Transit Economic Requirements Model: Technical Overview

Updated January 2025

Introduction

The Transit Economic Requirements Model (TERM), an analytical tool developed by the Federal Transit Administration (FTA), forecasts transit capital investment needs over a multi-year period. The model uses transit-related data and research, including data on transit capital assets, current service levels and performance, projections of future travel demand, and a set of transit asset-specific condition decay relationships, to generate the forecasts that appear in the biennial *Status of the Nation's Highways, Bridges and Transit: Condition and Performance* (C&P) Report and other publications.

TERM forecasts the level of annual capital expenditures required to attain specific physical condition and performance targets within a forecast period. These annual expenditure estimates cover the following types of investment needs: (1) asset preservation (rehabilitations and replacements) and (2) asset expansion to support projected ridership growth and other service improvements.

This document provides a technical overview of TERM and describes the methodologies used to generate the estimates. TERM was last updated in 2023–2024 to use the latest available NTD data (through 2022) and make minor corrections as needed. Changes were also made to improve TERM’s functionality and runtime.

TERM Database

The model uses a broad array of transit-related data and research, including data on transit capital assets, current service levels and performance, projections of future travel demand, and a set of transit asset-specific condition decay relationships. The input data, gathered from the National Transit Database (NTD) and local transit agencies, are the foundation of the model’s investment needs analysis, and include information on the quantity and value of the Nation’s transit capital stock.

Asset Inventory Data Table

The asset inventory data table documents the asset holdings of the Nation’s transit operators. These records contain information on each asset’s type, transit mode, age, and expected replacement cost. As FTA does not directly measure the condition of transit assets, asset condition data are not maintained in this table. Instead, TERM uses asset decay relationships to estimate current and future asset condition as required for each model run. These condition forecasts are then used to determine when each asset identified in the asset inventory table is due for either rehabilitation or replacement. The decay relationships are statistical equations that relate asset condition to asset age, maintenance, and utilization. The decay relationships and the ways in which TERM estimates asset conditions are further explained later in this document.

National Transit Database – Asset Inventory Module (NTD AIM)

TERM uses asset inventory data obtained from the 2022 National Transit Database's Asset Inventory Module (NTD AIM). With the NTD AIM, FTA obtains consistently reported asset inventory data for a large proportion of transit asset types, including revenue and service vehicles, stations and maintenance facilities, and guideway structures.

Although NTD AIM offers a significant improvement over data obtained through a sample of agency requests, it does have some limitations. First, it does not cover all asset types (e.g., communications, subway ventilation, or maintenance equipment) or provide year-built data for some asset types (e.g., track, switches, crossings). Given this limitation, data supplied through direct agency requests are still needed for these and some other asset types to support TERM's minimum asset inventory requirements. (TERM's minimum asset inventory requirements include owning agency and asset type, mode, year built (or acquired), unit quantity, unit cost, and cost year.) Second, NTD AIM only provides unit cost data for service vehicles, which represent only a small proportion of the value of the Nation's transit assets. Therefore, FTA has developed standard unit replacement cost values for assets such as stations and facilities (per square foot) and elevated structures (per linear foot). A key challenge here is that transit asset replacement costs can vary significantly across the Nation. Finally, the "date-built" values AIM provides for subway and elevated track structures, train control, and traction power equipment are reported as the decade built instead of the year built. This results in "lumpy" data that can lead to swings in estimated needs depending on TERM's period of analysis.

Given these limitations and the need for comprehensive coverage of all major transit asset types, the asset inventory has been developed using a mix of NTD AIM data, responses by local transit agencies to FTA data requests, and special FTA studies. The asset inventory data table is the primary data source for the information used in TERM's forecast of preservation needs.

Urban Area Demographics Data Table

This data table stores demographic information on 497 urbanized areas as well as for 10 regional groupings of rural operators. Fundamental data, such as current and anticipated population, in addition to more transit-oriented information, such as current levels of vehicle miles traveled (VMT) and transit passenger miles, are used by TERM to predict future transit asset expansion needs.

Agency-Mode Statistics Data Table

The agency-mode statistics table is generated from the 2022 NTD data and contains operations and maintenance (O&M) data on each of the individual modes operated by transit agencies. Specifically, the agency-mode data on annual ridership, passenger miles, operating and maintenance costs, mode speed, and average fare data are used by TERM to help assess current transit performance, future expansion needs, and the expected benefits from future capital investments in each agency-mode (both for preservation and expansion). Where reported separately, directly operated and contracted services are merged into a single agency-mode within this table.

Asset Type Data Table

The asset type data table identifies approximately 500 different asset types used by the Nation's public transit systems in support of transit service delivery (either directly or indirectly). Each record in this table documents each asset's type, unit replacement costs, and the expected timing and cost of all life-cycle rehabilitation events. Some of the asset decay relationships used to estimate asset conditions are also included in this data table. The decay relationships—statistically estimated equations relating asset condition to asset age, maintenance, and utilization—are discussed in greater detail later in this document.

Mode Types Data Table

The mode types data table provides generic data on all of the mode types used to support U.S. transit operations—including their average speed, average headway, and average fare—and estimates of transit riders' responsiveness to changes in fare levels. Similar data are included for non-transit modes, such as private automobile and taxi costs. The data in this table are used to support TERM's benefit-cost analysis.

Investment Policy Parameters

As part of its investment needs analysis, TERM predicts the current and expected future physical condition of U.S. transit assets over a multi-year period. These condition forecasts are then used to determine when each of the individual assets identified in the asset inventory table is due for either rehabilitation or replacement. The investment policy parameters data table allows the user to set the physical condition ratings at which rehabilitation or replacement investments are scheduled to take place, although the actual timing of rehabilitation and replacement events may be deferred if the analysis is budget-constrained. Unique replacement condition thresholds may be chosen for the following asset categories: guideway elements, facilities, systems, stations, and vehicles. All of TERM's replacement condition thresholds are set to trigger asset replacement at condition 2.5 for most analyses, unless specified otherwise in a publication.

In addition to varying the replacement condition, users can vary other key input assumptions intended to better reflect the circumstances under which existing assets are replaced and the varying cost impacts of those circumstances. For example, users can assume that existing assets are replaced under full service, partial service, or a service shutdown. Users can also assume assets are replaced either by agency (force-account) or by contracted labor. Each of these assumptions affects the cost of asset replacement for rail assets.

