) + \left[(Veh\,Time_{Rail} - Veh\,Time_{Auto}) + 2 * Wait\,Time_{Rail}\right] * Value\ of\ Time$$

Note that while automobile owners are assumed to have no "wait" time (and associated waiting cost), they are assumed to incur additional auto related costs including fuel, parking, insurance, maintenance and depreciation when they use their own vehicle.

TERM also considers two modal alternatives for current bus riders—automobile or taxi. The difference in user cost between the bus and auto or taxi options is quantified below; in equation (5-7) for a bus rider switching to an auto trip and in equation (5-8) for a bus rider shifting to a taxi trip[12].

$$\Delta Trip\ Cost_{Bus\ vs\ Auto} = \qquad (5\text{-}7)$$
$$\left(Fare_{Bus} - Auto\,Trip\,Cost\right) + \left[(Veh\,Time_{Bus} - Veh\,Time_{Auto}) + 2 * Wait\,Time_{Bus}\right] * Value\ of\ Time$$

$$\Delta Trip\ Cost_{Bus\ vs\,Taxi} = \qquad (5\text{-}8)$$

[12] It has been proposed that walking be added as a third modal alternative to bus. This option will likely be introduced under the 2006 work plan.

$$\left(Fare_{Rail} - Fare_{Taxi}\right) + \left[(Veh\,Time_{Rail} - Veh\,Time_{Taxi}) + 2*(Wait\,Time_{Rail} - Wait\,Time_{Taxi})\right]*Value\ of\ Time$$

Key Assumption: Inter-Modal Trip Cost Comparison Assumptions –TERM assumes that the distances covered by competing modes are the same. **This means that differences in travel times between modes are assumed to result entirely from differences in the average travel speed of each mode.** Any changes in time that may occur because of difference in the length of the route are not considered because there is no information available on these differences. (Note: TERM could be enhanced by including an estimate of the differences in access costs between modes.)

Equations (5-5) through (5-8) each considers the user cost differences between two modes. However, users of an existing mode also benefit from investments in that mode *beyond what is needed to maintain performance* (i.e., expansion to meet projected ridership growth). In this case, TERM again measures the benefits to transit users in terms of a reduction in total trip costs. Specifically, the addition of fleet capacity is assumed to lead to increased service frequency with shorter wait and dwell times. With fewer passengers per vehicle, boardings/alightings take less time, leading to increased average speeds and reducing the users' total trip costs. The difference between a pre- and a post-performance improving investment for an existing bus operator is outlined in expression (5-9) below. (Note that fares are assumed to remain constant when performance is improved by adding vehicles since there is no mode switch. By comparison, performance improving investments in faster rail or BRT include a fare change.)

$$\Delta Trip\ Cost_{Bus\ (New)\ vs\ Bus\ (Old)} = \tag{5-9}$$
$$\left[(Veh\,Time_{Bus\ (New)} - Veh\,Time_{Bus\ (Old)}) + 2*(Wait\,Time_{Bus\ (New)} - Wait\,Time_{Bus\ (Old)})\right]*Value\ of\ Time$$

Transit Rider Benefits by Investment Type

TERM assumes that a transit user will "benefit" from a new investment or continued re-investment in an existing mode if the total travel cost for that mode is lower than that of the next-best alternative. As detailed in **Exhibit 5-4** below, the total travel costs for each mode and its alternative, as considered by TERM, varies according to investment type.

Data Sources and Calculations for Equation Terms

Exhibit 5-5 below lists the variables used in equations (5-4) through (5-9) and describes the methodology and the data used to calculate them. This exhibit also identifies and defines all the ridership terms used by TERM to aggregate individual user cost savings across all transit users. These aggregating expressions are considered in the "summary of User Benefits" section below.

Use of Agency-Mode versus Regional (UZA) Data – TERM uses agency-mode data for all analyses associated with all investments for rehab and replacement (to "maintain or improve conditions"), fleet expansions by reducing occupancy on overcrowded transit systems (to "maintain performance" and "improve performance"). In contrast, TERM uses UZA level measures (average speed and ridership) when evaluating the impacts of investments undertaken to increase average speed. Both the agency-mode and UZA data are available from NTD. UZA values are calculated as the average or sum of the data as reported to the NTD for all agencies and modes located in a UZA.

Exhibit 5-4
Investment Benefits by Investment Type as Assessed by TERM

Investment Type	Investment Benefits
Rehab-Replacement	Ongoing re-investment in an existing agency-mode ensures the operation of that mode into the future. For existing users, the benefit of re-investing in and continuing to operate a mode is the net cost savings to users of that mode compared with the "next-best," i.e., or next-least-expensive alternative. TERM assigns a zero net-benefit value to continued re-investment in the primary mode (bus) for those users in the rare instances where the alternative mode (auto) turns out to be cheaper than the primary mode. It is extremely rare that all alternatives are cheaper. The user benefits from re-investment in the primary mode are either out-of-pocket savings, travel time savings, or both.
Fleet Expansion	Expansion of an existing agency-mode fleet to meet projected ridership growth ensures that current transit benefits (i.e., "performance") are maintained for existing users (relative to the next-best alternatives) and that these benefits accrue to new transit riders who are projected to start using the system in future years.
Reduce Vehicle Occupancy	TERM reduces the occupancy rates for high occupancy agency-modes by investing in fleet and system expansion beyond the levels required to service projected passenger growth. TERM assumes that the benefits of these fleet expansion investments accrue to users in the form of shorter wait times resulting from more frequent headways. Headways (wait times) for individual modes are reduced by the following factor: $[1/(1+(\text{Fleet Size}_{New}/\text{Fleet Size}_{Old}))]$. With fewer riders on each vehicle, boardings and alightings are made more quickly, leading to reductions in dwell time and overall travel time as shown in equation 5-9. As the performance improving investments attract riders from competing modes, additional user and societal benefits from the investment are generated. (equations 5-5 through 5-8).
Increase Average Speed	TERM increases average operating speeds for UZA's with low average operating speeds by investing in higher-speed transit modes (BRT, LRT or HRT). If a higher speed transit mode does not exist in a UZA with a low average operating speed, the user investment benefits are assessed relative to the next-best alternatives modes as considered in equations (5-5) though (5-8) above. If the selected higher speed investment mode currently operates within that UZA, the increased investment level yields a reduction in user travel times (equation 5-9), which TERM specifically evaluates as a reduced wait time using the factor: $[1/(1+(\text{Fleet Size}_{New}/\text{Fleet Size}_{Old}))]$. As these investments have a positive impact on ridership, additional user and societal benefits from the investment are generated(equations 5-5 through 5-8).

Exhibit 5-5
Calculation and Data Sources for Equation Terms: Transit User Benefits

Equation Term	Sub-Terms (if any)	Calculation	Data Sources
Fare $_{Agency\text{-}Mode}$		= *Fare Revenues / Unlinked Trips*	NTD
Veh Time $_{Agency\text{-}Mode}$		= *Average trip distance / average mode speed*	⇓
	Avg. Trip Distance	= *Passenger miles / unlinked trips*	NTD
	Avg. Mode Speed	= *Revenue Miles/Revenue Hours*	NTD
Wait Time $_{Agency\text{-}Mode}$		= *Average Headway / 2 (note: headway times are capped out at 20 minutes).*	⇓
	Avg. Headway	= *1/ Frequency*	⇓
	Frequency	$= [Average\ Speed / Total\ Route\ Miles] * Peak\ Vehicles$	NTD
Value of Time		*Wage based calculation supplied by OST*	OST
Auto Trip Cost		= *[(Auto cost per mile)*(Avg. trip distance)] + (daily parking cost)/2: Cost per mile includes fuel, insurance, maintenance and depreciation; parking costs by UZA size strata* http://www.colliers.com/Corporate/News/ParkingSurvey02003	AAA, NTD, Colliers parking rate study
Fare $_{Taxi}$		= *Rate per first mile + rate per subsequent mile *(avg. trip distance – 1): Rates by UZA size stratum*	Sample of UZA's by stratum
Ridership $_{Agency\text{-}Mode}$		= *Annual unlinked trips (for existing modes)*	NTD
Ridership $_{New\text{-}Mode}$		=*(unlinked trips per route mile)*(new route miles),* *Only for investment in avg. speed improvements*	NTD, TERM
Dependent Rider Share		*Percent of transit riders that do not have auto access, by mode – Input by agency-mode*	NPTS
TPM Growth $_{UZA}$		*Projected annual growth in TPMs, projected growth in VMT's used if local MPO does not generate a TPM forecast*	Sampled MPOs
ξ_{Mode}		*Trip cost elasticity for each mode*	Literature review

Aggregating Transit User Benefits

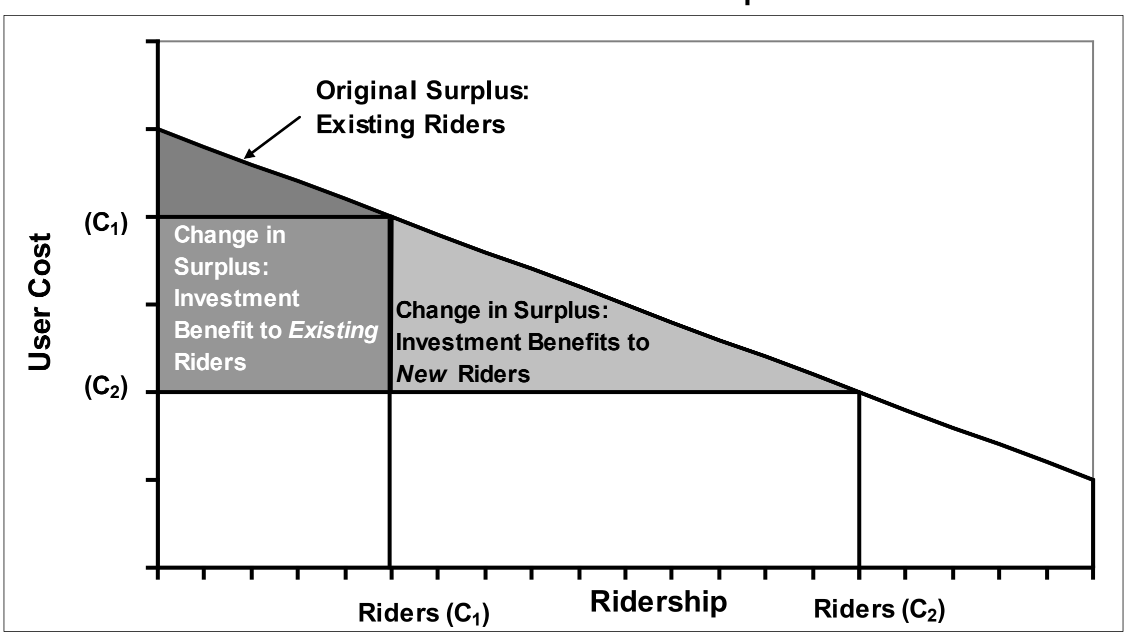
So far, only the benefits to individual transit riders from transit investment have been considered. The following subsections describe how TERM aggregates these individual user benefits to derive the total benefits to *all* transit users. The discussion includes an analysis of the elasticity impacts of each type of transit investment. It also describes how dependent and non-dependent transit users are characterized and used to assess the market size for each transit mode's next-best travel model alternative (e.g., what percent of rail riders would choose bus as their next-best alternative and what percentage would choose auto).

Benefit Aggregation and Consumer Surplus

TERM uses the concept of "consumer surplus" to aggregate the benefits of transit investments to multiple transit users. Consumer surplus is an economic concept used to measure the difference between the value a consumer places on a product (i.e., what the consumer is willing to pay for that product) and the product's price. For example, if the consumer's value of a product is above the product's purchase price, they are said to enjoy a positive consumer surplus. The consumer surplus is based on the notion that given a downward sloping demand curve, i.e., as price falls the demand for a product increases, a certain number of consumers would, in principle, be willing to pay more to purchase a product than they do. There are also a certain number of consumers who are not willing to pay the market price for a product. These consumers are said to have negative surplus value and choose not to purchase the product at all. At the margin, a consumer who values a product equally to its price would only continue to purchase the product as long as its price remains the same or decreases (but not if its price were to rise).

In the context of TERM, the product is a transit trip and the price is the total or "user" cost of the that trip to the transit rider. This user cost includes fare cost, travel time cost (in-vehicle) and wait time cost (out-of-vehicle) and access cost (not currently included in TERM). If one assumes a downward sloping demand curve for transit services (see **Exhibit 5-6**), all riders currently using transit enjoy some level of consumer surplus, with the exception of the "marginal rider" whose value of the transit trip equals the cost. For all of the existing riders, the aggregate consumer surplus is given by the area below the demand curve and above the current cost of a transit trip (C_1).

Exhibit 5-6
Transit Rider's Consumer Surplus



If the total user cost of a transit trip drops in response to the time saving impact of a new capital investment (from C_1 to C_2 for example), existing transit riders experience an increase in consumer surplus while new users — attracted by the drop in user trip cost — also capture some surplus value. Assuming a linear demand curve, the difference in benefits accruing to new and existing riders from a reduction in the user cost of a transit trip can be measured using the equations presented in **Exhibit 5-7**. These equations measure changes in the areas below the demand curve following reductions in user trip costs.

The change in user trip costs ($\Delta Trip\ Cost$) calculated by equations (5-5) through (5-9) is applied in equations (5-10) and (5-11). The value of ridership in equation (5-10) or value of the change in ridership in equation (5-11) depends on the type of investment being considered. Investments to "maintain conditions and performance" (i.e., rehab, replace and expansion to meet projected growth in demand) are all assumed by TERM to accrue to existing users. These riders' benefits are calculated assessed using equation (5-10),[13,14] based on the current annual ridership for each agency-mode ($Ridership_{\ Agency\text{-}Mode}$). Over the 20-year projection period, total user benefits increase by the projected growth in ridership ($TPM\ Growth$) as specified in equation (5-1).

Exhibit 5-7

Consumer Surplus Measures for New and Existing Riders

$$\textit{Benefits to Existing Riders} = \Delta Trip\ Cost * Ridership_{Old} \qquad (5\text{-}10)$$

$$\textit{Benefits to New Riders} = \frac{\Delta Trip\ Cost}{2} * \Delta Ridership \qquad (5\text{-}11)$$

In contrast to investments to maintain performance, investments to "*improve* performance" benefit both *existing* riders (for improvements to an existing agency-mode) and *new* riders (attracted by a reduction in user cost, either for an existing agency-mode or for investment in a new modal alternative to improve speed). In this case, the benefits to *existing* riders are evaluated using (5-10). TERM uses different methods to estimate the number of new

[13] Note that investments in fleet expansion are designed to "maintain the current performance" of existing systems by supporting projected growth in "new" transit riders while keeping user costs constant. Hence, these investments do not attract "new" riders from competing, alternative modes, they only maintain transit's current market share (within an expanding market) by maintaining current performance levels. In contrast, performance improving investments reduce user costs and attract new riders.

[14] TERM does not consider the effect of investments to improve the physical asset conditions of an existing agency-mode on transit ridership, due to the difficulty of assigning monetary values to subjective passenger assessments. In theory this investment would be expected to lead to an increase in ridership as the transit experience becomes more pleasant. In a sense, maintaining conditions is a proxy for maintaining the user benefits associated with these conditions.

riders resulting from performance improvements to *existing* modes and for performance improve for investments in *new* modes.

Performance Improvements for Existing Modes: TERM uses an arc elasticity based adjustment factor to estimate the increase in ridership resulting from performance improving investments for existing modes[15] (See equation (5-12)),

$$\Delta Ridership = 2 * Ridership_{Old} * \left[\frac{\xi_{Mode} * \Delta Trip\,Cost \Big/ \left(Trip\,Cost_{New} + Trip\,Cost_{Old}\right)}{1 - \left(\xi_{Mode} * \Delta Trip\,Cost \Big/ \left(Trip\,Cost_{New} + Trip\,Cost_{Old}\right)\right)} \right] \quad (5\text{-}12)$$

Where $Ridership_{Old}$ is equal to the current number of annual unlinked trips for that mode as reported by NTD and ξ_{Mode} is the price elasticity of demand for a transit trip for the existing transit mode.

Performance Improvements for New Modes: Ridership resulting from investment in new modes is assumed to occur in the same proportion as the average national ridership on that mode. More specifically, the change in ridership resulting from investment in a speed improving mode in a UZA where the speed improving mode does not exist, is assumed to equal the average number of unlinked trips per route mile for that mode on a national basis as reported in the NTD multiplied by the number of new route miles of the investment.

$$\Delta Ridership = (Unlinked\,Trips\,Per\,\,Route\,Mile_{New\,Mode}) * (New\,Route\,Miles_{New\,Mode}) \quad (5\text{-}13)$$

Finally, the change in trip cost before and after the investment contained in equations (5-10) and (5-11) and the magnitude of the change in ridership in equation (5-11), as estimated by equations (5-12) and (5-13), depends on which modes are included in these before and after comparisons. TERM assumes that either bus or auto is the next-best alternatives to rail, and either auto or taxi the next-best modal alternatives to bus. The method used by TERM to analyze how riders "choose" between these alternative modes is described in the next section.

Next-Best Modal Alternatives: Transit Dependent versus Non-Transit Dependent Riders

Equations (5-5) through (5-8) above compare user costs for rail and bus with the "next-best" modal alternatives for current transit riders. TERM assumes that a rider's choice of their next-best alternative is determined solely based on their assumed "transit dependency".

A transit dependent rider is defined as lacking auto access and hence selects transit as their preferred (lowest cost) alternative for local travel. A transit dependent rider will only

[15] Unlike "point" elasticity values, which change from one point to the next along a demand curve, arc elasticity values remain relatively constant.

select rail over bus if rail has the lower user cost, which could result in some cases from the fact that rail has a higher average operating speed. If no rail service is available, TERM assumes that a transit dependent rider's lowest cost alternative is bus. If bus is the only available transit alternative, TERM assumes that a transit dependent rider's only option to bus is a local (high cost) taxi service or forgoing the trip. (The model will be revised to include more options based on data from the National Household Travel Survey and the Transit Performance Monitoring System.) .

In contrast, TERM assumes that current transit riders who are not transit dependent (i.e., riders with auto access) *will always select auto as their next-best alternative*, regardless of their first choice transit mode. Hence, a non-dependent transit rail rider is assumed to shift to auto (not bus) if their rail service is discontinued. Similarly, non-dependent riders currently using bus are assumed to switch to auto (and not to rail) if their bus service is no longer available.

Exhibit 5-8 below outlines the choice options for dependent and non-dependent rail and bus riders. Within TERM, the percent of transit riders classified as "dependent" varies by mode. In general, the share of dependent riders is highest for bus and lowest for rail modes (See Exhibit 5-7). Commuter rail is believed to have a small share of transit dependent riders relative to other transit modes because they generally serve more affluent areas.

Exhibit 5-8
TERM Assumptions of Next-Best Modal Alternatives for Dependent and Non-Dependent Transit Riders

Rider Type	Transit Dependent*		Non-Transit Dependent*	
Current Transit Mode	Rail	Bus	Rail	Bus
	⇓	⇓	⇓	⇓
Next-Best Alternative	Bus	Taxi	Auto	Auto

* Riders are defined as "non-transit dependent" if they have auto access

Future Improvement Opportunity: Allow Non-Dependent Riders to Select Bus as an Option to Rail As discussed in the prior paragraph, non-dependent riders who currently select rail transit as their mode of choice, should have both bus and auto as their next-best alternatives. The challenge here is to determine a reasonable split of non-dependent riders between these two modes. It is believed that only a few riders with access to an auto will select bus as their next-best alternative, with the exception of express bus options provided in many urban areas.

The average transit dependency rates for each mode type, as currently assumed by TERM, are provided in Exhibit 5-9below. TERM allows users the flexibility to vary these percentages by mode and agency should additional information be available at the local level. For example, transit dependency rates for rail in New York City are likely very high relative to the national average given the relatively low rates of auto ownership, particularly in Manhattan.

Exhibit 5-9
Average Transit Dependency Rates by Mode

Mode	Transit Dependent Riders as Share of Total
Commuter Rail	25%
Demand Response	100%
Heavy Rail	33%
Light Rail	33%
Motor Bus – Regular	70%
Motor Bus – Express	50%
Van Pool	50%

Future Improvement Opportunity: Conduct Independent Review of Transit Dependency Rates TERM's benefit-cost analysis would benefit from a more detailed and more current review of the literature and/or the experiences of a sample of individual transit agencies with respect to dependency rates. The transit dependency rates currently utilized by TERM were obtained from a literature review conducted when the model was first constructed in the mid-1990's.