Financial Parameters

TERM also includes two key financial parameters. First, the model allows the user to establish the rate of inflation used to escalate the cost of asset replacements for TERM's needs forecasts. Second, users can adjust the discount rate used for TERM's benefit-cost analysis.

Benefit-Cost Parameters Data Table

The benefit-cost parameters data table contains values used to evaluate the merit of different types of transit investments forecasted by TERM. Measures in the data table include transit rider values (e.g., value of time and links per trip), auto costs per VMT (e.g., congestion delay, emissions costs, and roadway wear), and auto user costs (e.g., automobile depreciation, insurance, fuel, maintenance, and daily parking costs).

Transit Asset Conditions and Asset Decay Curves

To estimate continuing replacement and rehabilitation investments, TERM estimates the current and expected future physical condition of each transit asset identified in TERM's asset inventory for each year of the forecast. These projected condition values are then used to determine when individual assets will require rehabilitation or replacement. TERM also maintains an output record of this condition forecast to assess the impacts of alternate levels of capital reinvestment on asset conditions (both for individual assets and in aggregate). In TERM, the physical conditions of all assets are measured using a numeric scale of 5 through 1; see Table 1 for a description of the scale.

Table 1. Definitions of Transit Asset Conditions

Rating	Condition	Description
Excellent	4.8–5.0	No visible defects, near-new condition
Good	4.0–4.7	Some slightly defective or deteriorated components
Adequate	3.0–3.9	Moderately defective or deteriorated components
Marginal	2.0–2.9	Defective or deteriorated components in need of replacement
Poor	1.0–1.9	Seriously damaged components in need of immediate repair

Source: Transit Economic Requirements Model (TERM).

TERM asset decay curves were developed for use within TERM and are comparable to asset decay curves used in other modes of transportation and bridge and pavement deterioration models. Although the collection of asset condition data is not uncommon within the transit industry, TERM asset decay curves are believed to be the only such curves developed at a national level for transit assets. Most of the TERM key decay curves were developed using data collected by FTA at multiple U.S. transit properties specifically for this purpose. There are over 100 different decay curves used in TERM.

While TERM is designed to establish different asset replacement threshold conditions for each of the five asset categories (guideway, facilities, systems, stations, and vehicles), it is common practice to use a common condition rating replacement threshold across all 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.

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 2022, TERM uses a range of decay curves, which were developed over three primary time periods. Below is a description of that decay curve development, beginning with the original decay curves (developed in 1995 using CTA condition assessment data from 1992), through conclusion of the most recent decay curve development effort in 2019.

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

All of TERM's initial asset decay curves were estimated using a single primary data source, the Chicago Transit Authority's (CTA) 1992 Engineering Condition Assessment (ECA). This 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 scale presented previously in Table 1.

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.

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:

1. **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
2. **Utilization Rate*:*** Assets with high utilization rates will deteriorate more quickly than assets used with less frequency.
3. **Maintenance Rate*:*** For many asset types, increased maintenance yields improved asset conditions.[1]

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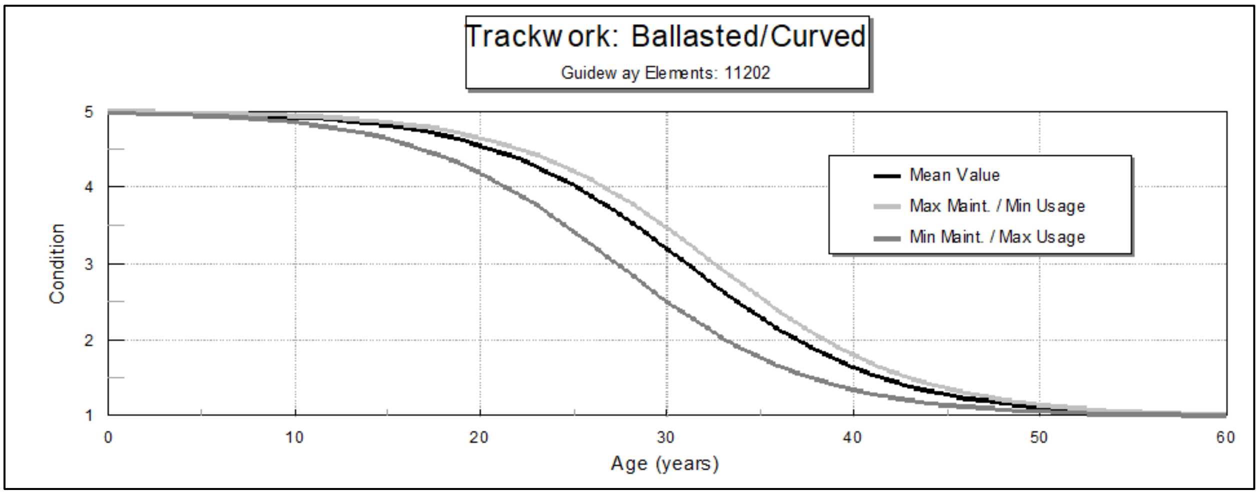
[1] Counterintuitively, asset conditions frequently appear to *decline* with increased maintenance rates. This finding confuses cause and effect. A negative statistical relationship between condition and maintenance highlights the increased cost of maintaining lower condition assets.

The mathematical formulation for these decay curves is as follows:

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

An example of this ECA based decay curves is found in Figure 1.

Figure 1. Sample Asset Decay Curve: Trackwork



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.

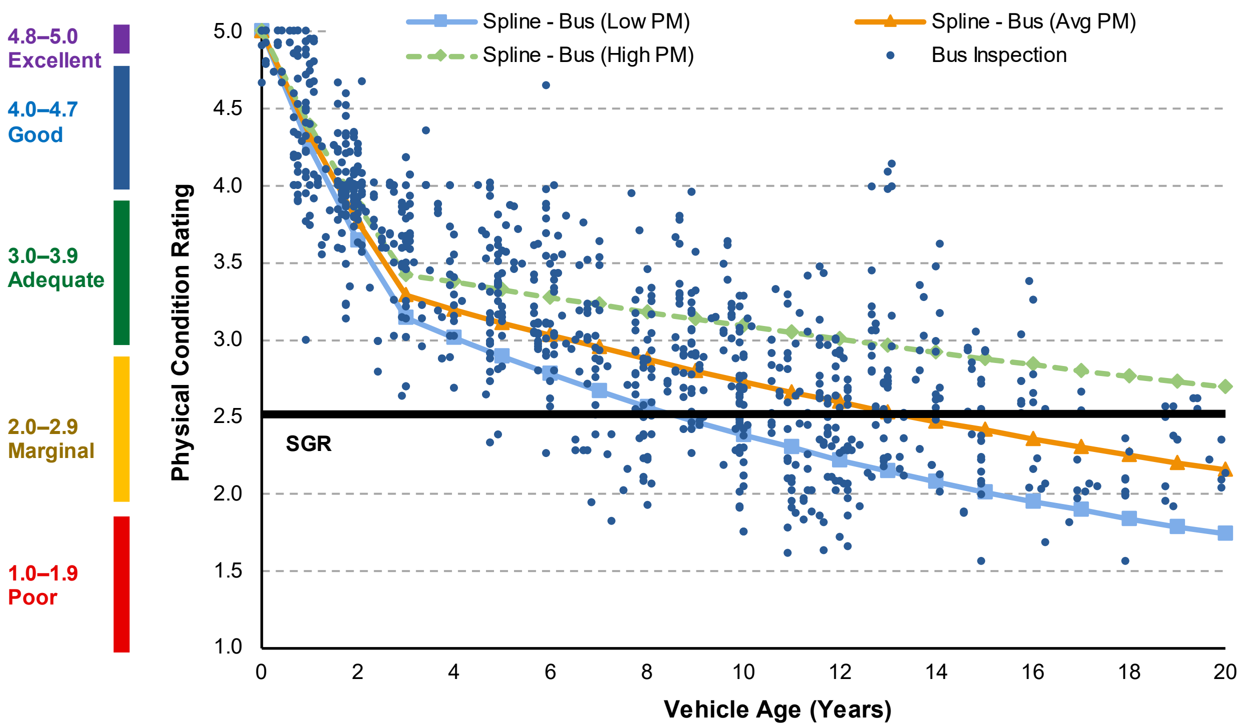
Given these concerns, the decision was made in 1998 to initiate a program to assess the physical condition of all transit asset types on a nationwide basis with the goal of developing a full set of nationally based asset condition decay curves for TERM. To date, these national physical condition inspections 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 linked together to model the asset's full lifecycle. 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. Figure 2 provides the mathematical form of the spline function and a graphic example of the spline models used by TERM.

Spline Model Functional Form

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

Figure 2. TERM Asset Decay Curve for 40-Foot Buses



Source: Federal Transit Administration; empirical condition data obtained from a broad sample of U.S. transit operators.

Given differences in the number of equation terms across these newly estimated relationships and slight differences in functional form (the timing of the spline breakpoints 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 (2018–19)

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 expanding the study to cover additional asset types not covered by prior work (e.g., tunnels, bridges, and LRT stations). In addition, this update also addressed 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.

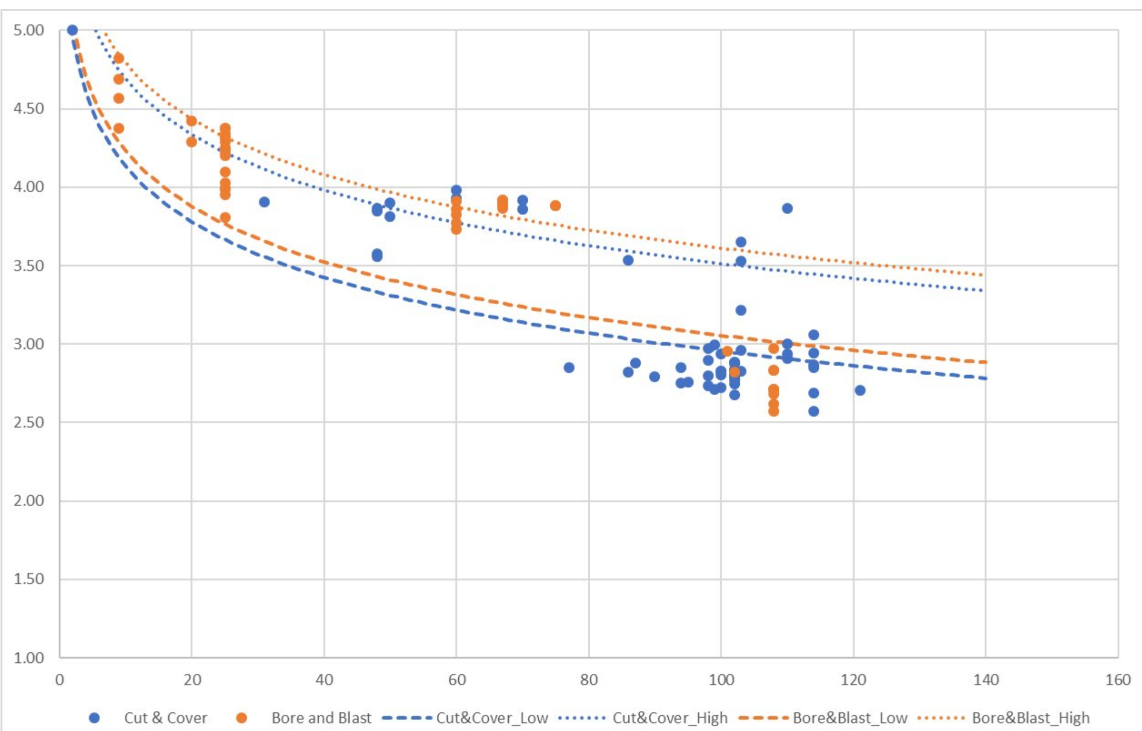
While the 2018 update resulted in the estimation of 71 new asset decay curves (based on empirical field data) and revisions to 28 additional, age-based curves (based on improved understanding of asset life expectancies). A key aspect of this work was the development and implementation of a third functional form: Linear-Log. The dummy variables noted in the equation represent a variety of indicator variables for categorical data.

An example linear-Log function for tunnels is presented in Figure 3. The figure uses tunnels as its example asset, and the various lines represent the types of tunnel assets with high and low estimates. The purpose of the figure is to show the general pattern of the linear-log function.