Summary of User Benefits

The preceding sections describe how cost savings for individual transit users from transit investments as compared to a next-best modal alternative are aggregated across users. It also describes how transit users are segmented into transit dependent and transit non-transit dependent groups in order to be able to determine the next-best alternative mode for each group. The following sample expressions illustrate how cost savings for individual users fit together to determine the total user benefits for each investment type by mode and rider.

Example 1: Benefits to Transit Dependent Riders of the Maintaining Condition and Performance of an Existing Rail Service

Equation (5-14) shows how the benefits to existing transit dependent rail riders for a specific agency are calculated. TERM calculates these benefits as the difference between the user cost on the existing mode and user cost that would be experience by the riders if they were to shift to the next-best alternative, currently assumed to be bus. This evaluation is applied to the ongoing rehab and replacement of an existing system and to the expansion of that system to maintain performance given projected ridership growth. This evaluation implicitly assumes that transit assets must rehabilitated and replaced to meet a condition standard (to be met at the end of the 20-year period) in order to keep these riders on that mode.

Within the context of the full benefit-cost ratio equations (5-1 through 5-3), equation (5-14) only depicts those benefits for the *current* (or most recent NTD) year, based on the current year rail ridership for the specific agency under consideration as obtained from NTD. The *future* twenty-year benefits of these transit investments are estimated by inflating the current years benefits as calculated in equation (5-14) by a factor of $(1+ TPM\ Growth)^t$ where *t* is the year (1 through 20), and where $TPM\ Growth$ is the projected growth in transit passenger miles for the corresponding urban area. This equation calculates the total trip benefits or costs, i.e., savings or dissaving's that will occur if the existing agency-mode is kept in operation. [With the exception of the value of time and the dependent rider share, all of the variables in equation (5-14) are based on agency-mode data from the NTD.]

Benefits to Transit Dependent Riders of an Existing Rail Service

$$Benefits = \Delta Trip\ Cost_{Rail\ vs\ Bus} * Ridership_{Dependent} \qquad (5\text{-}14)$$

$$= \Delta Trip\ Cost_{Rail\ vs\ Bus} * Ridership_{Rail} * Dependent\ Rider\ Share_{Rail}$$

$$= \{(Fare_{Rail} - Fare_{Bus}) + [(Veh\,Time_{Rail} - Veh\,Time_{Bus}) + 2*(Wait\ Time_{Rail} - Wait\ Time_{Bus})] * Value\ of\ Time\} * \{Ridership_{Bus} * Dependent\ Rider\ Share\}$$

Example 2: Benefits to New Transit Dependent Riders a of Performance Improving Investment in an Existing Rail Service

Equation (5-15) calculates the benefits to new transit dependent riders, attracted to an existing rail service by performance improving investments to reduce crowding. In this case benefit per trip is the difference between the user costs with the performance improving investment and the user costs without the performance improving investment (note that there is no change in mode for the before and after trip cost comparison).

Benefits to New Dependent Riders of Improvement in Existing Rail Service

$$Benefits = \Delta Trip\ Cost_{New\,vs\,Old} * \Delta Ridership_{Dependent} \qquad (5\text{-}15)$$

$$= \Delta Trip\ Cost_{New\,vs\,Old} * \Delta Ridership_{On\ Existing\ Rail\ Service} * Dependent\ Rider\ Share_{Rail}$$

$$= \{[(Veh\,Time_{Rail(New)} - Veh\,Time_{Rail(Old)}) + 2*(Wait\ Time_{Rail(New)} - Wait\ Time_{Rail(Old)})] * Value\ of\ Time\} * \left\{ (Unlinked\ Trips_{Rail(Old)}) * \left[\frac{\xi_{Mode} * \Delta Trip\ Cost \big/ (Trip\ Cost_{New} + Trip\ Cost_{Old})}{1 - \left(\xi_{Mode} * \Delta Trip\ Cost \big/ (Trip\ Cost_{New} + Trip\ Cost_{Old}) \right)} \right] * (Dependent\ Rider\ Share_{Rail}) \right\}$$

In this equation, the change in trip costs before and after in the performance improving investment is derived by equation (5-9) on page 58. The total change in ridership resulting from the rail investment is calculated as the product of the annual number of unlinked trips per route mile for the rail mode prior to the improvement (based on NTD data) and the arc elasticity-based ridership adjustment factor to determine the ridership increase. This new ridership value is multiplied by the transit dependent rider share for rail to determine the share of new riders who are dependent on transit services to make the trip.

Example 3: Benefits to Non-Transit Dependent Riders of Increased Regional Operating Speeds Through Introduction of a New Rail Service

Equation (5-16) shows how the benefits of an investment in a new rail service are calculated for non-transit dependent riders. This equation compares the benefits of these non-transit dependent riders resulting from investment in rail with the benefits of these riders without the investment (which assumes that they will use an auto, the assumed next-best alternative). This evaluation is undertaken for performance improving investments to increase average operating speeds in UZA's with current average operating speeds one standard deviation below the national average as discussed on in Chapter 4.

Benefits to Non-Dependent Riders of a New Rail Service

$$Benefits = \frac{\Delta Trip\ Cost_{Rail\ vs\ Auto} * \Delta Ridership_{Non-Dependent}}{2} \qquad (5\text{-}16)$$

$$= \frac{\Delta Trip\ Cost_{Rail\ vs\ Auto} * \Delta Ridership_{New\ Rail} * (1 - Dependent\ Rider\ Share_{Rail})}{2}$$

$$= \frac{\{(Fare_{Rail} - Auto\ Trip\ Cost) + [(Veh\ Time_{Rail} - Veh\ Time_{Auto}) + 2 * Wait\ Time_{Rail}] * Value\ of\ Time\} * \{(Unlinked\ Trips\ Per\ Route\ Mile_{Rail}) * (New\ Route\ Miles_{Rail}) * (1 - Dependent\ Rider\ Share_{Rail})\}}{2}$$

The variable for the change in trip costs when shifting from auto to rail in Equation (5-16) is calculated by Equation (5-6) on page 57. The total change in ridership from a new rail investment is derived by multiplying the average number of unlinked trips per rail route mile (based on NTD data) for each agency rail mode by the number of route miles in each agency rail mode resulting from the investment. This change in riders resulting from the investment is multiplied by 1 minus the transit dependent rider share (i.e., the non-dependent ridership share) to determine the number of new rail riders who are not dependent on transit. Dividing the total by 2 provides the change in consumer surplus for new riders, as previously specified in equation (5-11).

Note on Data Sources for Investments to Improve Average Operating Speed

Investments to improve average operating speed within a UZA either (1) expand investment in a pre-existing high speed mode (heavy rail, light rail or BRT) or (2) introduce a new high speed mode if none currently exists in that urban area. If a high speed mode already exists in a UZA (case 1) then the ridership, O&M costs, Avg. fare and headway measures of this existing mode as reported to the NTD are used to evaluate the costs and benefits of the proposed performance improving investment. If the UZA does already have not an existing high-speed mode, then the cost benefit evaluation of the proposed new mode investment uses national average values for these measures (again from NTD).

AGENCY BENEFITS

In addition to the benefits accruing to transit riders, investments in rehab and replacement of existing assets also provide benefits to transit operators, most notably reductions in O&M costs resulting from the replacement of old equipment with new, more reliable equipment. TERM does not currently estimate the effect of transit investment on an agency's O&M costs, because no empirical data has been developed to analyze this relationship.

Future Improvement Opportunity: Agency Cost Savings in O&M Costs from Fleet Replacement Programs Transit operators currently record expenditures on labor, parts and fuel for individual transit vehicles in their fleet maintenance information systems. These records could be used to establish relationships between a vehicle's age (or mileage) and its annual operating costs. This relationship could, in turn, be used by TERM to measure the benefits to each agency from ongoing fleet replacement.

SOCIAL BENEFITS

Society as a whole receives important benefits, principally in the form of cost reductions, from transit investments. Note that all of the societal benefits and costs considered by TERM are calculated on a per auto vehicle mile of travel (VMT) and can summed to obtain total benefits and total costs to society per VMT of auto travel.

Reduced Congestion Delay — Improved transit services resulting from new investments or system modernization can lead directly to reductions in highway VMT's as some highway users shift from auto to transit. The resulting reduction in VMT's provides direct benefits to the remaining roadway users in form of reduced congestion and delay. FHWA has estimated that for each VMT reduced, society receives a congestion delay benefit of 11.2¢.[16]

Reduced Emissions: Air Pollution — Investment in transit services can lead to a reduction in air pollutant emissions. FHWA has estimated that for each VMT reduced society receives an air pollution benefit of 1.5¢ in 1981 dollars.[17]

Reduced Emissions: Noise Pollution — Investment in transit can lead to a reduction in auto noise emissions. FHWA has estimated that for each VMT reduced society receives a noise reduction benefit of 0.1¢[18].

[16] *Final Report on the Federal Highway Cost Allocation Study*, FHWA, May 1982.
[17] *Final Report on the Federal Highway Cost Allocation Study*, FHWA, 1997.
[18] *Final Report on the Federal Highway Cost Allocation Study*, FHWA, 1997.

Energy Conservation — Transit investment can help to conserve energy. Energy savings benefits from reduced auto travel are considered when calculating reductions in auto operating costs used in the calculation of consumer surplus (see above). Any further consideration of energy conservation benefits would constitute double counting.

Crash Costs — Reductions in VMTs also yield reductions in highway accidents. FHWA has estimated that for each VMT reduced society receives a crash cost reduction benefit of 1.19¢[19].

Total Social Benefits

TERM uses the information on society costs of auto travel, combined with data from other sources, to derive an aggregate measure of the impact on society from the (re-) investment in transit assets. A key step in this process is the recognition that a "transit trip" represents a trip taken by a single individual whereas an "auto trip" may include one or more individuals. Hence, substitution of transit for auto travel would, on average, create more than one transit trip for each auto trip eliminated. This relationship is presented below in equation (5-17).

$$TPM = \frac{VMT}{Avg.\ Auto\ Occupancy_{UZA\ x}} \quad (5\text{-}17)$$

Or

$$VMT = TPM * Avg.AutoOccupancy_{UZAx}$$

Where TPM is transit passenger miles. Note that TERM is configured to allow for differences in average auto occupancy rates by UZA.

TERM calculates the social benefits per transit trip as the product of equivalent VMTs per transit trip and the cost to society per VMT of auto travel (see equation. 5-18).

$$Societal\ Benefits\ Per\ Transit\ Trip = Equivalent\ VMTs\ Per\ Trip * Cost\ To\ Society\ Per\ VMT$$

$$= \left(Trip\ Length_{Agency\ Mode} * Avg.AutoOccupancy_{UZAx}\right) * Cost\ To\ Society\ Per\ VMT \quad (5\text{-}18)$$

Equivalent VMTs per trip are derived by multiplying average trip length ($Trip\ Length_{Agency\ Mode)}$ by the UZA average occupancy rate. Average trip length for the transit mode under consideration is calculated as passenger miles divided by unlinked trips using NTD data. *Cost to Society per VMT* is the sum of the costs per VMT of the auto on society as discussed above. The total benefits to society of each investment proposed by TERM is calculated by multiplying the societal benefits per transit trip by the estimated number of transit riders that are assumed to have cars and hence are *not* dependent on transit services for their

[19] *Final Report on the Federal Highway Cost Allocation Study*, FHWA, 1997.

trip. Societal benefits arise from the use of transit by *non*-dependent riders who presumably would switch directly to auto if their chosen transit service were discontinued.

$$Total\ Societal\ Benefits = Benefits\ Per\ Transit\ Trip * Number\ of\ Transit\ Trips_{Non-Dependent\ Riders} \quad (5\text{-}19)$$

$$= \{(Trip\ Length_{Agency\ Mode} * Avg.AutoOccupancy_{UZAx}) * Cost\ To\ Society\ Per\ VMT\} * \{Ridership_{Agency\ Mode} * (1 - Dependent\ Rider\ Share_{Mode})\}$$

For Which Investment Types Does TERM Include These Societal Benefits? TERM assumes all transit types of investment (rehab/replace, expansion and performance improvements) yield societal benefits by taking riders who would otherwise be using their automobiles off the road.

SUMMARY: TOTAL TRANSIT BENEFITS

The preceding sections of this chapter have provided a detailed description of the user (rider), agency and societal benefits of transit capital investments, as recognized by TERM's benefit-cost analysis. Together, these benefits, combined with factors to capture future growth in the demand for transit services (i.e., TPM growth), provide TERM's estimates of the *total* benefits to each transit investment. These total benefits are captured by the numerators of benefit-cost ratio equations (5-1) through (5-3) above.

TRANSIT INVESTMENT COSTS

This section examines the total cost of each investment, both capital and operating, undertaken by TERM. Together, these costs support calculation of the denominators of benefit-cost ratio equations (5-1) through (5-3) above.

Capital Costs

TERM's benefit-cost analyses only include those capital costs estimated by TERM's capital needs modules: the rehab/replace module (maintain and improve conditions), the asset expansion module (maintain performance) and the improve performance module (increase average speeds of low speed operators and reduce crowding on high use systems). Hence the total capital expenditures used by the benefit-cost analysis is equal to the sum of the capital investment requirements derived from each of these capital needs modules for over the full twenty-year period of each TERM model run. The denominators of equations (5-1) through (5-3) are designed to discount these streams of capital expenditures using standard NPV calculations.

Operating and Maintenance Costs

Equations (5-1) through (5-3) also capture the operating and maintenance (O&M) costs of each proposed investment. While all O&M cost data used by TERM's benefit-cost analyses are obtained from NTD, the actual costs used varies by investment type. The specific costs used for each investment type are presented below in **Exhibit 5-10**. Note that O&M costs associated with the "maintain performance" (asset expansion) investments are projected to increase from one time period to the next (i.e., to reflect the projected growth in fleet size).

For all investment types, TERM assumes that roughly 79% of the O&M costs reported by rail agencies are variable and that 21% are fixed; 86% of bus operator O&M costs are assumed to be variable and 14% fixed. These estimates were derived using modal average data from NTD. They assume that most administrative costs are fixed and most operational costs such as vehicle maintenance and non-vehicle maintenance costs are variable. (Ordinarily, most non-vehicle maintenance costs are considered non-variable but TERM considers these as variable over the twenty-year time frame considered by each model run). TERM's benefit-cost analysis of the rehab and replacement of *existing* assets in the rehab and replacement module includes all O&M costs, both fixed and variable. By comparison, when evaluating the benefits and costs of *expansion* investments – in the rehab and replacement, TERM only includes variable O&M costs.

Exhibit 5-10
O&M Cost Data by Investment Type

Investment Type	O&M Costs in year *t* (*t* = 1 to 20)	For
Maintain/Improve Conditions: Rehab/Replace	*Total Annual costs (fixed + variable)*	Agency-mode
Maintain Performance: Asset Expansion	*Annual variable cost* * *(1+TPM Growth)^t*	Agency-mode
Improve Performance:		
Reduce Occupancy	(*Variable cost per mile*) * (*route miles*)	Agency-mode
Increase Speed (*<u>Existing</u>* High Speed Mode in UZA)	(*Variable cost per mile*) * (*route miles*)	Agency-mode
Increase Speed (High Speed Mode *<u>New</u>* to UZA)	(*Variable cost per mile*) * (*route miles*)	National Modal Average

SUMMARY: BENEFIT-COST RATIO

In summary, all the cost and benefit components discussed in prior sections of this chapter are consolidated within equations (5-1) through (5-3) to determine the cost-effectiveness of all investments proposed by TERM. Once again, only those investments with a benefit-cost ratio greater than or equal to one are included in TERM's tally of national investment needs.

Discount Rate

Equations (5-1) through (5-3) include the variable i, which is the discount rate used to discount the projected streams of benefits and costs of investments proposed by TERM. The Office of Management and Budget's (OMB) Circular A-4 recommends that discount rates of 3 and 7 percent be used as the upper and lower bound limits for federal benefit-cost analysis. TERM has consistently used a rate at or near 7 percent. Note that in a TERM model run costs tend to be more heavily weighted to earlier time periods and, that deferred investment needs tend to be concentrated in the first year while most performance improving investments occur in the first five to seven years. On the other hand, the benefits of these investments tend to be spread out more evenly over the twenty-year model run period. Hence, use of a higher discount rate provides a more conservative benefit-cost test as the longer term benefits are given a lower value and the shorter term costs a higher value with the discounting process.

DATA AVAILABILITY AND BENEFIT–COST MODULE DESIGN

TERM's benefit-cost analysis is intended to provide the most comprehensive evaluation possible of investment costs and benefits given the constraints of readily available data sources and the ability to update the model on a regular basis (e.g., every one to two years). Given these constrains, the design of and the analyses performed by TERM's benefit-cost modules do not always closely match the types of analyses that would be undertaken in a more data rich environment. For example, in a more perfect world, all benefit-cost analysis would be performed at the travel corridor level of detail or lower, with multiple corridors represented within each UZA. However, there are currently no readily available data sources that identify transit assets (inventory and condition), performance (service levels, ridership) and competing modes at the corridor level. In the absence of such data, corridor level benefit-cost analyses are not feasible. Moreover, even if such data *were* available, this type of analysis would only be practicable for fixed rail assets only. In contrast, bus services for a large operator are typically distributed over fifty or more corridors, making corridor level analysis of bus services highly impractical.

Given these issues, the decision was made to focus benefit-cost analysis of existing rail and bus services at the agency-mode level. This level of analysis is the minimum that can currently be supported using readily available and data sources that are updated on a timely basis (i.e., NTD). Agency-mode analysis is undertaken for all TERM's investments for rehab and replacement, asset expansion and occupancy reductions for crowded systems. The analysis of investments to improve operating speeds is constrained to the UZA level, due to the absence of *consistent* and *comprehensive* corridor investment needs analysis for all US metropolitan areas. Here again, this UZA level analysis was found to be supportable using the annually published NTD data.

CHAPTER 6 - MODEL FLOW

INTRODUCTION

The preceding chapters described the calculation and benefit-cost assessment for each of the needs investment types considered by TERM, including rehab-replacement (maintain or improve conditions), asset expansion (maintain performance) and performance improvement. This chapter explains how each of these modules, along with other TERM functions, flow together within the context of an actual TERM model run. The chapter begins with a description of the logic of the flow across all internal modules. The chapter then provides a more detailed description of several smaller modules required to support a complete model run.

LOGIC FLOW: TERM

Upon clicking the "**Run Model**" button on TERM's Main Menu, the user sets in motion a series of steps that begins with re-initialization of the model's analysis tables and culminates in the output of several investment needs and asset condition forecasts. A flow chart depicting the flow of these analytic steps is provided below in **Exhibit 6-1**. Following are descriptions of each of the steps; including data preparation, data processing by the primary modules (rehab-replace, asset expansion, performance improvement and benefit-cost) and the recording of model run input settings.