Linear-Log Functional Form

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

Figure 3. Tunnel Linear-Log Function

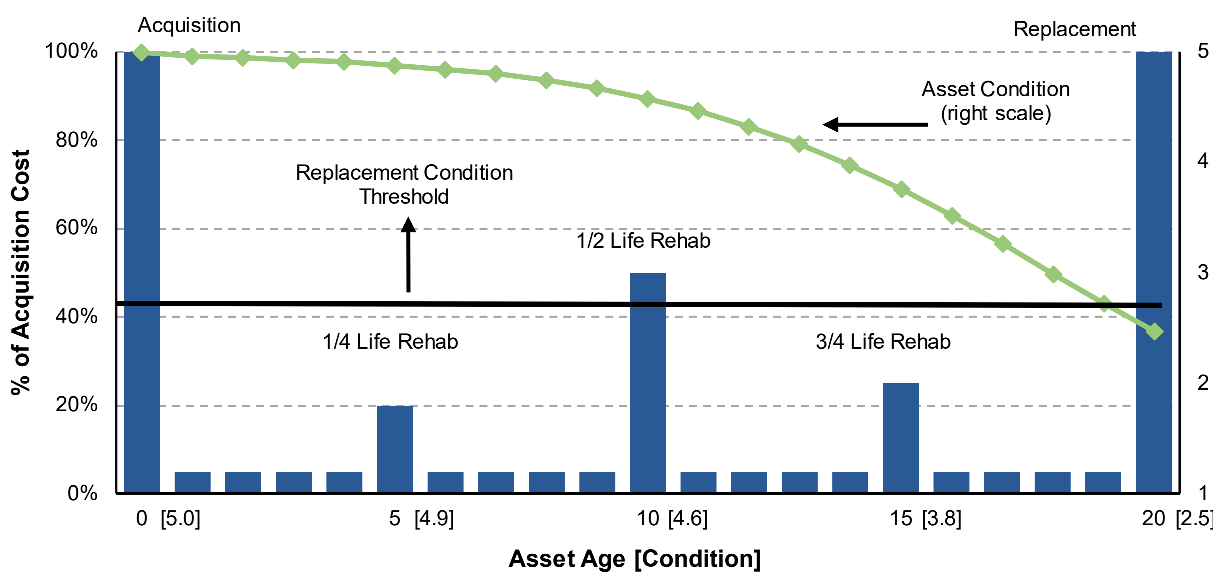


Estimation of Rehabilitation and Replacement Needs

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.

TERM's process of estimating rehabilitation and replacement needs is represented conceptually for a generic asset in Figure 4. In this theoretical example, asset age is shown on the horizontal axis, the cost of life-cycle capital investments is shown on the left vertical axis (as a percentage of acquisition cost), and asset conditions are shown on the right vertical axis. At the acquisition date, each asset is assigned an initial condition rating of 5, or "excellent," and the asset's initial purchase cost is represented by the tall vertical bar at the left of the chart. Over time, the asset's condition begins to decline in response to age and use, represented by the dotted line, 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 rating of 2.5, at which point the asset is retired and replaced.

Figure 4. Scale for Determining Asset Condition over Time, from Acquisition to Replacement



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 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 Type Data Table (see earlier subsection). 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 Type Data Table. 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, TERM's hierarchy of assets groups all assets into five broad categories of asset types: 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 lifespans 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 ensures that all vehicle types are evaluated equally using a common replacement standard.

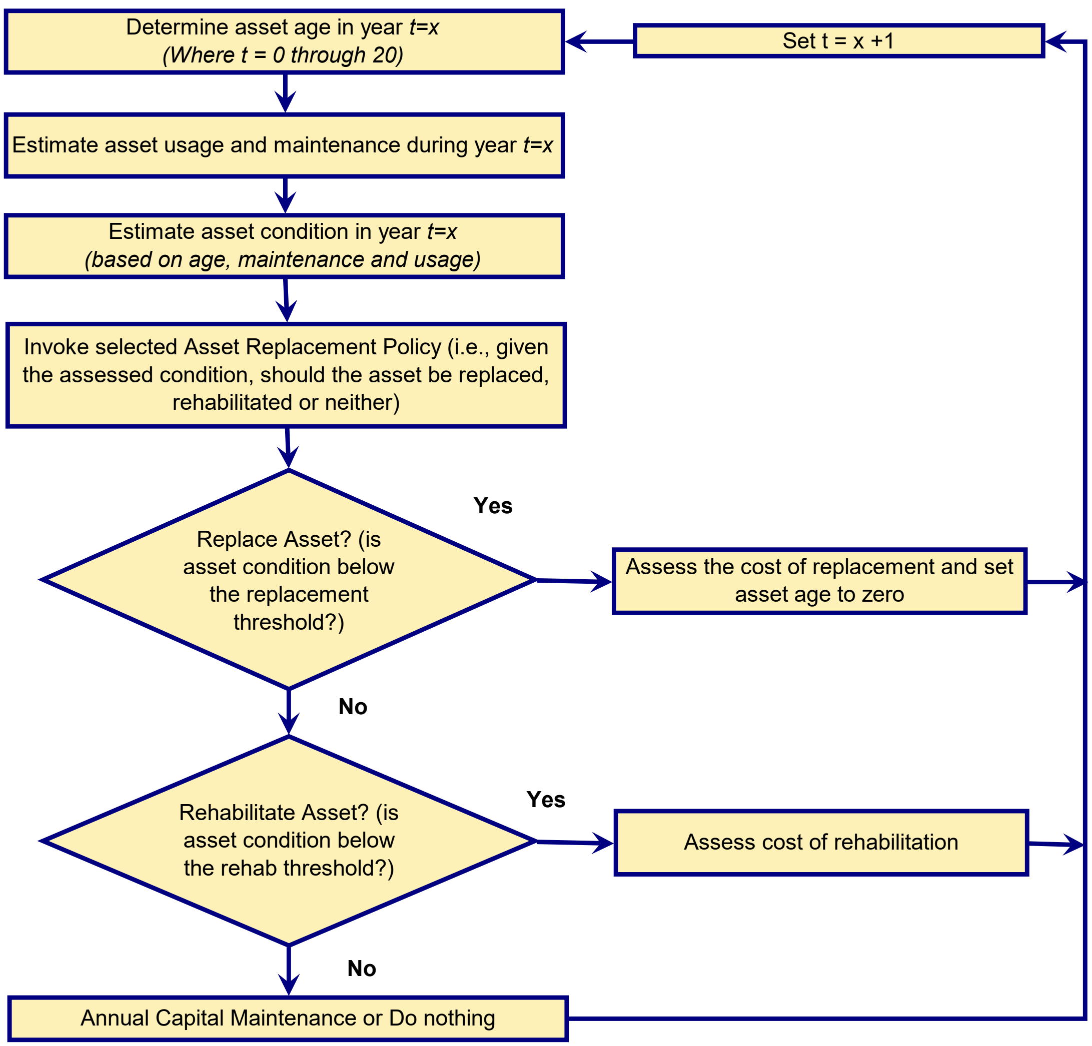
Model Decision Flow: Unconstrained Rehab and Replacement

To model the decay and financially unconstrained reinvestment processes, 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 Figure 5.

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.

Figure 5. Annual Condition and Investment Needs Evaluation Algorithm



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, 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 like those 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 $t = 20$.

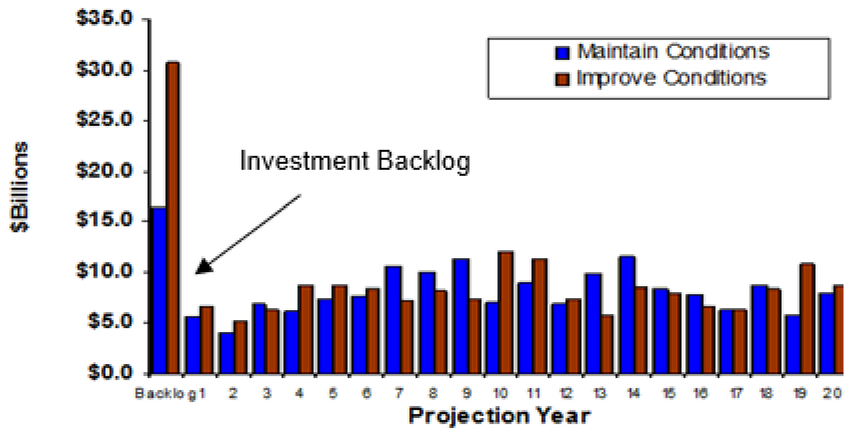
Asset Rehabilitation Does Not Impact TERM's Condition Estimates. The Rehab-Replacement Module does not increase its estimate of an asset's physical condition rating following a rehabilitation activity. This is contrary to expectation as the physical condition of real-world transit assets do improve following any rehabilitation activity.

There are two primary reasons for not modeling the 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 State of Good Repair Backlog

By default, the Rehab-Replacement Module 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 eliminated at the start of the model run, and sufficient funding is available to address all subsequent reinvestment needs as they arise. Existing funding capacity is not usually sufficient to address all outstanding needs, either now or in the future, resulting in the ongoing presence of a State of Good Repair (SGR) backlog (Figure 6). 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 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 for use in future periods.

Figure 6. Annual Expenditures to Maintain or Improve Asset Conditions

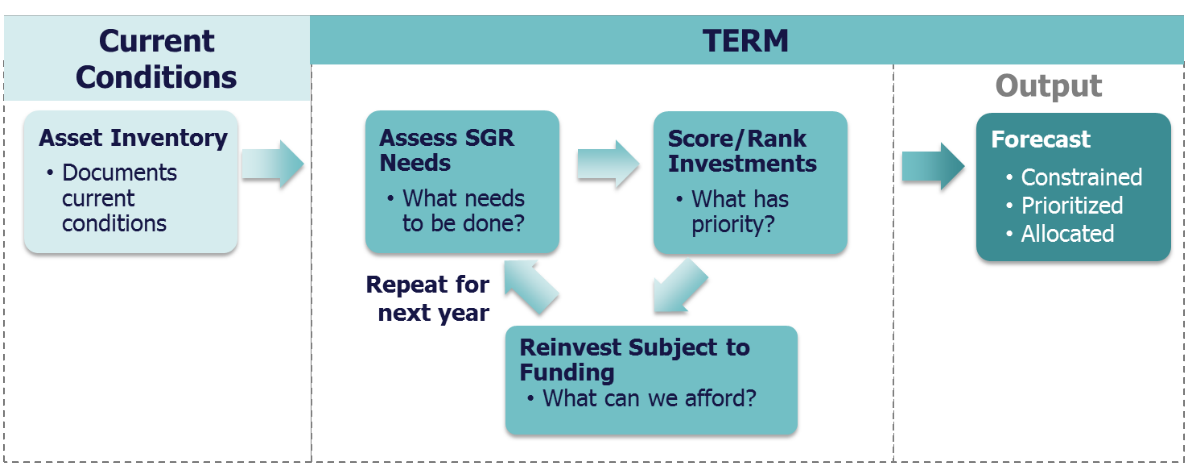


Investment Prioritization within TERM

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 Figure 7).

Notably, the size and composition of TERM's backlog projections are sensitive to the TERM prioritization settings.

Figure 7. 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, Many of the prioritization parameter settings used by TERM Federal were also adopted from RTA's default values, which were based on extensive research, testing and review.

Prioritization Criteria

TERM's prioritization routine uses five criteria to score and rank all reinvestment needs. 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.

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

- <u>Asset Condition</u>: This criterion is based on the principle that declining condition is an indicator of declining performance, declining useful life, and higher likelihood of failure – all pointing to higher prioritization for replacement.
- <u>Cost Effectiveness</u>: 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.
- <u>Reliability</u>: This criterion is designed to focus reinvestment dollars on those investments that contribute most to maintaining or improving transit service reliability.

- Safety & Security: This criterion is designed to focus reinvestment dollars on 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 on 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.

After generating 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 combines the 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 default weights used for this calculation were developed by Chicago RTA with the support of their three service boards, CTA, Metra, and Pace. The user can adjust these weights within TERM, but the default weights developed by Chicago RTA have consistently been the values used for recent TERM analyses. These weights are controllable parameters within TERM. 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.

Asset Expansion Investments

In addition to devoting capital to maintain and replace aging assets, transit agencies frequently need to expand their service offerings to improve system performance or to cope with rising consumer demand. TERM includes six components for the estimation of those expansion investment needs, which capture beneficial investments that improve transit performance.

Table 2 provides descriptions of the six components used to identify transit performance improvement investments. Each component can be independently enabled or disabled in model runs to simulate various conditions and perform sensitivity analyses.

Table 2. Components to Improve Performance and Accessibility

Expansion Analysis Component	Component Objective	Data Sources
Expand Service Coverage	Expand transit service to cover areas currently without service but with sufficient residential density to support fixed-route service.	Census Bureau; Generalized Network Transit Specification
Improve Service Frequency	Increase service frequency where service is inadequate based on residential density.	Census Bureau; Generalized Network Transit Specification
Implement CIG Projects	Invest in all CIG projects currently approved in the CIG pipeline.	FTA CIG Projects data; FTA Capital Cost Database
Improve Average Operating Speeds	Improve average transit operating speeds of urbanized areas that are well below the national average.	NTD; FTA Capital Cost Database; APTA Vehicle Database
Reduce Crowding	Reduce vehicle occupancy rates (crowding) for agencies that are well above the national average (calculated separately for each transit agency mode combination).	NTD; FTA Capital Cost Database; APTA Vehicle Database
Ridership Growth	Increases fleet to accommodate forecasted ridership growth.	NTD

Source: Transit Economic Requirements Model.