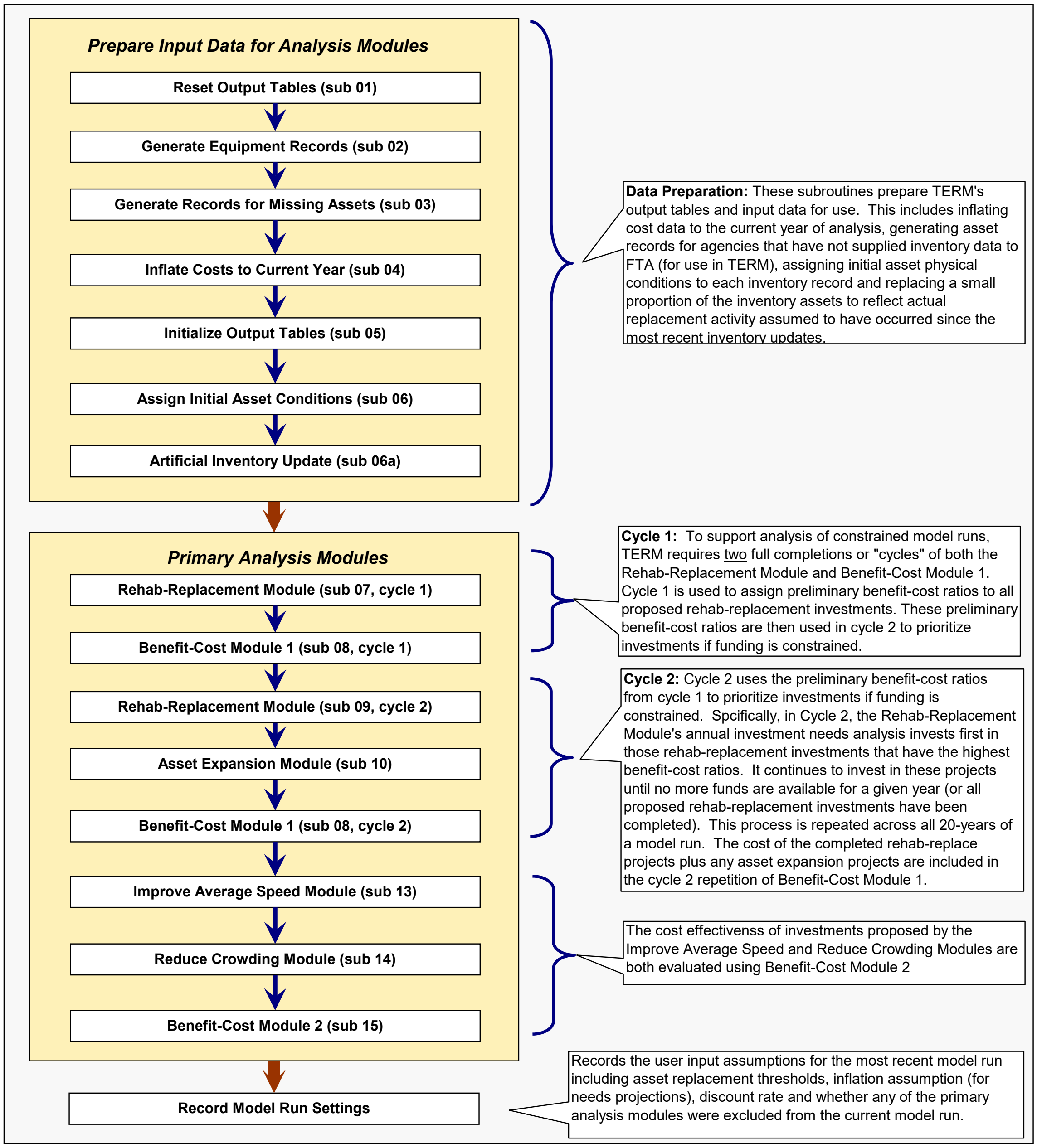
MODEL RUN INITIATION: DATA PREPARATION

At the start of each model run, TERM performs several steps required to prepare input data and output tables for use in the model run (see Exhibit 6-1). This includes inflating cost data to the current year of analysis, generating asset records for agencies that have not supplied inventory data to FTA (for use in TERM), assigning initial asset physical conditions to each inventory record and replacing a small proportion of the inventory assets to reflect actual replacement activity assumed to have occurred since the most recent inventory updates.

Reset Model Output Tables (sub 01)

This module deletes all records from TERM's output files, thus removing the output of the prior model run. This includes the contents of the Investment Needs Forecast table and related supporting tables (i.e., the Asset Expansion and Performance Improvement Module output tables).

Exhibit 6-1
TERM: Flow Chart



Generate Equipment Records (sub 02)

All transit agencies dedicate a portion of their annual capital budgets to the purchase of maintenance equipment, office equipment and other capital assets with small purchase values (defined as $15,000 or less). While these assets are characterized by small replacement values on a unit basis, in aggregate they comprise a material proportion of each agency's annual capital expenditures and hence need to be included in TERM's estimates of agency capital needs.

Unfortunately, the "equipment" asset records included with agency asset inventory submissions have been treated inconsistently across agencies, making use of these records problematic. In some instances, agencies have provided a full listing of these assets while other agencies have not included smaller value assets in their inventory submissions. In addition, where small value assets have been included in agency submissions, they have frequently included records for asset records unlikely to still be in use (e.g., personal computers and software with ages greater than 10 years). Finally, maintaining detailed asset records for small value assets has the additional problem of greatly expanding the size of TERM's asset inventory.

In order to ensure consistent treatment of investment needs for equipment and other small value assets and to reduce the size of the asset inventory database, TERM includes a module designed to generate standardized equipment records for all agency-modes. This module was developed by first selecting small asset expenditure data for ten agencies with the most consistent and reliable equipment information. These data records were grouped into the following four categories:

1. Computers and software
2. Office equipment
3. Office furniture
4. Maintenance equipment

Using this information, the average annual expenditures on each equipment category were calculated and converted to a constant dollar basis. Next, administrative employee full time equivalent (FTE) counts were used to normalize these annual expenditure rates for office related expenditures (computers, office equipment and office furniture) while vehicles in Maximum Service (VOMS) were used to normalize maintenance equipment expenditures across the ten agencies included in the sample. Finally, these normalized relationships were used to estimate annual computer, office equipment, and office furniture expenditure amounts for all other agency-modes using administrative FTE count and VOMS data from NTD. These relationships are presented in equations (6-1) through (6-4):

$$Annual\ Computer\ Needs_{Agency\ Mode\ x} = FTEs_{Agency\ Mode\ x} * Computer\ Cost\ Per\ FTE \quad (6\text{-}1)$$

$$Annual\ Office\ Equip\ Needs_{Agency\ Mode\ x} = FTEs_{Agency\ Mode\ x} * Office\ Equip\ Cost\ Per\ FTE \quad (6\text{-}2)$$

$$Annual\ Office\ Furniture\ Needs_{Agency\ Mode\ x} = FTEs_{Agency\ Mode\ x} * Furniture\ Cost\ Per\ FTE \quad (6\text{-}3)$$

$$Annual\ Maint\ Equip\ Needs_{Agency\ Mode\ x} = VOMS_{Agency\ Mode\ x} * Maint\ Equip\ Cost\ Per\ VOMS \quad (6\text{-}4)$$

Hence, the completed TERM "Equipment Module" creates four equipment records (one for each category) for each transit agency. These records record each agency's estimated annual expenditures on office and other equipment. These records are appended to the Investment Needs Forecast table and also included in TERM's tally of investment needs.

Generate Records for Missing Assets (sub 03)

The generation of records for missing assets was described in detail in the chapter on the Rehab-Replacement module (Chapter 2). Briefly, this module generates asset records for agency-modes for which asset inventory data have not been provided by the owner agency or where the inventory data supplied by an agency are considered unreliable or incomplete.

TERM runs the missing asset record generation module immediately after completing generation of equipment records module (sub 02). This module first deletes any generated asset records currently recorded in TERM's Asset Inventory File (any existing generated asset records in the asset inventory are an artifact of a prior model run). The module next generates new missing asset records based on the listing of missing assets as recorded in the Missing Assets Quantities Total table. These generated records are entered into TERM's Asset Inventory File. TERM's analysis modules (e.g., the Rehab-Replacement Module) will then treat these records exactly the same as any inventory record.

Inflate Costs to Current Year (sub 04)

TERM's investment needs analyses rely on cost data stored in the Asset Inventory and Asset Types File tables. These tables record both the cost of each record item and the year of that cost value (e.g., $1995). Given the breadth of data sources used to collect cost data, the records from these two tables represent a broad range of cost years (e.g., ranging primarily from the 1970s to the present but with some earlier cost values).

In contrast, TERM's needs estimates are valued in constant dollars. Specifically, the constant dollar value is set to the same year as the most recent year for which NTD data have been published (as NTD provides key baseline measures for model analysis including ridership, revenues, fleet vehicle counts, service levels and operating cost measures). Hence, if the most recently published NTD data are for 2003, TERM's needs estimates are valued in $2003.

Early in each model run, TERM's Inflate Costs Module inflates the replacement costs of all asset recorded in the Asset Inventory from their original cost year (e.g., $1995) to the constant dollar values to be used for that model run (e.g., $2003). (Note: The user must enter the correct constant dollar year into the "**Current Year**" field on TERM's **Main Menu**.) TERM uses the Gross Domestic Product (GDP) deflator to adjust costs to the desired constant cost year.

Initialize Output Tables (sub 05)

The Initialize Output Tables Module transfers data from the Asset Inventory, Asset Types Data, Agency and Agency Mode Statistics tables as required to support calculation of investment needs by TERM's Rehab-Replacement Module (note: records for expansion and performance improvement needs are added later in the model run). This step merely enters raw data into this table, it does not perform any of the rehab-replacement needs calculations. It also ensures that the values for all output fields (e.g., replacement needs in year x) are initialized to zero.

Assign Initial Asset Conditions (sub 06)

This module estimates the current physical condition of all assets recorded in the Asset Inventory as of the start of each model run (i.e., as of the year entered into the "**Current Year**" field on TERM's **Main Menu**). These condition values will be used later in the model run (by the rehab-replacement module – sub-07) to assess which assets are currently below the replacement threshold values and hence in need of immediate replacement (i.e., "backlog" investments). These starting condition values also establish the baseline for the "Maintain Conditions" scenario. Condition estimate values produced by this module are recorded in TERM's Investment Needs Forecast Table.

Artificial Inventory Update (sub 06a)

TERM's Asset Inventory provides a "snap-shot" of the types and ages of transit assets owned and operated by the nation's transit agencies. Note, however, that this inventory represents data obtained from a variety of sources, each collected and reported at a different point in time. (Given the large number of assets, the inventory is not updated completely in any one year but rather is updated in pieces from one year to the next. The objective is that no asset records be more than five years old.) Hence, at any given point in time, some asset records will be relatively recent while others provide a "snap-shot" of the owning agency's assets as they existed at some point in the past. Hence, it should expected that these older data include records of assets that have been replaced since the data were provided. If TERM estimates the current condition of this (replaced) asset to be below the replacement condition threshold, TERM will then include replacement costs for this (replaced) asset in its needs estimates.

The Artificial Inventory Update Module was created to help mitigate this problem. This module assumes that those inventory assets in the poorest physical condition may already have been replaced prior to the current model run's start date (i.e., the year entered into the "**Current Year**" field on TERM's **Main Menu**). It then replaces these assets, randomly selecting a replacement year value between the date the inventory record was last updated and current start year date.

To determine which low condition value assets to replace, this module first determines the level of capital replacement expenditures for non-vehicle assets since the last inventory update[20]. In practice, the amount of non-vehicle capital replacement expenditures used by this Module is estimated and entered by the TERM user using data provided from FTA's Statistical Summaries. This expenditure amount provides a ceiling on the value of assets that can be replaced prior to the start of the actual model run. The Module next sorts the non-vehicle assets from lowest to highest physical condition value (based on the output from the Assign Initial Asset Conditions Module – sub-06). Finally, it proceeds to replace as many of the lowest condition asset value assets as possible until the level of estimated non-vehicle capital replacement expenditures is exhausted.

Note that this module was initially created at a point in time when significant portions of TERM's Asset Inventory were well beyond the five year maximum asset record age. This situation raised concerns that many of the worst condition assets recorded in the inventory has already been replaced, leading to development of this module. Since that time, updating of TERM's asset inventory has been routinized and the average age of asset records reduced to well below the five year maximum target. Hence, while the Artificial Asset Inventory Module is still used to mitigate the problem of older asset records, the value of the assets replaced by this module is now quite small and of negligible impact to model needs estimates.

PRIMARY ANALYSIS MODULES

After completing those modules dedicated to data preparation, TERM next begins the process of running through the primary need estimation modules (Rehab-Replace, Asset Expansion and Performance Improvement) and the related benefit-cost modules. The overall analytic flow of TERM is to run the Rehab-Replacement Module first followed by the Asset Expansion Module, Benefit-Cost Module 1 (assessing investments by the Rehab-Replace and Asset Expansion Modules), the two Performance Improvement Modules (Improve Average Speed and Reduce Occupancy) and finally Benefit-Cost Module 2 (for the performance improvement investments). However, note from Exhibit 6-1 that the Rehab-Replacement Module and Benefit-Cost Module 1 are both repeated twice during each model run. This repetition is required to support TERM's "constrained investment" option. This requirement is described next.

Module Repetitions to Support Constrained Model Runs

TERM allows the user to impose expenditure constraints on the annual level of investment in rehabilitation and replacement activities permitted by TERM. In effect, the constraint feature allows TERM to invest in rehab and replacement activities until the annual investment constraint (input by the user) for each model run year is fully exhausted. The intent of the constraint is to be able to mimic the impact of real-world funding constraints on rehab-replacement activities and the subsequent secondary impact of constrained investments on asset conditions. (For most model runs, including the C&P Report, the

[20] There is no need to conduct an artificial inventory update for vehicles as the ages and quantities of these assets are reported in a timely fashion through NTD.

annual level of funding is set sufficiently high so as to be non-binding on replacement expenditures.) To yield realistic results, these constrained model runs require a mechanism to determine which rehab-replacement activities get funded and which do not.

Within TERM the prioritization of rehab-replacement investments is accomplished as follows. TERM first makes an initial pass through the rehab-replacement module to determine the total replacement needs for each asset identified in the Asset Inventory. This initial pass though is entirely unconstrained and hence captures the total rehab-replacement needs of each asset record over the twenty-years of a model run. Next, TERM runs Benefit-Cost Module 1 (i.e., excluding any asset expansion investments). This module provides benefit-cost ratio values for each asset record (based on the cost effectiveness of the agency-mode operations, see Chapter 5). These benefit-cost ratios are then used to rank all rehab-replacement investments, from highest to lowest (i.e., assets with the highest benefit-cost ratios have the highest investment prioritization).

TERM next runs the Rehab-Replacement Module for a second time. For each year in this second run, TERM re-estimates the cost of rehab-replacement activities by asset record, starting with the highest ranked asset (based on the benefit-cost ratio from the first run). As the Module passes downward through lower and lower ranked assets, the Module continues to invest in rehab-replacement activities until the (constrained) level of funding for that year is fully exhausted. If funding “runs out” before all assets have been addressed, the model ceases all rehab-replacement activities for that year (e.g., year 1) and then moves on to the next year (e.g., year 2). Note here that the user can enter different funding amounts for all twenty-years of a model run (as well as for backlog investments). Hence, while a lower ranked asset may not undergo any rehab-replacement activities in year 1 (due to constrained funding), it is possible that this asset will undergo these activities In year 2 if funding availability in that year is assumed to be higher (or if there are lower overall funding needs for higher ranked assets).

Following this second pass through of the rehab-Replacement Module, TERM next runs the Asset Expansion Module and then Benefit-Cost Module 2 to evaluate the overall cost effectiveness of these investment needs within the context of ongoing agency-mode operations (see chapter 5). Next, TERM runs the two Performance Improvement Modules (Improve Average Speed and Reduce Occupancy) and finally Benefit-Cost Module 2 (for evaluation of the proposed performance improvement investments).

RECORD MODEL RUN SETTINGS

The final step of each model run is to record several of the key input settings used to control that run. These input settings are output to several model run reports and provide a means of documenting input settings, data required to reproduce the results of a model run at some point in the future.

The specific input parameters recorded at the end of each TERM run include:

- Model Run ID (the time and date of the model run)
- Shut-Down Option Selected (yes/no)
- Inflation Assumption (annual percent rate of inflation)
- Discount Rate (for benefit-cost analysis)
- Replace Condition Threshold (by asset category)
- Service Condition (in-service, out-of-service, partial service)
- Service Condition Factor (adjustment factor to reflect cost of replacement under alternate service conditions)
- Labor Type (assets rehabbed-replaced using contractor or force account labor?)
- Cost-Benefit Analysis Included (yes/no)
- Asset Expansion Included (yes/no)
- Perform Improvement Modules Included (yes/no)

CHAPTER 7 - MODEL USE

INTRODUCTION

This chapter provides instruction on how to use TERM's user interface to execute and complete a model run. This includes how to revise cost data, set the model's input parameters, initiate the model run and view output.

OPENING THE MODEL

Access database files are loaded in much the same way as files for other Windows products such as Word and Excel. To open the Access software package, select and double click on the Access icon. From the Access Menu, select the **File** sub-menu and then **Open Database.** The Open Database window should now appear. Locate the (sub) directory where you first saved and unzipped TERM and search for the file "**term.mdb**". Open this file[21]. The PC will now load TERM and automatically open the model's Main Menu.

TERM — MAIN MENU

The main menu provides the central platform from which all TERM applications are launched (**Exhibit 7-1**). The menu is subdivided into three sections including:

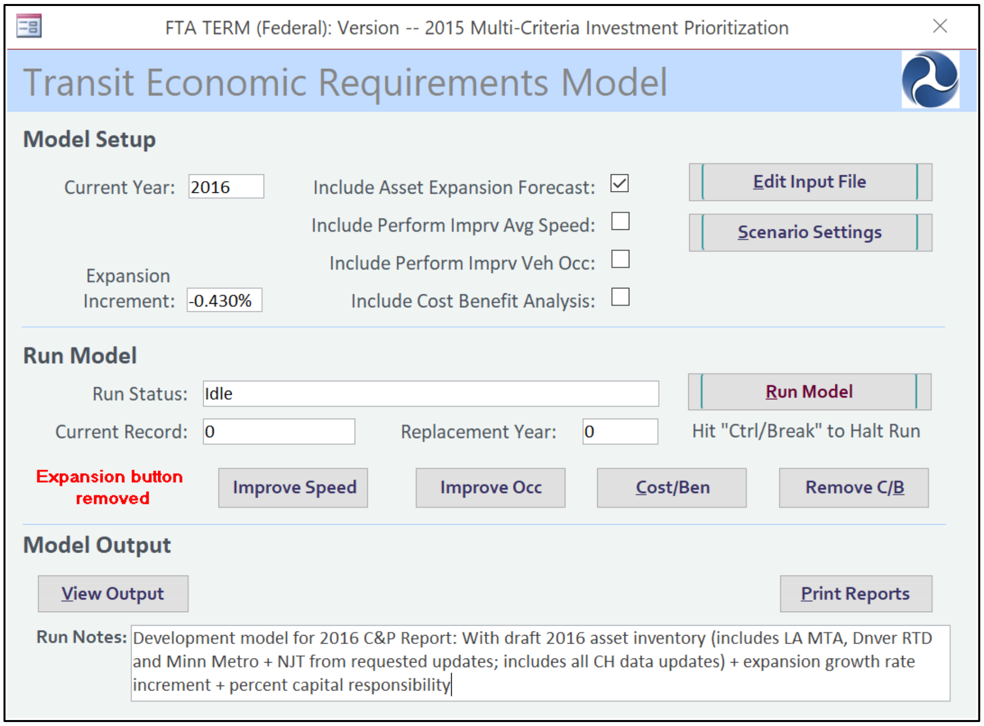
- **Model Setup** — This section is used to initialize the parameter values to be used in the next model run. Specifically, this section allows the user to access and edit the model's input data files (e.g., asset inventory, benefit-cost parameters, New Starts Projects Listing), to define the model run's rehabilitation and replacement policy, and to establish the run's financial assumptions. The Model Setup section also allows the user to select which modules are executed in the next run (e.g., the user can run the full model excluding Asset Expansion investments).

- **Run Model** — The **Run Model** button in this section initiates a model run using the run scenario assigned using the Model Setup. The display window provides information regarding the current status of the model run.

- **Model Output** — The results of each model run are provided by the model reports. These can be viewed or printed after the run is complete by clicking the **Print Reports** button. The results can also be viewed separately by clicking the **View Output** button.

[21] Note that each Access database (including TERM) consists of a single computer file. This single file contains all the data tables (i.e., input and output "files"), forms, programs, queries, and reports used by the model.

Exhibit 7-1
Main Menu



Each of these sections is covered in greater detail below. Clicking on the **Quit** button will exit the user from the Main Menu and return focus to the Access database window. From here the user can exit Access using the Access menu **File** and **Quit** commands.

Warning!	**Model Output:** TERM's database contains only one investment needs output file. Hence, each time the model is run, results from the previous model run will be deleted and the new output results stored in their place. It is important, therefore, that all results from a given model run be fully analyzed before a new run is initiated, and the previous output lost.

MODEL SETUP

The Model Setup section of the Main Menu allows the user to do the following:

- Activate / De-Activate Individual Modules — Including the Following:
  - Asset Expansion Forecast
  - Performance Improvement Forecast: Average Speed
  - Performance Improvement Forecast: Vehicle Occupancy
  - Cost Benefit Analysis
- Establish the Scenario Rehabilitation and Replacement Policy
- Establish the Scenario Financial Assumptions
- Edit the Model's Input Files — Including the Following:

- Agency Data
- Agency-Mode Statistics
- Annual Equipment Generation
- Asset Inventory
- Asset Types Files
- Cost–Benefit Parameters
- Transit Mode Data
- Missing Assets Listing
- New Starts Projects Listing
- UZA Demographics Data

Module Selection

The option box located within the Model Setup section allows the user to select which modules TERM will execute on the next model run. In general, all modules should be active for each model run. TERM provides this option of de-activating individual modules to exclude the results of these modules from model analysis if desired. Here, TERM allows the user to de-activate the following modules:

- Include Asset Expansion Forecast: Deactivate this module to avoid the generation of Asset Expansion asset records *and exclusion of Asset Expansion forecast results from the model output*.