Expand Service Coverage and Improve Service Frequency

These components identify and quantify capital expansion investment levels for communities that are either not served by fixed-route transit service or are underserved based on the frequency of service currently provided. Residents of these areas lack accessibility to fixed-route transit service, despite having sufficient residential density that supports this level of service. Other communities within urbanized areas may have some existing fixed-route transit service within walking distance, but not at a frequency level that is justified based on residential densities. In both instances, the supply of transit service may be insufficient relative to the potential demand that could be supported within these areas.

The Transit Capacity and Quality of Service Manual[2] identifies accessibility as a “measure of availability” and frequency as a “measure of comfort and convenience.” Both are central to the quality of transit service experienced by passengers.[3] The term “first mile/last mile” refers to the challenges and potential solutions to reducing the distance between a traveler’s origin/destination and a transit station/stop. Expanding coverage directly addresses first mile/last mile accessibility by reducing the distance to the nearest bus stop and making transit an option for travelers. Even if transit service is provided within walking distance, the frequency of the service provided is a key determinant in whether transit is chosen over other modes such as driving. Both coverage and frequency are critical issues for transit agencies as they strive to retain and attract transit riders in an equitable manner.

The analysis identifies block groups, which are clusters of census blocks, within the Nation’s large urban areas that warrant introducing fixed-route transit service or adding transit service based on

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[2] https://www.trb.org/Main/Blurbs/169437.aspx

[3] Transportation Review Board, 2013. *Transit Capacity and Quality of Service Manual*, 3rd Edition, Section 4.3, “Quality of Service Framework.”

housing unit density levels. Housing unit density was estimated nationally for all urbanized areas with population over 50,000 and with complete and validated Generalized Network Transit Specification (GTFS) transit networks, which included 232 urbanized areas. Investments to address underserved communities typically consist of investments in bus vehicles and their support assets.

Decades of research have established the strong relationship between density and transit ridership. For this analysis, housing unit density was selected to identify residential neighborhoods that have sufficient density to support fixed-route transit. Housing unit density is a useful measure that can be calculated using Census data at the block group level for all urbanized areas. However, other factors beyond the scope of this analysis will affect whether transit service expansion leads to increased transit ridership, including but not limited to connections to jobs and activities, connections to other transit services, the pedestrian network around bus stops, traffic congestion, and parking prices within the service area.

The two types of density-based analysis include:

- **Expand Coverage:** This component identifies block groups that are not currently served by transit but warrant transit service based on housing unit density levels that support fixed-route bus service.
- **Improve Frequency:** Similarly, this component identifies regions within block groups that *are* currently served by transit but warrant an increase in service frequency, again based on density thresholds.

Table 3 lists the dwelling unit density thresholds used to identify the minimum average headway supported. For example, based on these guidelines, an area with fewer than four dwelling units per acre is considered to have insufficient density to support regular fixed-route transit service. A dwelling unit density of at least seven dwelling units per net acre would be needed to support bus headways of 30 minutes or better.

Table 3. Minimum Headway Supported by Density Levels

Dwelling Unit Density	Minimum Average Headway Supported
< 4 dwelling units/net acre	Density insufficient to support regular fixed-route transit
4 dwelling units/net acre	60 minutes
7 dwelling units/net acre	30 minutes
15 dwelling units/net acre	15 minutes

Source: Pushkarev, B.S., and J.M. Zupan, 1977. Public Transportation and Land Use Policy, as cited in Transportation Research Board, 2013. *Transit Capacity and Quality of Service Manual*, 3rd Edition, Exhibit 5-2.

These headway thresholds are the current standards established by the Transit Capacity and Quality of Service Manual published by the Transportation Research Board of the National Academies of Science, Engineering, and Medicine. This research explicitly used the number of riders that would produce enough fare revenue to cover operating costs to determine minimum average headway.[4] In recent years, public subsidies for fixed-route transit service have become more widely accepted. This is in part because fixed-route transit service is a public benefit for disadvantaged members of the community and because riders of public transportation provide positive externalities to the rest of the community by reducing roadway congestion and reducing demand for scarce parking spaces. Additional research may yield insights for updating these standards with an eye toward the need to provide high-quality transit service to a diverse array of communities with the need to maintain efficient and sustainable transit operating practices.

Nevertheless, transit service with headways of 30 minutes and 60 minutes is of limited benefit. Few people with access to automobile transportation will choose to use transit with such long headways. Furthermore, transit service at these headways is of limited value to disadvantaged populations. For example, a transit-dependent person using a bus service with 60-minute headways usually cannot set their own work hours, and they cannot set the schedule of classes at a community college. A bus route with 60-minute headways may offer a rider the choice between arriving 50 minutes early for work or class or arriving 10 minutes late. If the rider needs to make a connection to another bus route, also with infrequent headway, the usefulness of the system becomes even more limited.

Data Sources and Pre-Processing

The service coverage and service frequency analyses are based on the same data sources used to calculate residential densities and the availability and frequency of transit service. The density-based analysis uses multiple data sources to identify housing unit densities and existing transit service levels within urbanized areas:

- Block group and urbanized area geographies were downloaded from the Tiger/LINE portal on the Census Bureau website in shapefile format.
- Demographic information, including population and housing units, for all block groups was downloaded separately from the Census Bureau's data portal.
- GTFS feeds were compiled for all urbanized areas, where available.
- Dwelling unit density was calculated for all block groups that fall within urbanized areas boundaries by dividing the housing units by the land area of each block group in square miles. For the existing density conditions, the primary source used in this analysis was the 2020 Census at the block group level.

To project the transit service expansion levels out to 2042, it is necessary to determine which block groups might move into a different dwelling unit density stratum in the next 20 years. In the absence of a source for long-range population and dwelling unit forecasts at the block group level, trendline

[4] Pushkarev, B.S., and J.M. Zupan, 1977. Public Transportation and Land Use Policy, as cited in Transportation Research Board, 2013. *Transit Capacity and Quality of Service Manual*, 3rd Edition

growth rates were used to project future densities. Historical population and dwelling unit counts from 2013 and 2022 American Community Surveys were compiled for each block group.

ACS data are reported in geographic units matching those used for the most recent Decennial Census available at the time the ACS data were released. This means that ACS data from 2013 uses Block Groups from the 2010 Census, while ACS data from 2022 uses data from the 2020 Census. Before it is possible to calculate the growth rate for each block group, it is important to establish a geographic "common denominator" between these two datasets to allow for comparison across data years. To do this, 2013 ACS data was reweighted so that it conforms to the Census 2020 Block Group geometries.

Once the ACS data has been reweighted to use Census 2020 Block Group geometries, the 2013 and 2022 population and dwelling unit totals are used to calculate a compound annual growth rate (CAGR) for population and dwelling units separately for each block group.

Population CAGR (year 2013 to year 2022) = [(Population in 2022/Population in 2013) ^ (1/9)-1]

This CAGR was applied to each year between 2022 and 2042 to project the future dwelling units for each block group. Due to the potential for outlier block groups with extremely high growth or decline between 2013 and 2022 to skew the data, a 3-percent annual growth cap was applied to ensure reasonableness. The dwelling unit densities for each block group in 2024 were used in the analysis of future service coverage and service frequency expansion levels.

Coverage Analysis

The coverage analysis is designed to account for portions of urbanized areas that are not served by any regular fixed-route transit service but where housing unit densities are high enough to support regular service. As shown in *Exhibit C-8*, areas with a residential density of four housing units per acre and above can support at least hourly fixed-route bus service. This analysis determines which block groups in an urbanized area were not served by regular transit service and applies a factor to calculate the vehicle revenue miles (VRM) needed to serve the block groups where coverage deficiencies were identified.

The analysis includes the following steps, as shown in Figure 8:

1. **Create transit buffers.** Block group geography and transit stop locations, using the GTFS feeds, were compiled for all urbanized areas in a geographic information system (GIS). For this analysis, areas within one-half mile of each bus stop or station were classified as being within a walkable buffer zone of the bus stop. These transit buffers indicate the areas that currently have walking access to fixed-route transit service.

2. **Identify unserved areas.** Overlaying the transit stops with the block groups in the urbanized areas allows for the identification of block groups that are expected to have a density greater than four dwelling units per net acre in 2042 but are not currently served by fixed-route transit.

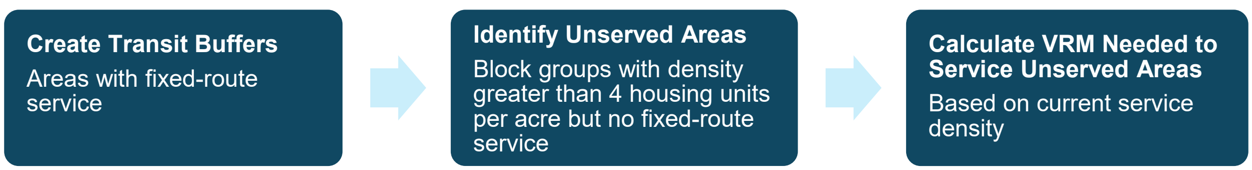
3. **Calculate VRM needed to serve unserved areas.** The VRM needed to serve unserved areas is calculated by applying the service density ratio of the entire UA to the area of the block groups. Annual fixed-route VRMs for each UA were calculated by summing the existing annual VRM of the Motor Bus, Commuter Bus, and Rapid Bus modes in the NTD's service tables. The factor used is the overall service density for the UA, which can be calculated as:

   Urbanized Area Service Density *= Total fixed-route VRM for 2022 summed up across all bus modes (MB, CB, RB) in the urban area / Total area of Unserved Block Groups (Sq Mi)*

   Hence the new annual VRM needed to serve all the unserved block groups in an urbanized area can be expressed as:

   *New VRM to Provide Service to Unserved Block Groups = UA Service Density * Area of Unserved Block Groups (Sq Mi)*

Figure 8. Coverage Analysis Methodology



Source: Analysis by Federal Transit Administration.

This approximation of service needs assumes that the amount of VRM required to serve the unserved block groups will be proportional to the area of the block groups. This is a rough approximation: actual service levels would be expected to differ from the estimate if development is uneven within the block group, requiring service to just a portion of the block group, if the service levels in the existing service area are much higher than is needed to serve unserved block groups, or if the block group is far removed from the existing service area, requiring additional VRM to connect block groups to existing transit routes.

Frequency Analysis

The transit coverage analysis identifies service deficiencies only for areas with no existing fixed-route transit service. An additional analysis of service frequency was conducted to account for portions of urban areas that do have fixed-route service, but where service is inadequate based on its residential density. The transit frequency analysis was designed to account for new service needed in these areas by dividing block groups into residential density categories that each have a recommended hourly peak fixed-route transit headway, as shown in *Exhibit C-8*. For example, block groups with a density of seven dwelling units per net acre are assumed to be able to support fixed-route bus service at 30-minute headways or better.

Each block group was evaluated based on its existing peak period transit service, calculated from the highest-frequency transit stop within a half-mile buffer of the block group. If the existing peak period service was less frequent than the recommended service level based on the density threshold of a given block group, the transit route serving the block group was flagged as having a frequency deficiency. A calculation was made of the VRMs necessary to increase service on the deficient route to meet the recommended peak headway.

The analysis includes the following steps, as shown in Figure 9:

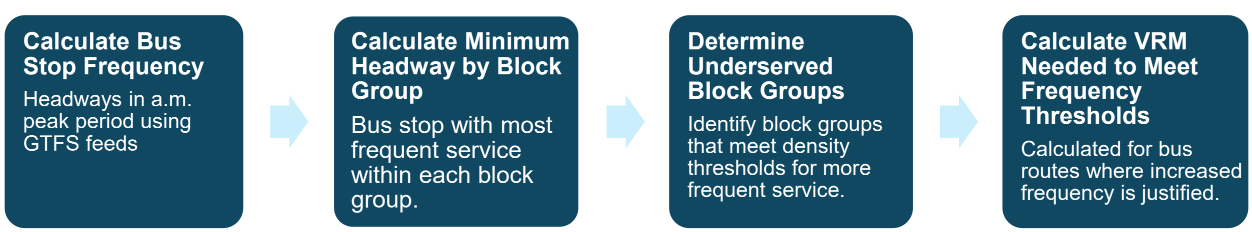
1. **Calculate stop frequency from GTFS.** The average headway was calculated at each bus stop along each route in the a.m. peak period from 5 a.m. to 9 a.m., using GTFS feeds.