- Include Performance Improvement Average Speed: Deactivate this module to avoid the generation of average speed performance improvement records *and exclusion of Performance Improvement Average Speed results from the model output*.

- Include Performance Improvement Vehicle Occupancy: Deactivate this module to avoid the generation of vehicle occupancy performance improvement records *and exclusion of Performance Improvement Vehicle Occupancy results from the model output*.

- Include Cost-Benefit Analysis: Deactivate this module to avoid running the model's Cost-Benefit Module. In this instance, the model will delete the cost-benefit results from the previous model run and assume that all projects pass the B/C $\geq$ 1 test.

Edit Input Files

The Edit Input Files option allows the user to access and revise the baseline input data included in the TERM Database. Given the importance of the data in these files to model accuracy, the user should only change this data either as part of a baseline revision process (e.g., when the model's asset inventory is updated) or if the user is absolutely sure that the current data are inaccurate. Hence, unlike the data included in the replacement policy and financial assumptions files (data which is frequently altered from one model run to the next), these data should only be altered on an infrequent basis. Clicking the **Edit Input Files** button brings the user to a tab selection of files included in TERM's database (**Exhibit 7-2**):

- Agency Data (General)
- Agency-Mode Statistics
- Annual Equipment Expenditures
- Asset Inventory
- Asset Types File
- Cost–Benefit Parameters
- Missing Asset Listing
- New Starts Modal Input Data
- Rehabilitation Policy
- Service Occupancy Parameters
- Transit Mode Data
- UZA Demographics

Exhibit 7-2
Edit Input Files

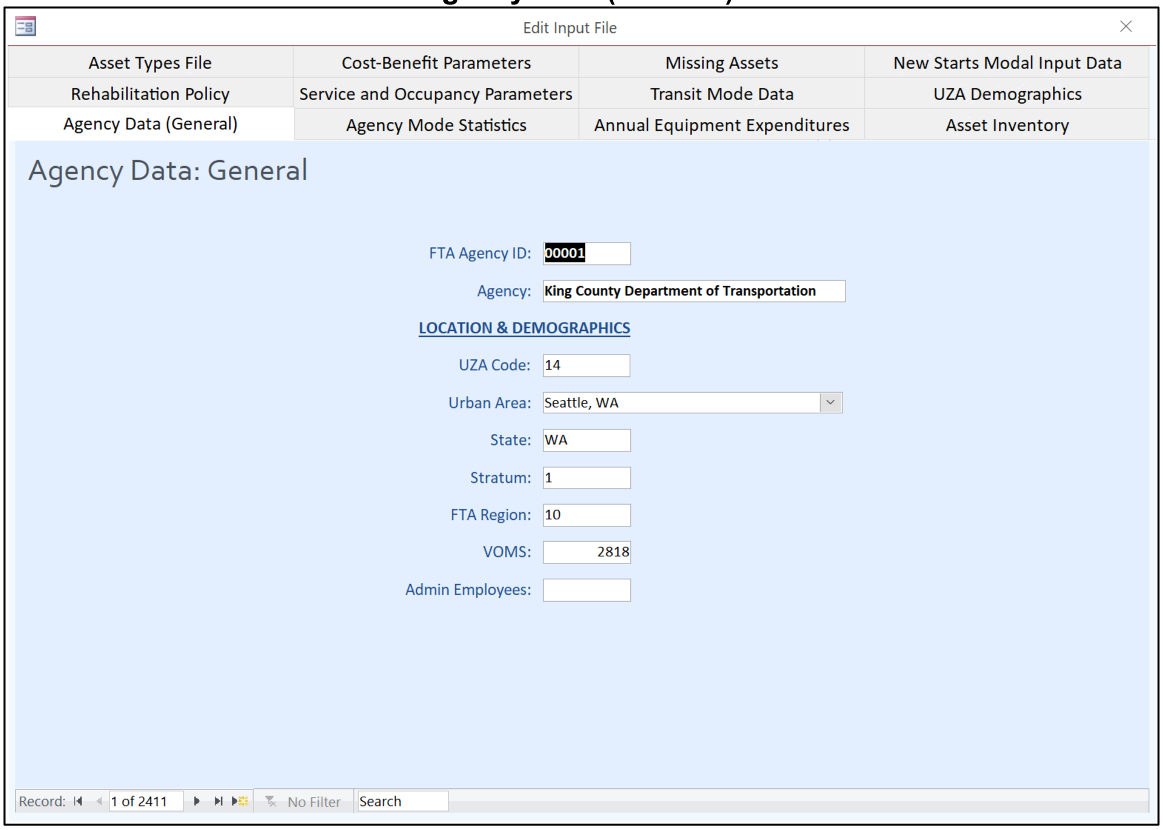
Edit Input File

Asset Types File	Cost-Benefit Parameters	Missing Assets	New Starts Modal Input Data
Rehabilitation Policy	Service and Occupancy Parameters	Transit Mode Data	UZA Demographics
Agency Data (General)	Agency Mode Statistics	Annual Equipment Expenditures	Asset Inventory

Click on the tab corresponding to the file you wish to edit. Clicking the **Edit Input Files** on the main menu brings the user to Agency Data (General) by default. The following sections describe the contents of each file and directions on how to modify this data.

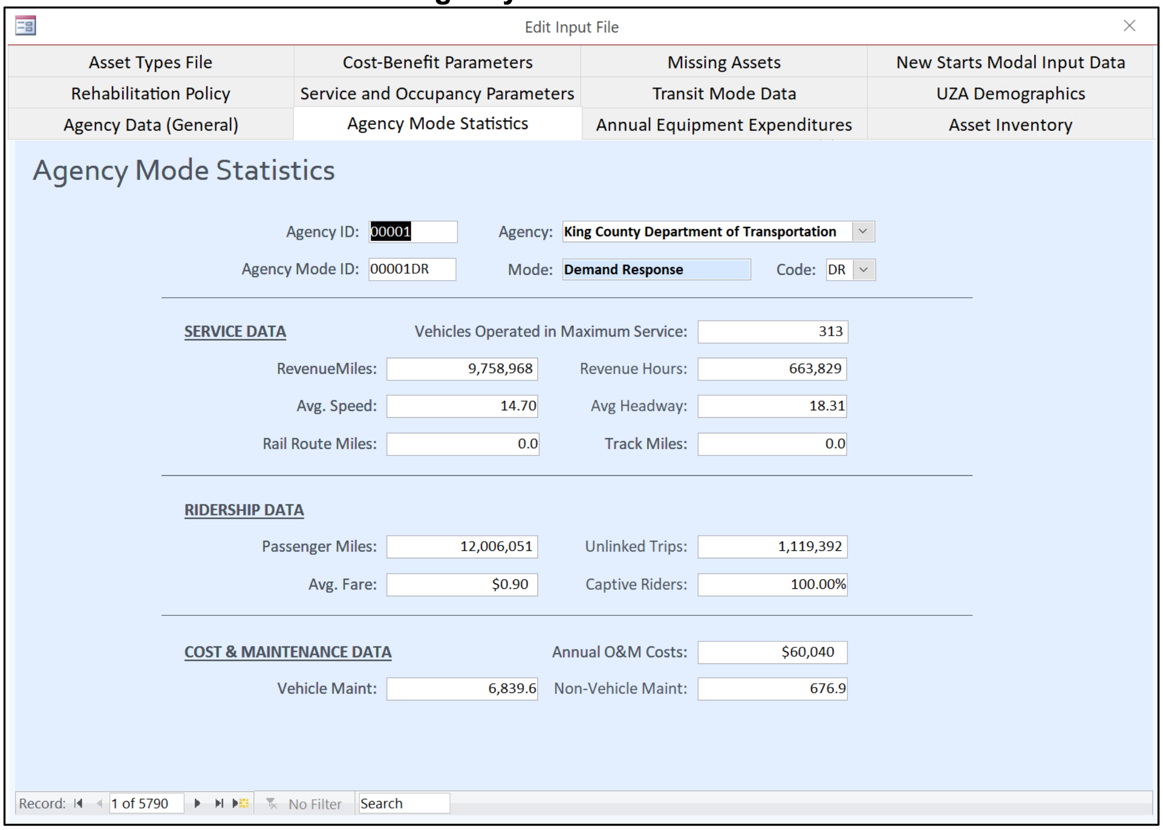
Agency Data (General): This data table (**Exhibit 7-3**) identifies all public transit systems operating in the US, including their Name, FTA ID Code, location (city, state, UZA, and FTA region), and the population strata to which they belong. To locate and edit an agency record, click the record selector buttons at the bottom of the form or page through the records using the **PgUp** and **PgDn** keys. Alternatively, click the find (binocular) icon and use the automated search function. To enter a new agency, move to the last record and hit the **PgDn** key. This action will open up a new record, allowing the user to enter data for a new agency. Note that the name entered in the **Urban Area** field, must be included in the drop-down list. (If the desired urban area name is not included in the list, close the Agency Data form, open the UZA Demographics form, and enter the required data for the desired urban area. Return to the Agency Data form when this process is complete and continue with data entry. To switch to a different input file, simply click on the tab in the upper portion of the window corresponding to the desired input file. Finally, to close the form, click the **Close** button at upper right.

Exhibit 7-3
Agency Data (General)



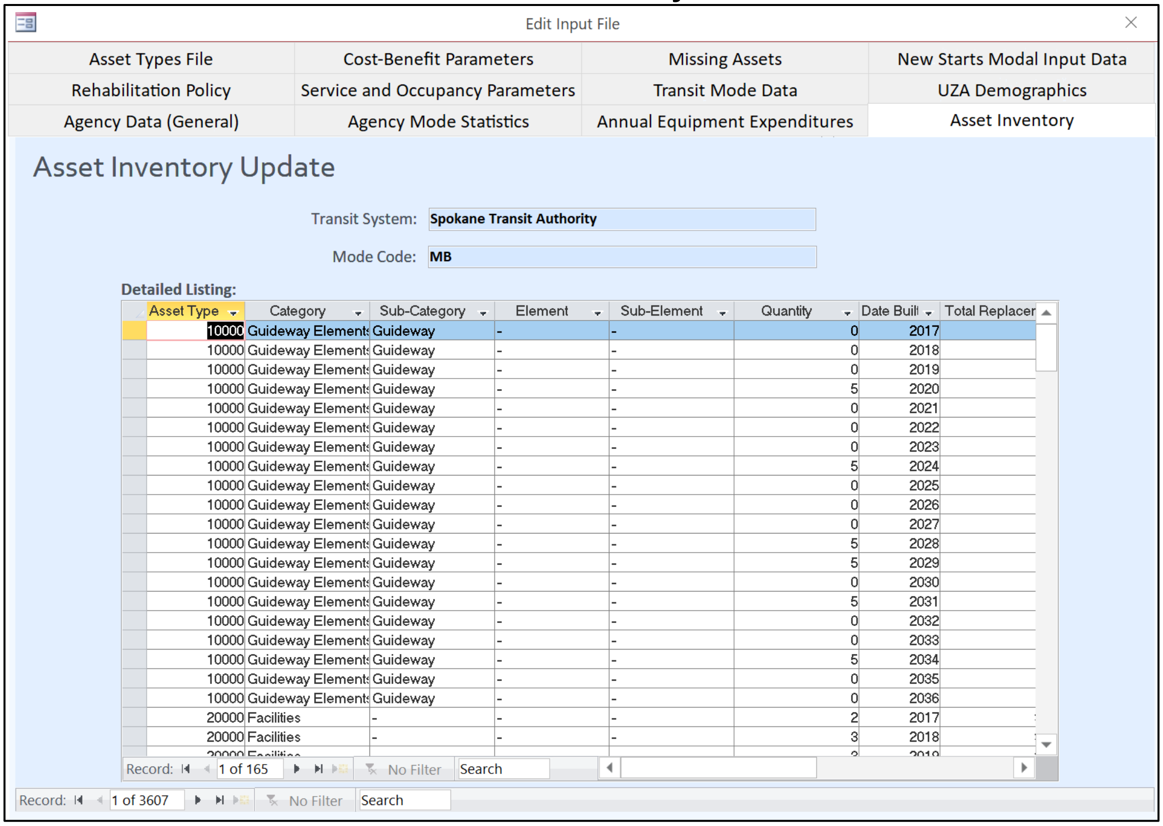
Agency Mode Statistics: This data table (**Exhibit 7-4**) contains detailed agency operations and maintenance statistics by mode. Specifically, table fields document the level of transit service consumed and supplied in recent years, and the level of maintenance applied to each agency's asset base (by mode). This data is used primarily to estimate the future costs and benefits derived from continued operation of each agency–mode. To locate and edit an agency record, click the record selector buttons at the bottom of the form or page through the records using the **PgUp** and **PgDn** keys. Alternatively, click the find (binocular) icon and use the automated search function. To enter a record for a new agency, move to the last record and hit the **PgDn** key. This action will open up a new record, allowing the user to enter data for a new agency. Note that the name entered in the **Agency** name field must be included in the drop-down list. If the desired agency name is not included in the list, toggle to the UZA Demographics form, and enter the required data for the desire agency. Return to the Agency Mode Statistics form when this process is complete and continue with data entry. To switch to a different input file, simply click on the tab in the upper portion of the window corresponding to the desired input file. Finally, to close this form, click the **Close** button at upper right.

Exhibit 7-4
Agency Mode Statistics



Asset Inventory: This table (**Exhibit 7-5**) contains the detailed asset inventory used by TERM in its estimation of agency–mode asset replacement and rehabilitation needs. The inventory data for this table are derived from NTD, from agency asset inventory submissions and from FTA studies (see chapter 2). To locate and edit the asset records for a given agency-mode record, click the record selector buttons at the bottom of the form or page through the records using the **PgUp** and **PgDn** keys. To alter the data for individual asset records, click the second set of record selector buttons and/or page through the data. To switch to a different input file, simply click on the tab in the upper portion of the window corresponding to the desired input file. To close this form, click the **Close** button at upper right.

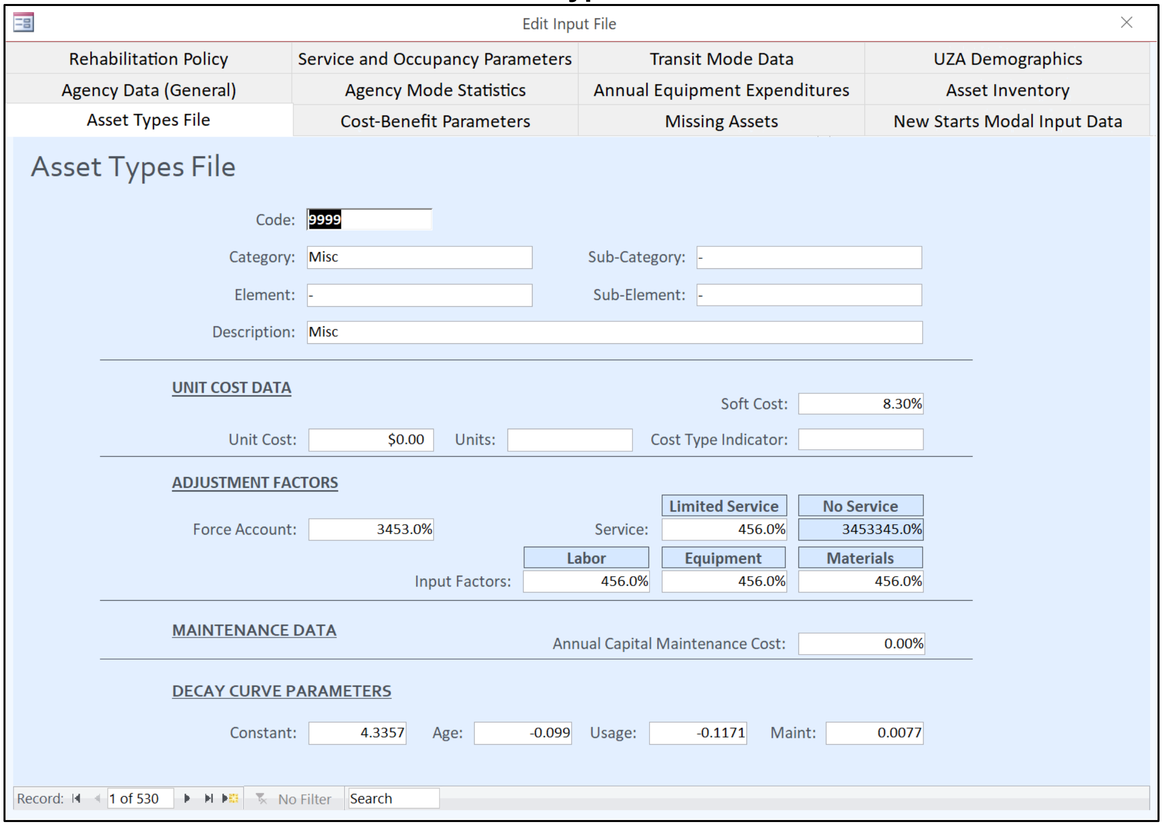
Exhibit 7-5
Asset Inventory



Asset Type	Category	Sub-Category	Element	Sub-Element	Quantity	Date Built	Total Replacer
10000	Guideway Element	Guideway	-	-	0	2017	
10000	Guideway Element	Guideway	-	-	0	2018	
10000	Guideway Element	Guideway	-	-	0	2019	
10000	Guideway Element	Guideway	-	-	5	2020	
10000	Guideway Element	Guideway	-	-	0	2021	
10000	Guideway Element	Guideway	-	-	0	2022	
10000	Guideway Element	Guideway	-	-	0	2023	
10000	Guideway Element	Guideway	-	-	5	2024	
10000	Guideway Element	Guideway	-	-	0	2025	
10000	Guideway Element	Guideway	-	-	0	2026	
10000	Guideway Element	Guideway	-	-	0	2027	
10000	Guideway Element	Guideway	-	-	5	2028	
10000	Guideway Element	Guideway	-	-	5	2029	
10000	Guideway Element	Guideway	-	-	0	2030	
10000	Guideway Element	Guideway	-	-	5	2031	
10000	Guideway Element	Guideway	-	-	0	2032	
10000	Guideway Element	Guideway	-	-	0	2033	
10000	Guideway Element	Guideway	-	-	5	2034	
10000	Guideway Element	Guideway	-	-	0	2035	
10000	Guideway Element	Guideway	-	-	0	2036	
20000	Facilities	-	-	-	2	2017	
20000	Facilities	-	-	-	3	2018	

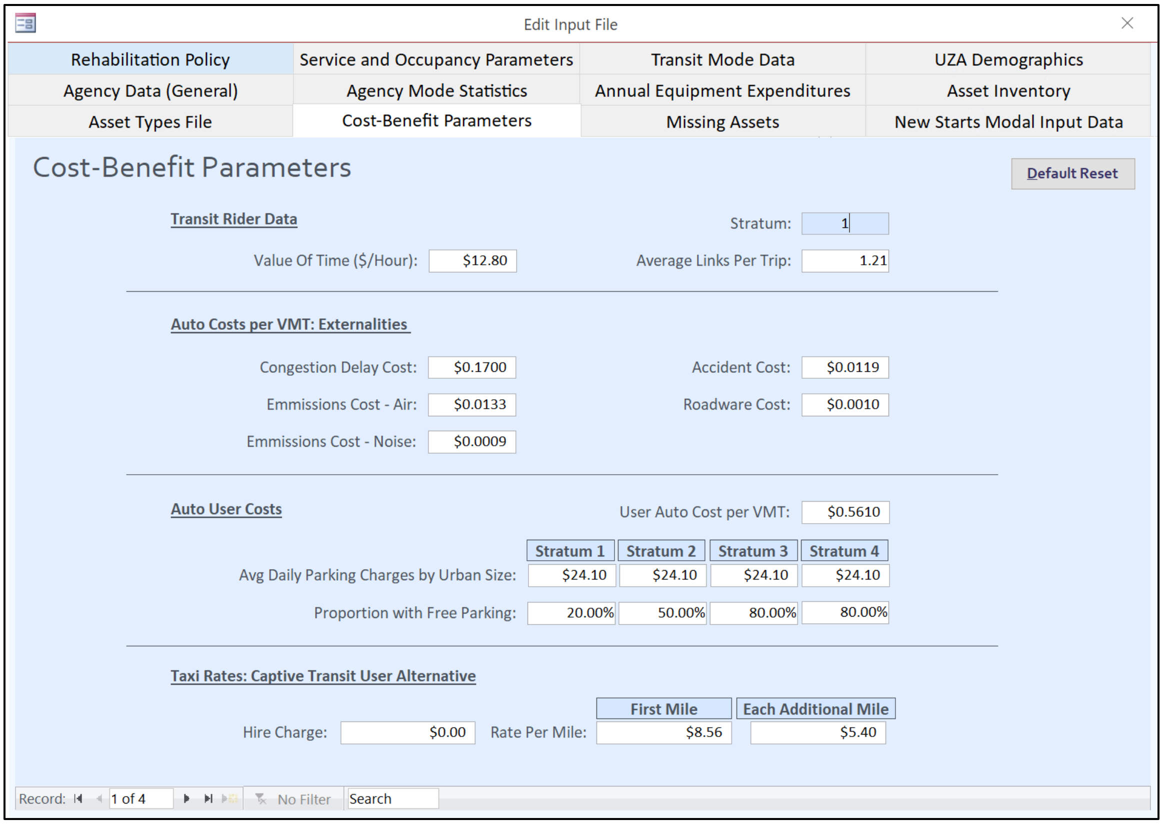
Asset Types File: This table (**Exhibit 7-6**) identifies all asset types owned and operated by the nation's public transportation agencies (with one record for each type of asset identified). For each asset type identified, the table includes data fields for asset unit (replacement) cost, rehabilitation cost, rehabilitation life expectancies, and asset-type specific inflation factors. These asset-type records also document the asset decay relationships used to estimate asset condition given asset age, maintenance, and usage. To locate and edit the asset records for a given asset type, click the record selector buttons at the bottom of the form or page through the records using the **PgUp** and **PgDn** keys. To switch to a different input file, simply click on the tab in the upper portion of the window corresponding to the desired input file. To close this form, click the **Close** button at upper right.

Exhibit 7-6
Asset Types File



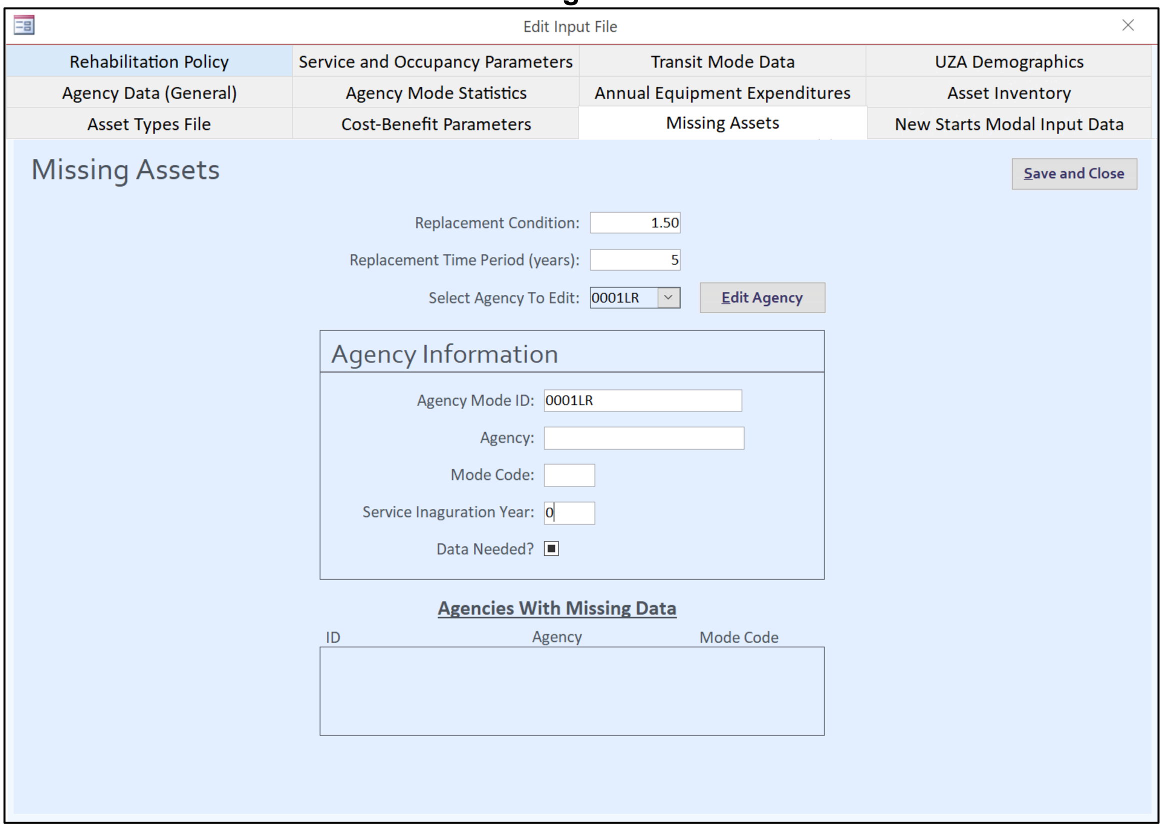
Cost–Benefit Parameters: This table (**Exhibit 7-7**) documents the benefits associated with increased transit investment. These measures include transit rider values (e.g., value of time and links per trip), automobile costs per VMT (congestion delay, emissions costs, and roadway wear), and automobile user costs (auto depreciation, insurance, fuel, maintenance and daily parking costs). Unlike some other tables associated with the Edit Input Files option, the user can change these values as desired. The user can then return the input values to their default values (if desired) by clicking the **Default Reset** button at the top right of the form. To switch to a different input file, simply click on the tab in the upper portion of the window corresponding to the desired input file. To close this form, click the **Close** button at upper right.

Exhibit 7-7
Cost Benefit Parameters



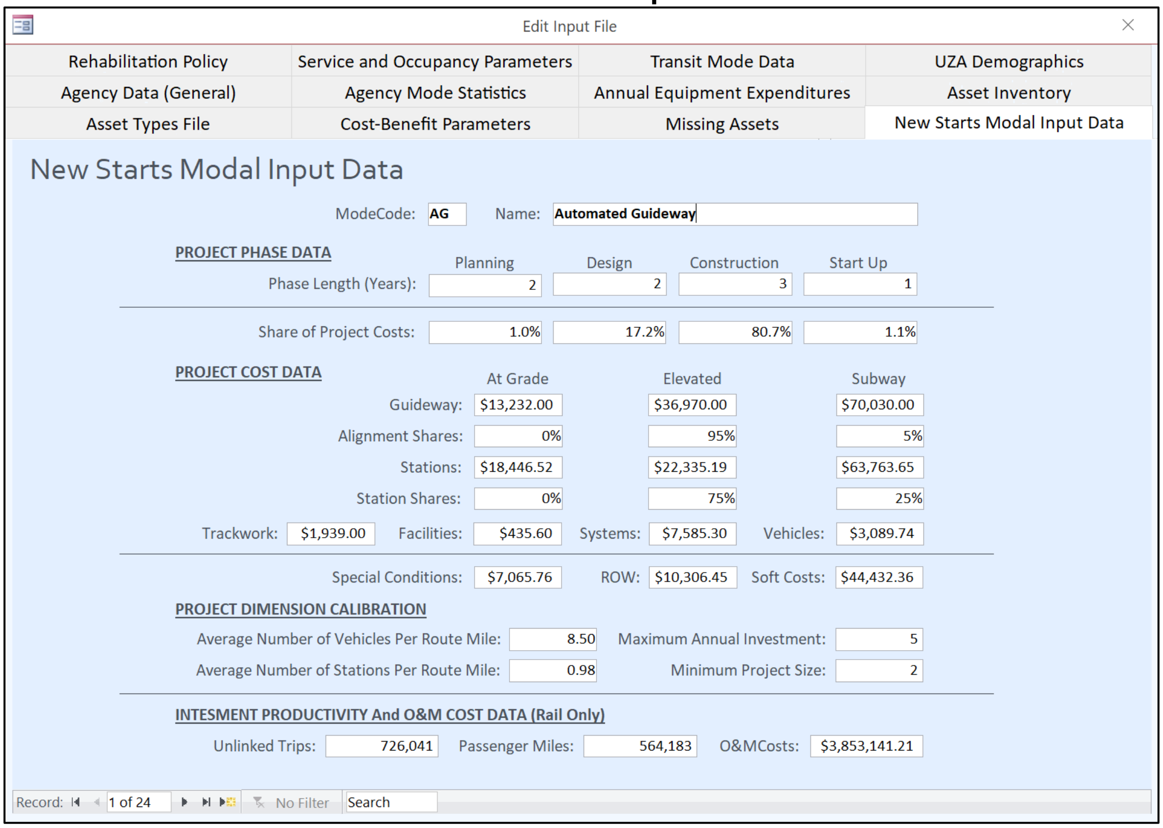
Missing Assets: This form (**Exhibit 7-8**) is used to generate asset records for those agencies which did not provide asset inventory data or whose inventory data was incomplete (i.e., not all asset types were represented in the agency data submission). This form lists all assets entered into the model that are believed to be "missing" (i.e., for which no data have been provided by local agencies or where the data provided are incomplete) (see Chapter 2). TERM's generate assets module will creates an asset record for all assets presented on this form. To delete records, just highlight the records you wish to delete and hit the delete key on your computer keyboard. To add a record, just find the name of the agency mode combination you want to enter data for and type in the desired values.

Exhibit 7-8
Missing Assets



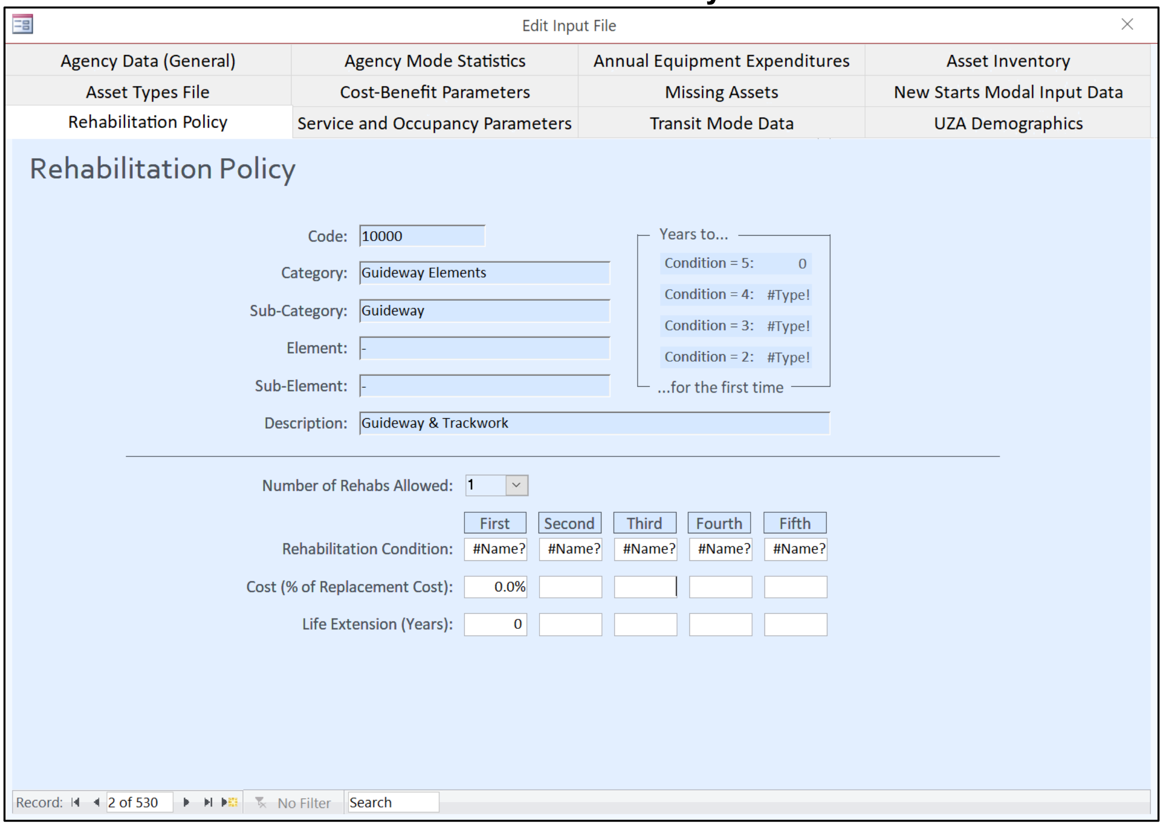
New Starts Modal Input Data: This table (**Exhibit 7-9)** contains data required by the model to estimate the level of costs and benefits associated with New Starts investments (on a mode-by-mode basis). Included are estimates of the average length of project phases, share of total costs devoted to each phase, average unit investment costs by category (e.g., vehicles, guideway, stations, soft costs, etc.), average investment productivity in terms of new riders, and O&M costs on a per mile invested basis. To locate and edit the asset records for a given mode, click the record selector buttons at the bottom of the form or page through the records using the **PgUp** and **PgDn** keys. Alternatively, click the find (binocular) icon and use the automated search function. To switch to a different input file, simply click on the tab in the upper portion of the window corresponding to the desired input file. To close this form, click the **Close** button at upper right.

Exhibit 7-9
New Start Modal Input Data



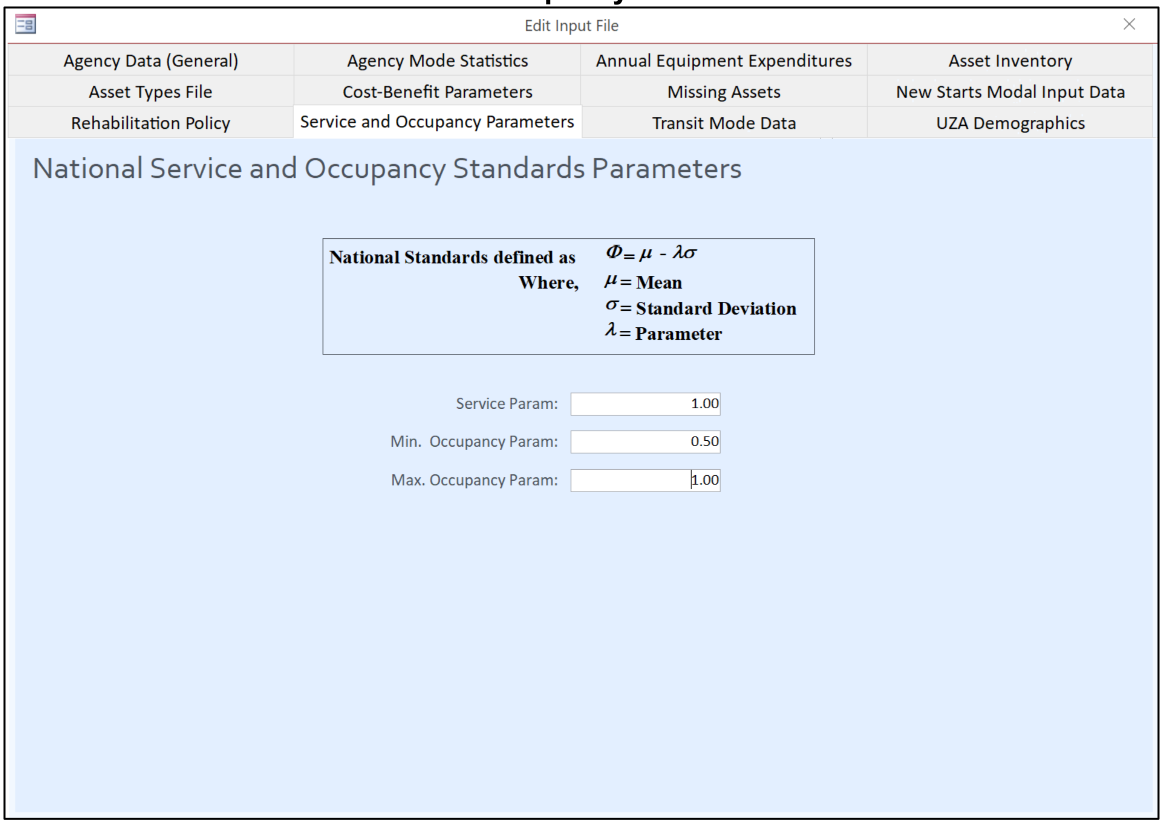
Rehabilitation Policy: This table (**Exhibit 7-10)** contains user input data determining those points in the asset life cycle (based on asset condition) when each asset type will undergo rehabilitation activities and the cost of that activity. The input form also allows the user to determine the number of rehabilitations each asset can undergo over its life cycle, up to a maximum of five (5). Finally, for each rehabilitation, the user must enter the estimated cost of that rehabilitation activity as a percent of the asset's total replacement cost (replacement costs can be found in the Asset Types file). While the form also allows the user to enter life extending impact of each rehabilitation (in years), this feature is not currently in use.

Exhibit 7-10
Rehabilitation Policy



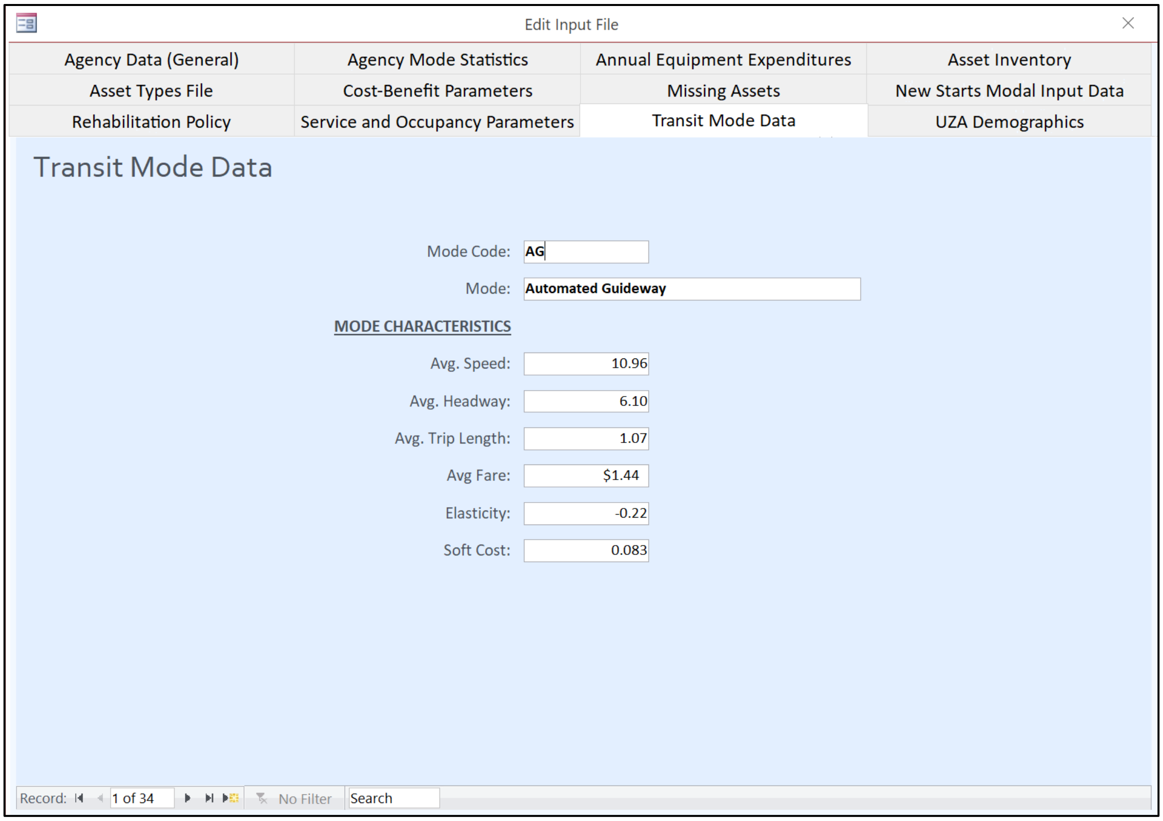
Service Occupancy Parameters: This table (**Exhibit 7-11**) contains user input occupancy parameters required by the Performance Enhancement Module. The inputs include minimum and maximum vehicle occupancy proportions and a service parameter used to set occupancy standards. The service parameter value is the number of standard deviations from the mean that the occupancy standard is set to.

Exhibit 7-11
Service Occupancy Parameters



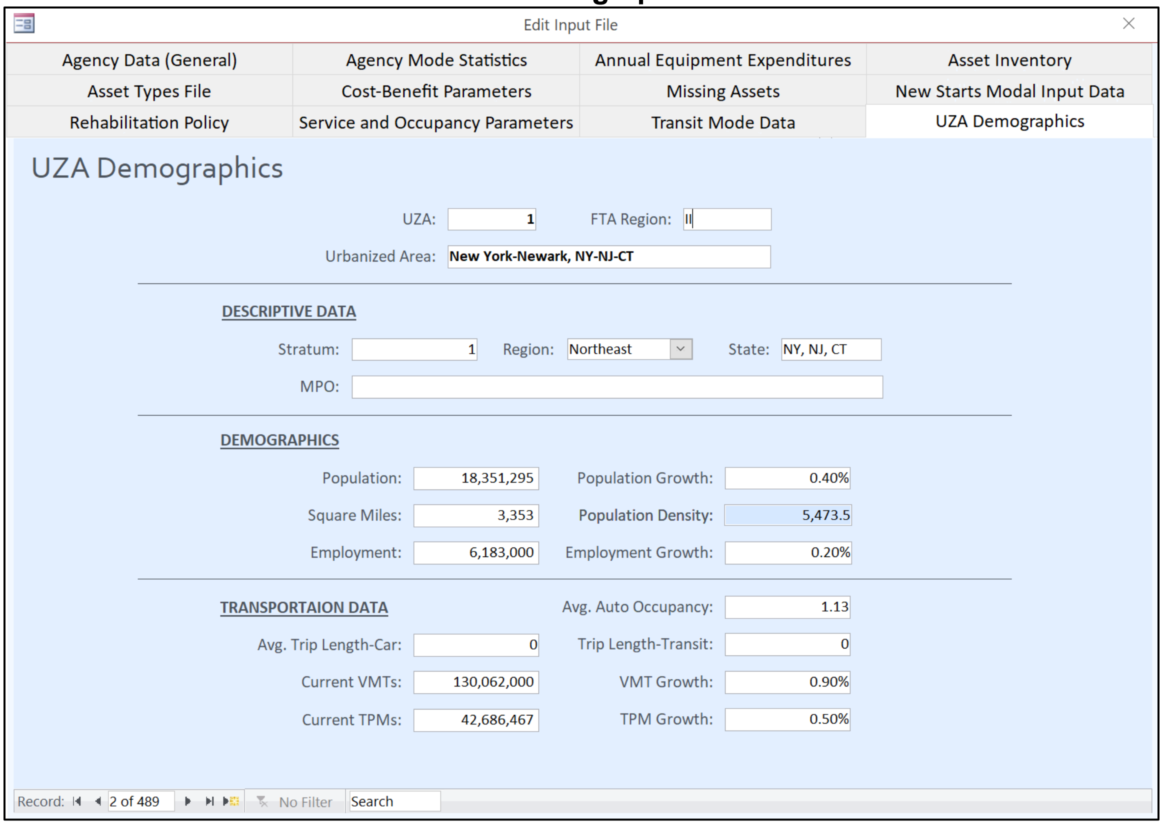
Transit Mode Data: This table (**Exhibit 7-12**) provides descriptive data for the full range of transit modes operated by US transit agencies. The data includes average speeds, average headways, average fares, and typical rider elasticities. The table also includes similar data for modes not operated by local agencies but required for the completion of model analyses (e.g., private auto, taxi, and an artificial mode designation "SY" or system for agency assets — such as office furniture and computers — utilized by multiple transit modes). To locate and edit the asset records for a given mode, click the record selector buttons at the bottom of the form or page through the records using the **PgUp** and **PgDn** keys. Alternatively, click the find (binocular) icon and use the automated search function. To switch to a different input file, simply click on the tab in the upper portion of the window corresponding to the desired input file. To close this form, click the **Close** button at upper right.

Exhibit 7-12
Transit Mode Data



UZA Demographics: This table (**Exhibit 7-13)** contains demographic data for over three hundred of the nation's largest urbanized areas. For each area, the table includes the UZA Code, local MPO(s), population level and growth rate, employment level and growth rate, state(s), population stratum, area (in square miles), current VMT levels and growth rates, and current TPM levels and growth rates. To locate and edit an agency record, click the record selector buttons at the bottom of the form or page through the records using the **PgUp** and **PgDn** keys. Alternatively, click the find (binocular) icon and use the automated search function. To enter a record for a new UZA, scroll to the last record and hit the **PgDn** key. This action will open up a new record, allowing the user to enter data for a UZA as needed. To switch to a different input file, simply click on the tab in the upper portion of the window corresponding to the desired input file. Finally, to close this form, click the **Close** button at upper right.

Exhibit 7-13
UZA Demographics



Replacement Policy

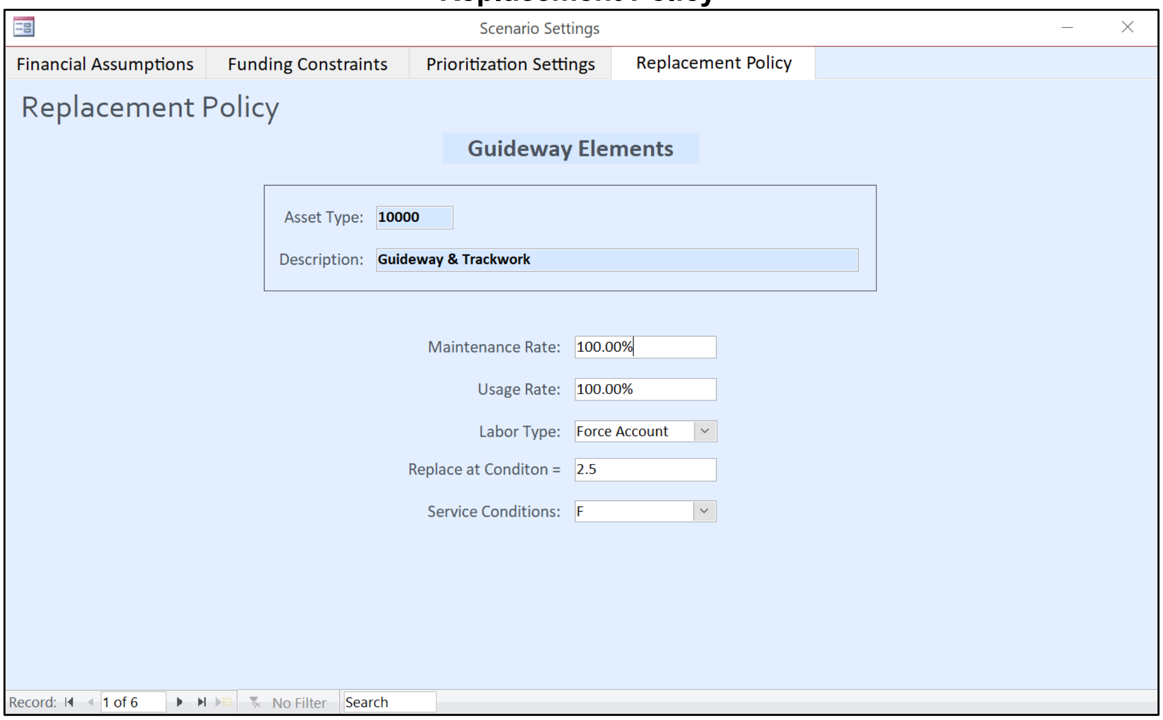
The Rehabilitation and Replacement Policy option allows the user to specify how and when assets are replaced and/or rehabilitated. In particular, the user can specify the following types of capital investment policy options:

- Physical condition at which assets are replaced
- Physical condition at which assets are rehabilitated
- Operating conditions under which assets are replaced (i.e. full service, partial service, or shut-down)
- Labor type (contract or force account)
- Asset maintenance rate
- Asset usage rate

The user defined values for these policy variables will directly impact the total replacement cost forecasts, the timing of those costs, and the life expectancies and forecast condition ratings of all asset types. Policies are set independently for the five types of asset categories — including guideway elements, facilities, systems, stations and vehicles.

To revise the investment policy, click the **Scenario Settings** button on the **Main Menu** and click the tab labeled **Replacment Policy**. This action will open the **Replacement Policy** form (**Exhibit 7-14**). This menu displays the investment policy parameter settings for each of the five categories of investments — one category at a time. The user can view the current policy settings for different categories either by using the **PgUp** and **PgDn** keys or by clicking the arrowheads at the bottom of the screen.

Exhibit 7-14
Replacement Policy



To edit the current policy parameters for any given asset category, use either the tab key or mouse to select the desired form cell and edit the cell contents. The model will only allow users to edit the white background cells in the lower portion of the form. Users can implement the following types of changes:

- **Maintenance Rate:** This factor adjusts the annual asset maintenance rate to reflect anticipated changes in system maintenance practices over time. The default value is 100% which sets the maintenance rate equal to 100% of the historical rate as documented in the NTD rate (e.g., setting the value to 200% would double the historical rate). Increasing in this rate will prolong asset life expectancies while decreasing it will reduce life expectancies. Users can use this function to consider the impacts of reduced or increased asset maintenance overtime. (Note: Variations in this rate will only impact those asset types featuring a maintenance term in their decay curve).

- **Usage Rate:** This factor adjusts the annual asset usage rate to reflect anticipated changes in system use over time. The default value is 100% which sets the usage rate equal to 100% of the historical, NTD rate. Increasing in the rate will accelerate the rate of asset decay while decreases will reduce the rate of decay. Users can use this function to consider the impact of reduced or increased service levels overtime. (Note: Variations in this rate will only impact those asset types featuring a usage term in their decay curves).

- **Labor Type:** This option selects the type of labor used to replace or rehabilitate capital assets. Users can select either Contract or Force Account labor (where force account labor costs are roughly 50% higher than those for contract labor depending on asset type). These factors are applied directly to the replacement and rehabilitation cost calculations.

Note:	Click the arrow to the right of the Labor Type cell to view the option values.

- **Replace at Condition =:** This option allows the user to select that physical condition rating at which assets are replaced (the replacement threshold – See **Exhibit 7-16** below). Increasing the condition at which assets are replaced will tend to increase the frequency with which assets are replaced and, in turn, increase the model's estimates of annual replacement costs and its estimates of the aggregate physical conditions. Conversely, variation of this input value allows the user to pinpoint the level of funding required to attain or maintain a given overall condition rating. Analysis suggests that agencies tend, on average, to replace assets somewhere between condition 2 and condition 3 (e.g., replacement condition = 2).

  Even though the original condition ratings were designed as integer valued measures, the model will accept real number (i.e., decimal) values as input. However, input values must lie between 5.0 and 1.0.

- **Service Conditions:** This option determines those operating conditions under which assets are replaced or rehabilitated. Users can select to replace or rehabilitate assets under the Full Service, Partial Service, or complete Shut Down (i.e., no service) conditions.

Note:	Clicking the arrow to the right of the Service Conditions cell will display this range of options. The desired option can then be selected from the list using the mouse.

  The Service Conditions option is used to adjust unit costs to reflect variations in cost relating to the operating conditions under which work is performed. In general, replacement and rehabilitation costs are considered lowest under full Shut Down conditions and highest under Full Service conditions — depending on asset type.

For some asset types (e.g., maintenance facilities, and vehicles) unit costs are assumed independent of service condition and hence are the same under all operating conditions. Operating condition cost factors are applied directly to the replacement and rehabilitation cost calculations and were derived primarily from Engineering Condition Assessment reports supplied by the Chicago Transit Authority.

Exhibit 7-15
Asset Condition Ratings

Condition Rating	Condition	Description
5	Excellent	No visible defects, near new condition
4	Good	Some (slightly) defective or deteriorated component(s)
3	Fair	Moderately defective or deteriorated component(s)
2	Marginal	Defective or deteriorated component(s) in need of replacement
1	Poor	Critically damaged component(s) or in need of immediate repair

- **Rehabilitate at Condition:** By clicking on the **Edit** button on the replacement policy menu this option allows the user to select that physical condition rating at which assets are rehabilitated (**Exhibit 7-10**). The policy is set individually by asset type and allows a maximum of five rehabilitations per asset. Increasing the condition at which assets are rehabilitated will tend to increase the frequency with which assets are rehabilitated and in turn the cost of annual rehabilitations predicted by the model.

Hint!	**Turning Off the Rehabilitate Function:** Note that the model will not rehabilitate capital assets if the value in the **Rehabilitate at Condition =** cell is less than that in the **Replace at Condition =** cell — in effect turning this option off.

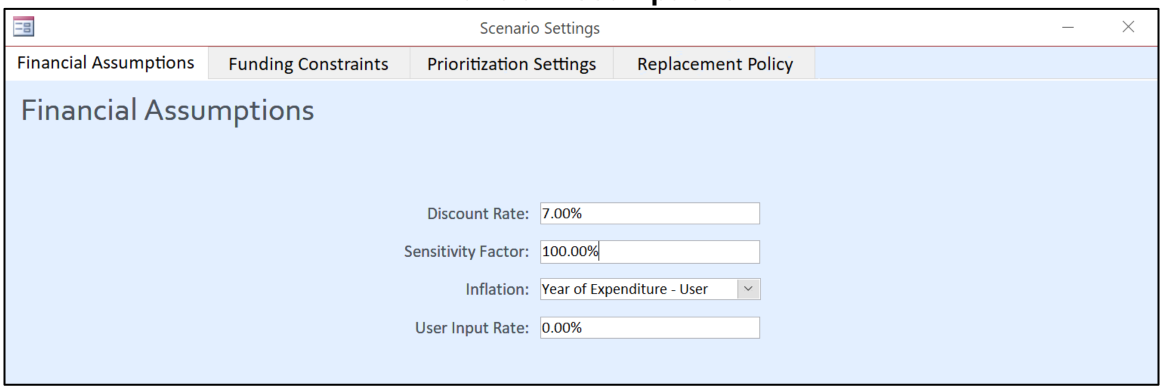
Clicking on the **Close** button at the top of the form will close the **Replacement Policy** form, returning the user to the **Main Menu**.

Notes:	**No Default Values:** The parameter settings in the Replacement Policy category records do not have default values. Hence, any change to parameter values made by the user will be saved until altered again by the user (even if the user exits the model). Hence, the user should always review these settings before initiating a model run. Furthermore, the values for any given category record are updated (i.e., saved) as soon as focus is shifted to a new record. **Model Output — Record of Policy Parameter Settings:** The investment policy parameter settings used in a model run appear as output on the final page of any reports generated using output from that model run.

Financial Assumptions

The Model Financial Assumptions allows the user to specify the discount rate used in the model's benefit–cost analysis as well as the model's inflation assumptions (**Exhibit 7-16**). To set the model's financial assumptions, click the **Financial Assumptions** button in the Scenario Settings section.

Exhibit 7-16
Financial Assumptions



- **Discount Rate**: Enter the discount rate value to be used in the model's benefit–cost analysis. This value must be greater than zero. For public finance analyses, such as that performed by TERM, the current long-term (e.g., 30 year) bond rate is suggested.

- **Inflation**: Click the drop down arrow to select the desired inflation assumption for the current model run. The current software provides the following choices:
  - *Constant Dollars ($1994):* This option is recommended for most analysis
  - *Year of Expenditure - FTA:* Here, model needs estimates are inflated using a Booz Allen/FTA forecast of future transit capital costs.
  - *Year of Expenditure - User:* Selecting this option will open a new field on the Financial Assumptions form entitled: **User Input Rate**. Enter the desired annual rate of inflation.

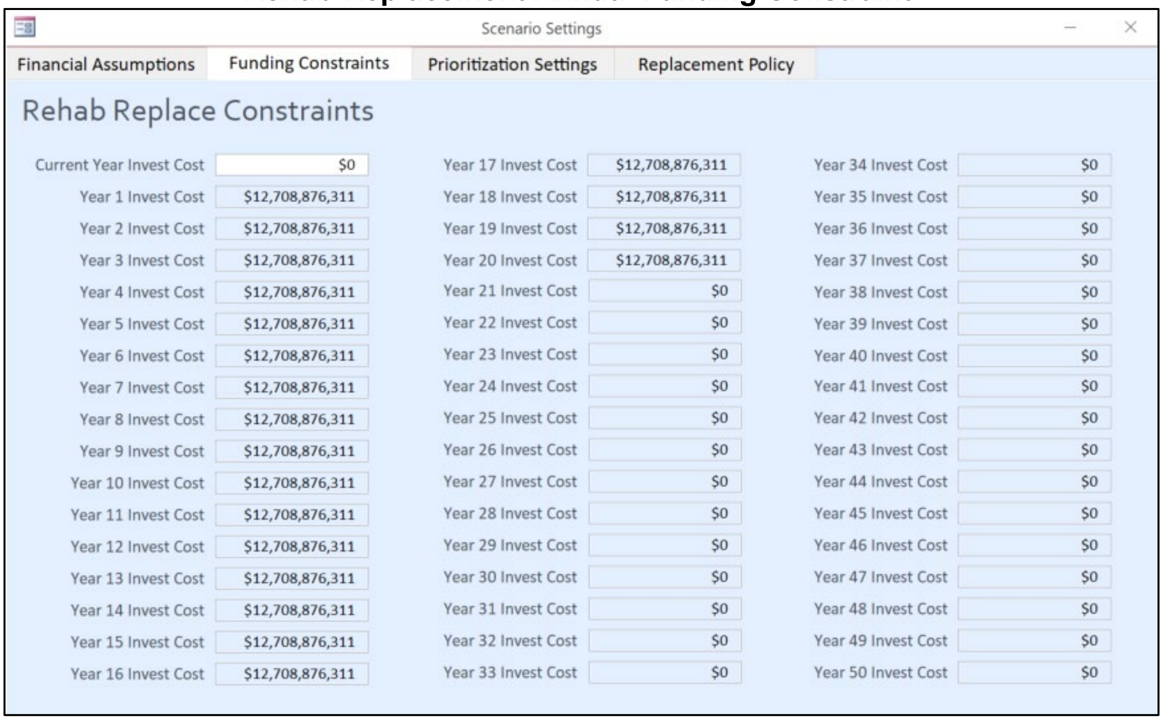
Warning!	**Automatic Save Feature:** All changes to field values in TERM's input forms are saved automatically and can only be "un-done" for the most recent change entered. Only alter input values when you are certain of the changes you are entering.

Funding Constraints

TERM's Rehab-Replace Funding Constraint feature, allows the user to limit the availability of funding for rehabilitation and replacement activities for each year of the model run (including year "0" backlog investments; **Exhibit 7-17**). To set the model's Rehab-Replace

Funding Constraint, click the **Funding Constraints** button in the Scenario Settings section of the **Main Menu**. This action will open the Rehab-Replace Funding Constraint data entry form. Here, enter the level of funding as desired for each model run year. If the constraint is to be non-binding (as with a C&P Report needs estimate), set the funding constraint values at a very high level (e.g., $100 billion annually)

Exhibit 7-17
Rehab-Replacement Annual Funding Constraint


Scenario Settings

Financial Assumptions | Funding Constraints | Prioritization Settings | Replacement Policy

Rehab Replace Constraints

Current Year Invest Cost	$0	Year 17 Invest Cost	$12,708,876,311	Year 34 Invest Cost	$0
Year 1 Invest Cost	$12,708,876,311	Year 18 Invest Cost	$12,708,876,311	Year 35 Invest Cost	$0
Year 2 Invest Cost	$12,708,876,311	Year 19 Invest Cost	$12,708,876,311	Year 36 Invest Cost	$0
Year 3 Invest Cost	$12,708,876,311	Year 20 Invest Cost	$12,708,876,311	Year 37 Invest Cost	$0
Year 4 Invest Cost	$12,708,876,311	Year 21 Invest Cost	$0	Year 38 Invest Cost	$0
Year 5 Invest Cost	$12,708,876,311	Year 22 Invest Cost	$0	Year 39 Invest Cost	$0
Year 6 Invest Cost	$12,708,876,311	Year 23 Invest Cost	$0	Year 40 Invest Cost	$0
Year 7 Invest Cost	$12,708,876,311	Year 24 Invest Cost	$0	Year 41 Invest Cost	$0
Year 8 Invest Cost	$12,708,876,311	Year 25 Invest Cost	$0	Year 42 Invest Cost	$0
Year 9 Invest Cost	$12,708,876,311	Year 26 Invest Cost	$0	Year 43 Invest Cost	$0
Year 10 Invest Cost	$12,708,876,311	Year 27 Invest Cost	$0	Year 44 Invest Cost	$0
Year 11 Invest Cost	$12,708,876,311	Year 28 Invest Cost	$0	Year 45 Invest Cost	$0
Year 12 Invest Cost	$12,708,876,311	Year 29 Invest Cost	$0	Year 46 Invest Cost	$0
Year 13 Invest Cost	$12,708,876,311	Year 30 Invest Cost	$0	Year 47 Invest Cost	$0
Year 14 Invest Cost	$12,708,876,311	Year 31 Invest Cost	$0	Year 48 Invest Cost	$0
Year 15 Invest Cost	$12,708,876,311	Year 32 Invest Cost	$0	Year 49 Invest Cost	$0
Year 16 Invest Cost	$12,708,876,311	Year 33 Invest Cost	$0	Year 50 Invest Cost	$0

RUNNING THE MODEL

To initiate a model run, click the **Run Model** button located on the Main Menu. The model will then process all asset records and new starts projects based on the input parameter settings and selection of active modules established during the Model-Set-Up. The **Run Status** and **Current Record** displays in the center of the Main Menu will indicate where the model is in its processing sequence. Model runs will vary in time depending on the number of records. The "Run Status" display will indicate "Run Completed" upon successful termination of the model run.

Halt!	**Stopping a Model Run:** To stop the model once a run has been initiated, hit the **Ctrl** and **Break** keys simultaneously. This action has the disadvantage of placing the user within the model code! To exit this code, double click on the dash-filled square immediately to the left of the Access menu at the top of the screen. Respond "OK" to the Access prompt. This will place the user back at the Main Menu. The "Run Status" message will continue to display the message printed at the time the model run was terminated.

Warning	**Model Output:** The TERM database only contains one output file. Hence, each time the model is run, the results from the previous model run will be deleted and the new output results stored in their place. It is important, therefore, that all results from a given model run be fully analyzed before a new run is initiated; otherwise they will be lost.

Once again, TERM provides the option of re-running select TERM modules on a one-at-a-time basis. This option allows the user to alter the input parameters for a particular module and to re-run that module without having to re-run the full model scenario (leading to considerable time savings). Specifically, this option allows the user to re-run the following modules on an individual basis:

- Improve Vehicle Speed
- Improve Vehicle Occupancy
- Cost-Benefit Analysis Modules
- Remove Cost–Benefit Analysis — This option sets all B/C ratios equal to 1 (i.e., all projects pass the B/C ≥ 1 test)

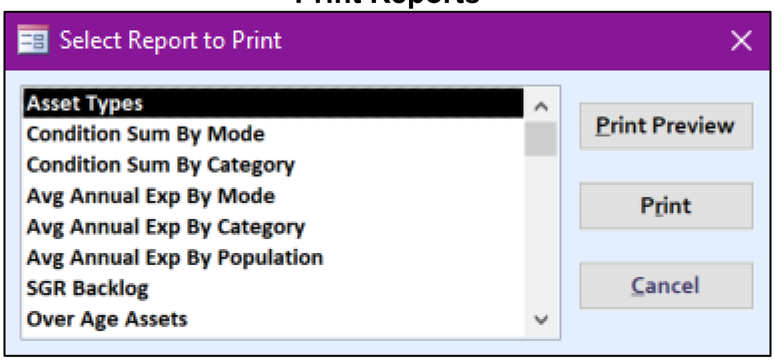
To re-run the Operating Speed Performance Enhancement Module, click the **Improve Speed** button located in the Run Model Section. Similarly, clicking on both the **Improve Occ** button will re-run TERM's Vehicle Occupancy Performance Enhancement Module. Clicking the **Cost/Ben** button will re-run TERM's Cost-Benefit Modules. Finally, clicking the **Remove C/B** button sets all B/C ratios equal to 1 — thus allowing all rehab/replacement, fleet expansion, and performance improvement projects to pass the B/C ≥ 1 test.

After TERM has completed running an individual module (or the entire model), the user can view the results using either the **View Output** or **Print Reports** options (as described below). It is important to note here that, following the re-run of a specific module, TERM's output files will contain the results from that module re-run combined with all other output results from the last complete model run. (In other words, TERM writes over the previous output results for that specific module leaving all other model output results intact. For example, re-running the Fleet Expansion Module will write over the Fleet Expansion output from the previous model run leaving all other output — including the rehab/replacement and New Starts analysis — unaltered). This is in direct contrast to the **Select Modules** option available in the **Model Setup** Section. There the user can choose to omit specific modules such that their results are not included in the model's tally of investment needs. Once again, the Module buttons in the **Run Module** Section are designed to update specific portions of the analysis without writing over the other components of the existing analysis.

VIEWING OUTPUT

To print reports from a model run, click the **Print Reports** button located in the Model Output Section of the Main Menu. This action will display a listing of model output reports. Select the desired model report from the option list and click **OK**. TERM will open the selected report. Options found on this list include the following (**Exhibit 7-18**):

Exhibit 7-18
Print Reports



- ***Asset Types Report***: This report documents all asset types used by TERM including the asset type codes, descriptions, and unit costs.

- ***Asset Inventory Report***: This report documents the individual asset records owned/operated by each agency mode. This information includes the asset ID number, asset type code, descriptive information, quantity and date built data.

- ***Model Output Reports***: TERM produces two basic types of output reports. The first considers total investment needs segmented by mode, asset type, investment type, and other variables. Investment needs expenditures are expressed in five-year groupings. The second report type considers the change in asset conditions over the twenty year period covered by each model run. Each report provides a record of the model run input parameters, so the user can recreate the model run conditions if desired.

Viewing Raw Output

Alternatively, the user can view the raw output for the Investment Needs Forecast table by clicking the **View Output** button found in the **Model Output** section of TERM's **Main Menu**. This action will open the table for viewing. At this point the user can scroll through records to seek a desired data for copy and paste the contents of this table for viewing and analysis in a spreadsheet environment (e.g., MS Excel).

DATABASE MAINTENANCE

Frequent use of TERM including additions or deletions to the files, frequent model runs and/or changes in model programming or structure can result in problems in terms of file size and/or contamination. To prevent these types of problems, the user should "Compact" and "Repair" the **term.mdb** file on a periodic basis. These procedures are executed from the main Access menu under the **File** sub-menu when all Access database files are closed. Note that these operations will produce a new (compressed and/or repaired) version file with a name like "**db1.mdb**". Hence, you will want to copy this file over your old version of **term.mdb** if you want to keep using that file name.

Warning!	To avoid losing any files inadvertently, make a copy of the database file before compacting or repairing your database file.

APPENDIX A - RETIRED INVESTMENT MODULES

NEW STARTS INVESTMENT MODULE

The New Starts Investment Module represents an alternative methodology for estimating the nation's long-term investment needs for new rail capacity. Originally the only module within TERM capable of estimating these needs, the New Starts Investment Module has since been replaced by the better designed Asset Expansion and Performance Improvement Modules. Specifically, the Asset Expansion and Performance Improvement Modules represent model "upgrades" which are better considered on a theoretical basis and better designed from the viewpoint of developing the maintain and improve performance scenarios. At the same time, the original New Starts Investment Module provides an alternate methodology for estimating new starts investment needs and thus can be used as a "check" on forecasts produced using the other two modules. For this reason, the New Starts Module remains an option on TERM's Main Menu. At the same time, this module should *not* be run simultaneously with the Asset Expansion and Performance Improvement Modules as this will lead to double-counting of new starts investment needs (i.e., over-estimation of long-term investment needs).

The current New Starts Investment Module is composed of the following two sub-modules:

- New Starts: *Planned Investments Module*
- New Starts: *New Starts Investments Forecast Module*

The first module uses existing data documenting all new starts projects currently under development. To increase model accuracy, the listing only includes those projects currently beyond the planning stage and which therefore have a higher probability of completion. In general, this data is of high quality, and provides detailed information on project dates, costs, expected ridership impacts, and other project characteristics — furnishing a reasonable basis for the estimation of New Starts funding needs. Note, however, that these data only cover a fraction of the twenty-year time period covered by each model run. Hence, model runs depending entirely on data from this source would severely underestimate new starts funding needs during the later years of the model forecast. For this reason, it is necessary to supplement this module's investment needs estimates with the results from the second module: The New Starts Investments Forecast.

This second module estimates the "expected" level of total rail investment for each urbanized area given its population, historical ridership, and size (square miles). The module then invests in additional track mileage if the *actual* track mileage for that UZA is less than a theoretically *expected* amount predicted by the model. To reflect real world investment constraints, the module limits the level of annual investment possible in an urban area in any given year (e.g., 5 track miles or less per annum). This module is subservient to the Planned Investments Module and will only invest in *forecast* track mileage once investment in all *planned* projects is complete and added to the region's actual track mileage investment total. Given these assumptions, this module uses the following expression to estimate annual track mile investment needs:

$$\Delta Track\,Miles_{t=x} = \min\left\{ \begin{array}{l} Maximum\,Annual\,Invesment\,Rate(e.g., 5\,miles\,per\,year), \\ Expected\ Track\ Miles_{t=x} - Actual\ Track\ Miles_{t=x-1} \end{array} \right\}$$

Within this expression, the expected level of total track mile investment in year x (*Expected Track Mile* $_{t=x}$) is given by two separate formulas: one for light rail and heavy rail (combined) and a second for commuter rail. These mode types have been segmented due to their differing sensitivities to UZA characteristics (e.g., commuter rail investment levels are more sensitive to UZA area than are light and heavy rail). The statistically estimated relationships are presented below. These relationships were estimated using data available from and NTD and the Bureau of Labor Statistics.

Expected Track Mile Investment: Light Rail and Heavy Rail (Combined)

$$(\overline{R}^2 = .9121)$$

$$\begin{array}{c} Expected\ Track\ Miles_{LRHR,UZA=i,t=x} = \\ -54.4 + 0.0000067 * Pop_{UZA=i,t=0} * (1 + Pop\ Growth_{UZA=i})^x \\ + \left\{ \dfrac{0.000079 * Pax\ Miles_{UZA=i,t=0} * (1 + Pax\ Miles Growth_{UZA=i})^x}{Square\ Miles_{UZA=i}} \right\} \end{array}$$

Expected Track Mile Investment: Commuter Rail

$$(\overline{R}^2 = .8623)$$

$$\begin{array}{c} Expected\ Track\ Miles_{CR,UZA=i,t=x} = \\ -209.8 + 0.000069 * Pop_{UZA=i,t=0} * (1 + PopGrowth_{UZA=i})^x \\ + \left\{ \dfrac{0.000136 * Pax\ Miles_{UZA=i,t=0} * (1 + Pax\ Miles\ Growth_{UZA=i})^x}{SquareMiles_{UZA=i}} \right\} \end{array}$$

APPENDIX B - SELECT TERM DATA TABLES

Following are the table definitions and 2019 values for select data tables used by TERM. Note that the table definitions for other key tables are presented in the preceding chapters.

COST-BENEFIT MEASURES TABLE

Exhibit B-1
BENEFIT-COST MEASURES: Data Structure

Field Name	Data Type	Description	Value (2019)
Value Of Time	Currency	Value of Time (per hour) - In-Vehicle	$12.90
Congestion Delay Cost	Currency	Congestion Delay Cost ($ per VMT)	$0.17
Emmissions Cost - Air	Currency	Air Pollution Emissions Cost ($ per VMT)	$0.01
Emmissions Cost - Noise	Currency	Noise Pollution Emissions Cost ($ per VMT)	$0.00
Accident Cost	Currency	Highway Administration Cost ($ per VMT) - Police, Accidents, Maint.	$0.01
Roadware Cost	Currency	Road ware Cost ($ per VMT)	$0.00
AvgParkingCost_I	Currency	Average Daily Parking Cost - Strata I City	$24.10
AvgParkingCost_II	Currency	Average Daily Parking Cost - Strata II City	$19.76
AvgParkingCost_III	Currency	Average Daily Parking Cost - Strata III City	$12.65
AvgParkingCost_IV	Currency	Average Daily Parking Cost - Strata IV City	$13.24
AvgParkingSub_I	Number	Proportion with Employee Subsidy or Parking Free - Strata I City	20%
AvgParkingSub_II	Number	Proportion with Employee Subsidy or Parking Free - Strata II City	50%
AvgParkingSub_III	Number	Proportion with Employee Subsidy or Parking Free - Strata III City	80%
AvgParkingSub_IV	Number	Proportion with Employee Subsidy or Parking Free - Strata IV City	80%
AutoCost	Currency	Auto Owner Cost per Vehicle Mile (dep., ins., maint, fuel, oil, tires, etc.)	$0.56
AvgTransfersPerTrip	Number	Average Number of Unlinked Trips per Transit Trip	1.21
CabRate_Initial	Currency	Taxi Rates - Initial Fee	$0.00
CabRate_FirstMile	Currency	Taxi Rates - First Mile	$8.56
CabRate_AdditionalMiles	Currency	Taxi Rates - Each Additional Mile	$5.40

MODE TYPES DATA TABLE

Exhibit B-2
MODE TYPES: Data Structure

Mode Code	Name	Avg. Speed	Avg. Trip Distance	Avg. Headway	Avg. Fare	Elasticity	Soft Cost
AG	Automated Guideway	10.96	1.07	6.10	$1.44	-0.22	0.083
AOI	Automobile - Stratum I City	12.80				-0.35	0.083
AOII	Automobile - Stratum II City	12.80				-0.35	0.083
AOIII	Automobile - Stratum III City	15.00				-0.35	0.083
AOIV	Automobile - Stratum IV City	17.00				-0.35	0.083
AR	Alaska Rail Road	26.14	132.13	30.00	$99.82	-0.22	0.083
BK	Bicycle (For Cost Benefit Analysis)	11.2		1.99	$0.00	0.00	0.000
BRT	Bus Rapid Transit	16.34	4.26	8.40	$1.47	-0.40	0.083
CB	Commuter Bus	31.35	23.18	24.50	$5.05	-0.22	0.083
CC	Cable Car	5.60	1.14	8.40	$3.27	-0.36	0.083
CR	Commuter Rail	31.35	23.18	24.50	$5.05	-0.22	0.083
DR	Demand Response	14.63	7.81	15.00	$2.30	-0.40	0.083
DT	Demand Taxi	12.10	0.41	10.00	$1.72	-0.35	0.083
FB	Ferry Boat	9.53	5.98	30.00	$4.03	-0.22	0.083
HR	Heavy Rail	20.53	5.08	6.10	$1.14	-0.40	0.083
IP	Inclined Plane	2.97	0.41	30.00	$2.57	-0.22	0.083
JT	Jitney	12.80	3.10	18.10	$0.93	-0.35	0.083
LR	Light Rail	13.88	4.26	8.40	$0.79	-0.40	0.083
MB	Motor Bus	12.58	3.73	18.10	$1.02	-0.35	0.083
MG	Monorail and Automated Guideway	10.09	0.99	3.05	$1.59	-0.11	0.083
MO	Monorail	9.21	0.90	0.00	$1.74	0.00	0.083
NoTp	No Make Trip (For Cost Benefit Analysis)	0.00		0.00	$0.00	0.00	0.000
OR	Other	12.80	3.62	18.10	$1.47	-0.35	0.083
PB	Publico	12.54	37.48	15.00	$1.02	-0.35	0.083
RB	Bus Rapid Transit	16.34	4.26	8.40	$1.47	-0.40	0.083
SH	Shared Trip (For Cost Benefit Analysis)	0.00				0.00	0.000
SR	Streetcar Rail	5.01	2.03	10.04	$0.65	0.00	0.083
SY	System-wide Assets	0.00	0.00	0.00	$1.02	0.00	0.083
TB	Trolleybus	7.17	1.59	18.10	$1.03	-0.35	0.083
TR	Aerial Tramway	10.60	0.41	30.00	$1.72	-0.22	0.083
TX	Taxi (For Cost Benefit Analysis)	12.10	0.41	10.00	$1.72	-0.35	0.083
VP	Vanpool	39.47	37.48	15.00	$2.56	-0.35	0.083
WK	Walking (For Cost Benefit Analysis)	3.18	0.91		$0.00	0.00	0.000
YR	Hybrid Rail	22.62	12.72	16.45	$2.92	-0.31	0.083

APPENDIX C - INTEGRATING NTD DATA

NTD DATA MODULE

The NTD Data Module serves to update the asset inventory list by comparing the current asset inventory list with a list of generated assets. Specifically, this module is designed to generate asset records for all non-vehicle assets for which data have not been provided by the owner agency (either directly or through an FTA study) or where the inventory data provided were incomplete (do not cover all asset types) or of poor quality. These generated asset records are quantified using NTD data, which provides the number of route miles, track miles, crossings, maintenance facilities and stations for most US transit agencies by mode.

Integrating NTD data into Access and tables compatible with the current version of TERM is a semi-automatic process that involves importing the NTD data from Excel tables into Access and running sub-modules to assign these data inputs to specific TERM asset types.

1. Importing NTD tables from Excel into Access

The first step involves formatting the NTD tables that contain data on the number of route mils, track miles, crossings, maintenance facilities and station elements. These data elements are currently found in Tables 21-24 (as of 2003):

Table 21: Passenger stations : Details by Transit Agency
Table 22: Maintenance Facilities : Details by Transit Agency
Table 23: Transit Way Mileage - Rail Modes : Details by Transit Agency
Table 24: Transit Way Mileage - Non-Rail Modes : Details by Transit Agency

For each of the tables, blank and sub-total (or summary) rows are deleted and agency "State" and "Name" are copied into each corresponding row, such that each row contains pertaining agency information and only individual agency quantities are left. A single header row is left at Row 1 and it must follow the naming convention described in **Exhibit C-1**. A new column for "AgencyModeID" is created and populated by concatenating the "ID" (Agency) and "Mode" columns.

Exhibit C-1
Header Naming Convention

NTD Table	Data Source	Old Header Name	New Header Name
Table 21: Stations	Number of Stations	ADA Accessible Non-ADA Accessible Total Stations Number of Escalators Number of Elevators Number of Multi-modal Stations	Station_ADA Station_NonADA Stations_Total Stations_Escalators Stations_Elevators StationsMultimodal
Table 22: Facilities	General Purpose	Under 200 Vehicles 200 to 300 Vehicles Over 300 Vehicles Total General Facilities	Facilities_Under200 Facilities200_300 Facilities_Over300 Facilities_GeneralTotal
	----	Heavy Maintenance Facilities Total Facilities	Facilities_HeavyMaint Facilities_Total
Table 23: Rail Mileage	Track Mileage	At-Grade Exclusive Right-Of-Way At-Grade with Cross Traffic At-Grade Mixed and Cross Traffic Elevated on Structure Elevated on Fill Open-cut Subway Total Miles	TrackMile_AtGradeExclusive TrackMile_AtGradeCross TrackMile_AtGradeMixed TrackMile_ElevStruct TrackMile_ElevFill TrackMile_OpenCut TrackMile_Subway TrackMile_Total
	Number of Crossings	With Cross Traffic Mixed and Cross Traffic Total Crossings	Crossings_CrossTraffic Crossings_Mixed Crossings_Total
	----	Directional Route Miles	DirRouteMiles
Table 24: Non-Rail Mileage	Lane Miles	Exclusive Right-of-Way Controlled Right-of-Way	LaneMiles_Exclusive LaneMiles_Controlled
	Directional Route Miles	Exclusive Right-of-Way Controlled Right-of-Way Mixed Traffic	DRouteMiles_Exclusive DRouteMiles_Controlled DRouteMiles_Mixed

The tables can now be imported into Access without errors. The NTD tables may not necessarily provide a quantity for all of the above described data values for each known agency mode. Therefore, a number of *null* values is expected, and the process requires judgment on part of the analyst to recognize which data values are missing or may simply not exist for the given agency mode.

A series of queries group together the four imported NTD tables by agency mode and calculates a set of new data values described in **Exhibit C-2**. Miles are converted to feet in order for NTD data to conform to the units used by TERM's Asset Types File (tbl05AssetTypeData).

Exhibit C-2
Additional NTD Quantities

Data	Description
GuidewayRouteMiles	Directional Route Miles (DirRouteMiles) divided by 2
Guideway by grade type:	GuidewayRouteMiles times the proportion of trackwork that is at specified grade type:
Guideway_AtGradeExclusive	(TrackMile_AtGradeExclusive / TrackMile_Total)
Guideway_AtGradeCross	(TrackMile_ AtGradeCross / TrackMile_Total)
Guideway_AtGradeMixed	(TrackMile_ AtGradeMixed / TrackMile_Total)
Guideway_ElevStruct	(TrackMile_ ElevStruct / TrackMile_Total)
Guideway_ElevFill	(TrackMile_ ElevStruct / TrackMile_Total)
Guideway_OpenCut	(TrackMile_ OpenCut / TrackMile_Total)
Guideway_Subway	(TrackMile_ Subway / TrackMile_Total)
Guideway_AtGrade	*Sum(AtGradeExclusive, AtGradeCross, AtGradeMixed)*
TrackMile_AtGradeTotal	Sum (TrackMile_AtGradeExclusive, TrackMile_AtGradeCross, TrackMile_AtGradeMixed)
TrackMile_AtGradeBallast	Assumes only exclusive and cross trackwork is ballasted. Sum of TrackMile_AtGradeExclusive and TrackMile_AtGradeCross.
TrackMile_DirectFix	Assumes only these two types of trackwork are direct fixation. Sum of TrackMile_ElevStruct and TrackMile_Subway)
TrackMile_Ballast	Assumes fill and open cut are ballasted. Sum of TrackMile_ElevFill and TrackMile_OpenCut.
TrackMile_TotalBallast	Includes all assumed ballast trackwork: (TrackMile_AtGradeBallast + TrackMile_Ballast)
Stations by grade type:	Stations_Total times the proportion of trackwork that is at specified grade type:
Stations_AtGrade	(TrackMile_AtGradeTotal)
Stations_Elevated	(TrackMile_ElevStruct+TrackMile_ElevFill) / (TrackMile_Total)
Stations_Underground	(TrackMile_OpenCut+TrackMile_Subway) / (TrackMile_Total)

The end product is a single matrix of agency modes and 41 different NTD data quantities (*qry00_DataNTD*), which are referred to through an assigned [NTD Code]. However, this matrix is transposed into a list that has a record for each agency mode and NTD code pair and its corresponding NTD quantity. Three more data values are added for asset type assignment purposes: 1) an assumed unit value of 1; 2) unassigned; and 3) unassigned vehicle).

Reference: Form "CreateTables", which creates "tbl01AgencyModeQntyList". The process takes approximately 1 minute to generate the table, and only needs to be done once any time new NTD tables are imported into Access.

2. TERM Asset Types and NTD Data

The NTD data described above are used to quantify specific non-vehicle assets of agency modes. This is a one-to-many relationship, where a TERM asset type (tbl05AssetTypeData) can be assigned a specific [NTD Code] and each [NTD Code] can correspond to several asset types. Of the 326 non-vehicle asset types in TERM, 214 assets can be matched with a corresponding [NTD Code] and 2 assets are assumed as 1 unit per agency mode. The remaining 110 assets cannot be quantified using the NTD data available.

Reference: "tbl03AssetTypesNTDCodes" matches all 409 of TERM's asset types to a specified [NTD Code], which indicates the corresponding NTD quantity (see Exhibit B-1 and B-2) used by that particular asset type.

3. Generating Assets with NTD Quantities

The module generates a list of "minimum" assets for all known agency modes reporting to NTD. This listing is founded on the principle that each transit mode must include a core set of asset types without which mode operations would be infeasible (e.g., a rail system must have trackwork, train control, stations, etc.).

Ultimately, this list of generated asset records serves as a base to compare the current asset inventory list (tbl06AssetInventory) in order to identify the asset types by agency mode that are "missing" or that have not been documented within TERM using the primary data collection sources.

Of the 326 non-vehicle asset types in TERM, 81 are considered within the core set of asset types to 16 relevant mode types (tbl14ModeTypes). **Exhibit C-3** presents the generated assets for each mode type grouped into three major categories that share the same "minimum" assets.

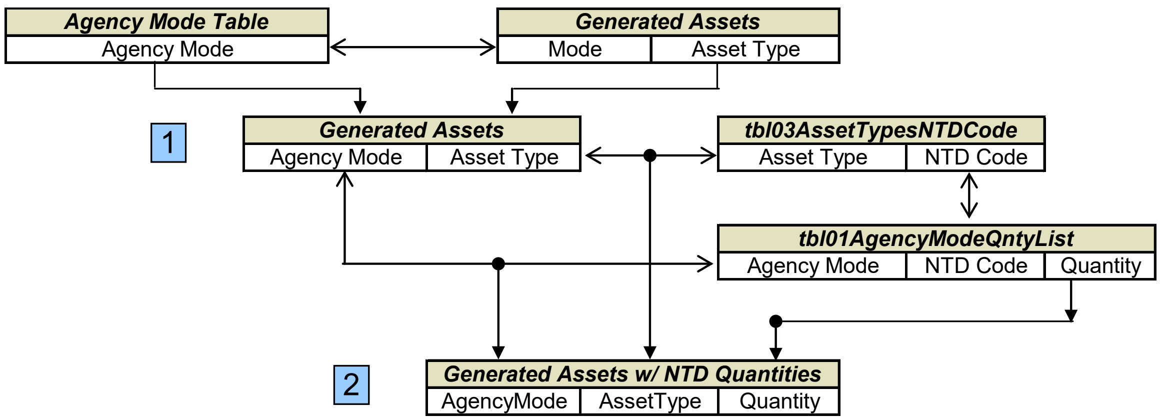
Exhibit C-3
Minimum Generated Assets by Mode

Rail	Non-Rail (Facilities only)	Non-Rail (Facility and Station Elements)
*Includes: automated guideway, cable cars, commuter rail, heavy rail, light right and monorails ** Some rail asset types are specific to HR, LR and CR.*	*Includes: demand response, ferry boats, taxi and vanpools*	*Includes: bus rapid transit, inclined plane, jitneys, motor bus, trolley bus and aerial tramways*
Guideway At Grade Ballast	Maintenance Building (<200)	Maintenance Building (<200)
Guideway At Grade In-Street	Maintenance Building (200-300)	Maintenance Building (200-300)
Guideway Elevated Structure	Maintenance Building (300+)	Maintenance Building (300+)
Guideway Elevated Fill	Major Bus Shop	Major Bus Shop
Guideway Underground		Bus Guideway
Guideway Retained Cut		Station At-Grade
Trackwork Direct Fixation		Station Elevated
Trackwork Ballasted		Station Below Grade
Trackwork Embedded		Bus shelters
Administration Building		Bus Station Elevators
Maintenance Building		Bus Station Escalators
Major Rail Shop		
Train Control Center		
Train Control System		
Electrification		
Communications		
System Utilities		
Station PA System		
Revenue Collection System		
Station At-Grade Platform		
Station Elevated Platform		
Station Underground Platform		
Station Escalators		
Station Elevators		
Station Parking		

Although the list is not all-inclusive and it recognizes that not all agency modes have at least one asset by grade type or fleet size (i.e., not all non-rail modes have all three different types of facilities), this methodology includes more specific asset types which match directly to the level of detail reported in NTD.

Exhibit C-4 presents a diagram of the tables used to create the generated asset records for agency modes.

Exhibit C-4
Flow Diagram of Generating Assets



The module generates the "minimum" asset records from a model user input table of agency modes. The first step joins this table by mode type (i.e., motor bus (MB), heavy rail (HR), etc.) with the table of generated assets by mode type (see **Exhibit C-3**) and outputs a table of generated assets records for all input agency modes. For example, an input of 3 agency rail modes will result in an output table of 75 generated asset records (25 generated assets per rail mode). The second step assigns quantities to the generated assets in this table through query joins with the asset types data and NTD quantities tables (tbl03AssetTypesNTDCodes and tbl01AgencyModeQntyList).

As previously noted, there may be assets that are assigned a *null* quantity value, which require judgment on part of the analyst to determine whether these assets may not exist or will remain "missing" after this process.

An examination of the generated assets for a recent C&P Report reveal that null quantities exist for 15 different asset types out of the set of 81 core asset types. **Exhibit C-5** lists these assets by category.

Exhibit C-5
Generated Asset Types with Null Quantities

Guideway Elements	Facilities	Stations	Systems
Bus Guideway	Maintenance Buildings (3 asset types by fleet size) Major Bus Shops	Rail Station Escalators Rail Station Elevators Rail Station Parking Motor Bus Station Platform (3 asset types by grade level) Motor Bus Shelter Motor Bus Station Elevators Motor Bus Station Escalators	PA Comm. Systems

Further examination of those agency-modes with null quantities reveals the following:
- Rail station null quantities (escalators, elevators, parking, PA system) is for single cable car operator. Therefore, these can be assumed to be zero.
- Other modes are motor bus (MB), ferry boat (FB), inclined plane (IP), jitneys (JT), trolley bus (TB) and aerial tramway (TR). Out of these, it is determined that only the maintenance facility is a basic requirement and all other asset types can be assumed at zero.

To estimate a quantity of maintenance facilities where NTD data is not available, the agency mode's Vehicles Operated in Maximum Service (VOMS) is used, which is a good indicator of the fleet size. The estimated quantity is equal to the agency mode's VOMS times an average (facility) quantity per VOMS. This average is calculated using agency modes a VOMS less than 50 and with known facilities quantities from NTD data. For 2003 NTD data, this average is equal to 0.08 facilities per VOMS.

These assumptions are implemented into the data when the generated assets and quantities are transferred into tbl07GeneratedAssetInventory.

4. Comparing Generated Assets with Asset Inventory List

TERM's asset inventory is checked against the table of "minimum" asset records for all known agency modes (using NTD as a source) with the objective of identifying which data types "should" be included in the inventory but are currently not. This is done by matching all of the generated assets with the assets in the inventory assets table (left join query).

Because the generated asset records are specific asset types (i.e., three different maintenance facilities by bus fleet size) and it is known that agency modes do not have to have all assets by grade type or fleet size, the assets in both tables are grouped up to the [Category] and [Sub-Category] levels. By this methodology, the comparison is based on whether there are any assets of that [Sub-Category] group in the asset inventory, versus specific asset type. For example, the process only considers whether, for a particular bus mode, there are any maintenance facilities in the existing inventory, regardless of fleet size.

Identification of which specific assets are missing for each operator is accomplished by queries with a directional join to identify all non-vehicle asset categories and sub-categories that were generated with no corresponding match in TERM's asset inventory. (Reference: qry06_tblAssetInventory_Grouped, qry07_GeneratedAssets_Grouped, qry08_CompareCosts).

Asset sub-categories not in the inventory (qry09_AssetGroupsNotInventory) are identified with a *null* asset inventory quantity in the query. These "missing" assets are brought back down to the asset type level of detail by running a grouping query comparing this list of groups and the complete table of generated asset records.
(Reference: qry10_AssetsNotInventory)

The output is a list (query) of agency mode asset types that are "missing" in TERM's asset inventory.

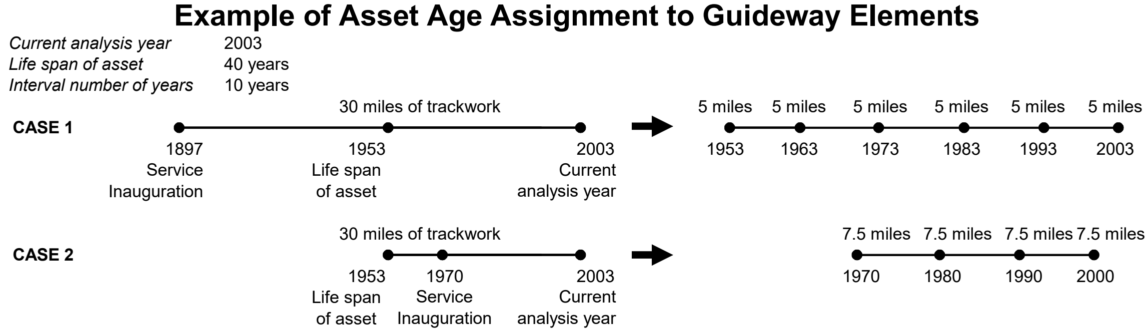
5. Assigning Date Built Year to Generated Assets

The final step in generating asset records is to assign date built values to the missing asset quantities. This is accomplished by three different processes based on the asset type and whether the agency mode's service inauguration year is known.

The first process assigns [Date Built] years to all guideway element and system asset types (with the exception of revenue collection and PA systems). The distribution of asset ages is determined by a uniform distribution over a number of years. The asset is distributed over the span determined by the lowest of: a) the expected replacement life of the asset, or b) the number of years the agency mode has been in service. Based on judgment of known assets and their current life spans, the expected replacement life for this evaluation is increased by 25%.

Exhibit C-5 presents two case examples of this distribution for 30 miles of trackwork assumed to have a life span of 40 years and where the model user has selected to distribute the asset every 10 years. For Case 1, the agency mode has a service inauguration year of 1897, while for Case 2, the service inauguration is 1970.

Exhibit C-5
Example of Asset Age Assignment to Guideway Elements

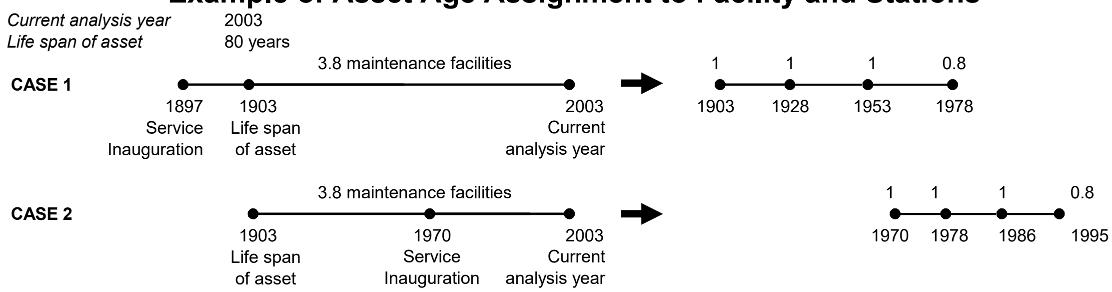


In **Exhibit C-5** Case 1, the 30 miles of trackwork are distributed over 6 different generated asset records, each with 5 miles and a [Date Built] year every 10 years between 1953 to 2003. For Case 2, the 30 miles of trackwork are distributed over 4 different generated asset records, each with 7.5 miles of trackwork and a [Date Built] year every 10 years between 1970 to 2000.

The second process assigns date built years to facility and station elements, and revenue collection and PA systems, where the agency mode service inauguration year is known. Each unit quantity of the asset is distributed based on the total quantity of assets and the span determined by the lowest of: a) the expected replacement life of the asset, or b) the number of years the agency mode has been in service. Again, the expected replacement life used is increased by 25%.

Exhibit C-6 presents the distribution of 3.8 facilities for the case where the agency mode has a service inauguration of 1897 (Case 1) and 1970 (Case 2).

Exhibit C-6
Example of Asset Age Assignment to Facility and Stations



In **Exhibit C-6** Case 1, the 3.8 maintenance facilities are distributed over 4 generated asset records with a [Date Built] year every 15 years between 1903 and 1978. In Case 2, the 3.8 maintenance facilities are distributed over 4 generated asset records with a [Date Built] year every 8 years between 1970 and 1995.

The third process assigns date built values to facility and station assets of agency modes where their service inauguration year is unknown. Asset records are generated for each unit quantity of the asset and the built date is assigned as a random year generated within either: a) the adjusted expected life of the asset or b) a span of 50 years (defined by the model use. Reference: form "CreateAssetYears"). This process applies a more or less uniform distribution to the generated asset records and avoids bias towards any existing distribution of asset ages.

The output generated assets with [Date Built] from the three processes are incorporated into a final table of "missing" assets (tbl10MissingAssets), which is exported to the working version of TERM to be appended to the asset inventory (tbl06AssetInventory).

APPENDIX D - NTD AIM DATA IMPORT PROCESS

INTRODUCTION

The AIM data import process is a feature added to TERM Federal that will pull data from the NTD forms A15, A20, A30, and A35 and create asset records in TERM Federal Tbl06 based on a set of business rules by asset type.

1. Extracting the data from the NTD

The AIM data can be pulled from the NTD report environment for users that have access to it using a program such as MySQL workbench. There are a series of stored procedures (one for each form) that will return a data table that should be exported into CSV format and can then be used to import into the MS Access TERM Federal Database.

To connect to the NTD report environment go to:

Hostname: FTANTDBRANCH
Port: 3306
Schema: cpexhibits

Execute the following store procedures and save the results to CSV files.

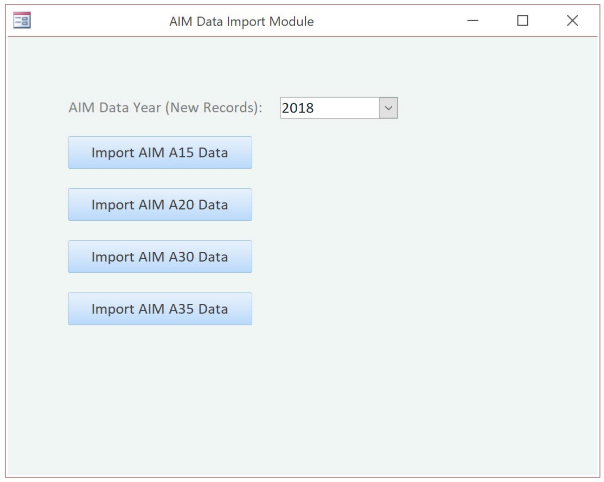
Exhibit E-1
Store Procedures

NTD Form	Stored Procedure	Parameters	Description
A15	sp_AIM_A15_Export	yr INT	Report year of the NTD data
A20	sp_AIM_A20_Export	yr INT	Report year of the NTD data
A30	sp_AIM_A30_Export	yr INT	Report year of the NTD data
A35	sp_AIM_A35_Export	yr INT	Report year of the NTD data

2. Importing the data into a TERM Federal MS Access file

Within TERM Federal there is a form, "frmAIMImport" that the user can open. This will present them with the import menu (Figure 1) that allows the user to import one or more AIM data forms form the NTD and select the report year. Simply click on the button for the desired form and select the appropriate CSV file export and the process will run.

Exhibit E-2
AIM Import Form Main Menu



3. AIM Import Business Rules

The following table shows the business rules by form and asset type to translate records from the NTD in TERM federal asset records.

Exhibit E-3
AIM Import Business Rules

Element Name	Group	Number of Records	Date Built (Start year is NTD data year)	Unit Quantity
At-Grade/Ballast (including expressway)	A	1) Convert decade built distribution to year built records (ten records per decade)	1) For Pre-1930 records, set start year to [Service Inauguration Year] in tbl03AgencyMode	0) First convert values recorded in "Percent" units to track miles (will need data from either tbl03AgencyMode or NTD "Track and Roaway" table) 1) Unit quantity for each record = total linear miles / number of records
At-Grade/In-Street/Embedded				
Elevated/Retained Fill				
Elevated/Concrete				
Elevated/Steel Viaduct or Bridge				
Below-Grade/Retained Cut				
Below-Grade/Cut-and-Cover Tunnel				
Below-Grade/Bored or Blasted Tunnel				
Below-Grade/Submerged Tube				
Substation Building	B	2) One record for each asset substation count (e.g., if count = 15, then generate 15 asset records)	2) Assume mid-point of decade built	2) Unit quantity = count
Substation Equipment	C		2a) Assume mid-point of decade built for subsation	3) Unit quantity = number of substations

Third Rail/Power Distribution	D	3) One record for each year from age = 0 to age = 1.25*[Age250] years (divisable as quantity based on track miles)	3) Uniform distribution of ages across the records for age = 0 to age = 1.25*[Age250] years (divisable as quantity based on track miles) i) Date built cannot be less than the [Service Inauguration Year] in tbl03AgencyMode	4) Unit quantity = total track miles (from 15 Tangent, 16 Curve, 17 non-revenue service track and 18 Revenye Track - No Capital respnsibility)
Overhead Contact System/Power Distribution				
Train Control & Signaling				
Tangent --Revenue Service	E			5) Reported track miles / number of records
Curve -- Revenue Service				
Non-Revenue Service				
Revenue Track - No Capital Replacement Responsibility				
Double Diamond Crossover	F	2) One record for each asset count (e.g., if count = 15, then generate 15 asset records)	4) Random age/date built for each asset record (assume assets are from 0 to 1.25*[Age250] years of age i) Date built cannot be less than the [Service Inauguration Year] in tbl03AgencyMode	2) Unit quantity = count
Single Crossover				
Half Grand Union				
Single Turnout				
Grade Crossings				

APPENDIX E - REFERENCES

Title	Author	Publication Year	Web Address
Condition Assessment Calculation	FTA	2018	https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/regulations-and-guidance/asset-management/60361/tam-facility-performance-measure-reporting-guidebook-v1-2.pdf
Capital Cost Database	FTA	2016	https://www.transit.dot.gov/capital-cost-database
Rail Modernization Study	FTA	2009	https://www.transit.dot.gov/sites/fta.dot.gov/files/Rail_Mod_Final_Report_4-27-09.pdf
National State of Good Repair Assessment	FTA	2010	https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/National_SGR_Study_072010%282%29_1.pdf
Small Systems Waiver Reporting Manual	FTA	2013	https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/SSW_Manual.pdf
Guidance on Value of Time	USDOT	2014	https://www.transportation.gov/office-policy/transportation-policy/guidance-value-time
2016 Annual Database Agency UZA	FTA	2016	https://www.transit.dot.gov/ntd/data-product/2016-annual-database-agency-uza
Transit Asset Management Pilot Program: Volume 1	CH2MHill	2013	https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/RTA_Final_Rpt._COMBINED_TAM_Pilot_Grant_v1.pdf
National Transit Database 2019 Polic Manual	FTA	2019	https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/subdoc/181/2019-ntd-reporting-policy-manual.pdf
Circular A-4	OMB	2003	https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/circulars/A4/a-4.pdf