2. **Calculate the minimum headway for block groups with transit service.** For each block group, the frequencies of service at bus stops within walking distance (less than one-half mile) of the block group were compiled. The bus stop with the most frequent (lowest headway) service was associated with the block group in which it is located.

3. **Determine underserved block groups and underserved routes.** All block groups where the calculated bus stop headway was greater (less frequent) than the required minimum headway, based on dwelling unit density, were classified as "underserved." The next step was to determine which specific routes need more service to bring every block group up to its recommended frequency thresholds.

4. **Calculate VRM required to meet frequency thresholds.** The number of additional peak-period trips on each route needed to meet the frequency threshold was multiplied by the length of the route to calculate the additional revenue miles needed to meet frequency thresholds in the peak periods. The total daily additional VRM was summed for the urbanized area and factored to obtain the annual VRM needed to address frequency deficiencies. Service increases are assumed over the entire length of a route that is serving any block groups with deficient frequency levels, affecting the additional service required.

Figure 9. Frequency Analysis Methodology



Source: Analysis by Federal Transit Administration.

Improve Coverage and Frequency Components Asset Record Development

The Improve Coverage and Frequency components are both designed to estimate the level of fleet expansion required to support the projected VRM requirement estimates. Specifically, TERM determines the number of vehicles required to deliver the required VRM levels based on current VRM per active fleet vehicle for the urbanized area in which the expansion investment is being made (as determined by data reported by local operators for the urbanized area to NTD). These fleet vehicle assets are then added to TERM's asset inventory, after which they undergo the same asset decay, rehab, and replacement analyses applied to existing assets. Should there be insufficient funding to cover the future replacement or rehabilitation costs of any of these assets, the value of those deferred investment needs will be added to TERM's national backlog estimate.

Implement CIG Projects

The objective of the Implement CIG Projects component is to assess the expected investment cost of all CIG projects for the period 2022 through 2042. This component assures that these planned expansion investments were accounted for both in terms of project acquisition costs and expected asset rehab and replacement costs within this 20-year period of analysis. For the 2023–24 update of TERM, all CIG projects with construction grants as of January 2024 were included.

CIG Asset Records: To help better assess the long-term life-cycle reinvestment requirements of these expansion investments, this component used standard project parameters available for each project—including project route miles, station counts, and fleet size—to convert the CIG records into up to 45 different asset records (depending on the investment mode and the project parameter values). This included records for all major replaceable asset types—including track, structures, facilities, systems assets (train control, electrification, and communications), and fleet. These project records also document one-time project costs, including right-of-way acquisition, planning, design, sitework, environmental mitigation, and project management.

The mapping of project parameters to TERM asset records is presented in Table 4. The generated assets are then added to TERM's asset inventory as "expansion" assets, which are then acquired, decayed, rehabbed, and replaced in the same manner as existing assets. If capital funding is insufficient to rehab or replace these assets after they are acquired, these deferred needs are added to TERM's estimate of the SGR backlog.

Data Source: FTA maintains a detailed listing of transit projects seeking Federal CIG funding assistance. The project listing documents the sponsoring agency, project mode, expected project design initiation and completion dates, cost estimate, alignment length and grade mix, and finally the number of expansion stations, vehicles, and maintenance facilities. In the 2023–24 update of TERM, 15 new CIG projects with construction grants as of January 2024 were added to the pre-existing list in TERM.

Table 4. Mapping of CIG Project Parameters into TERM Asset Records

CIG Project Parameter	Assets with Recurring Costs (Rehab/Replace)	One-Time Project Costs
Total Alignment Length	Train control Crossing protection Traction power Communications Central control	Right-of-way acquisition Sitework (earthwork, clearing) Utility relocation Temporary structures Environmental mitigation
Alignment Length by Grade	At-grade alignment Elevated structures Subway tunnels Retained cut / fill Ballasted track Embedded track Direct fixation track Special trackwork	
Station Count (with Alignment by Grade)	At-grade stations Elevated stations Subway stations Parking Pedestrian access Fare collection	
Facility Count (with Fleet Count)	Maintenance facilities (light and heavy maintenance, storage) Admin facilities Rail yard	
Fleet Vehicle Count	Revenue vehicles Service vehicles	

Source: New Starts Project Pipeline.

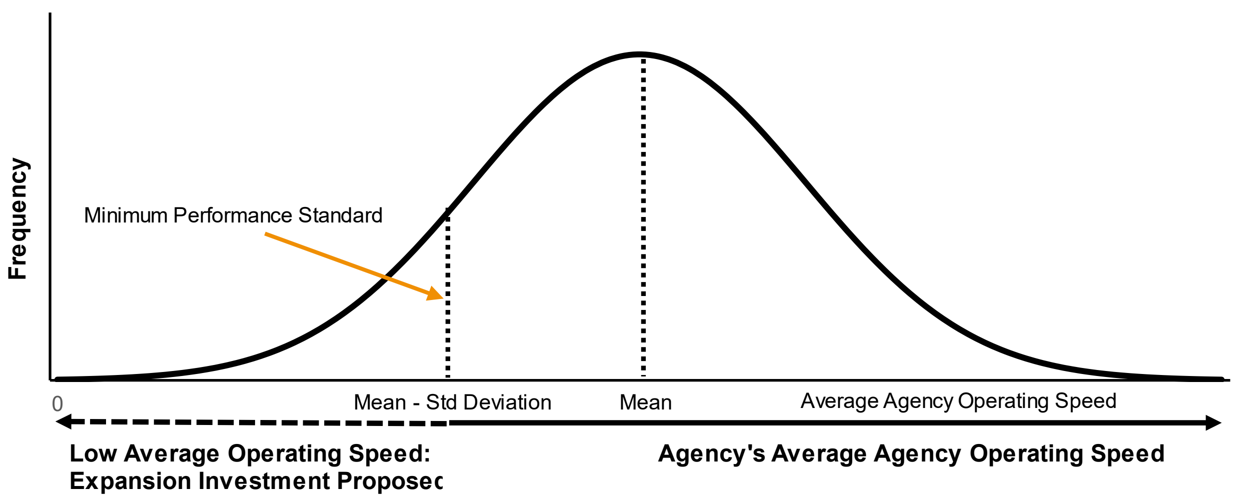
Improve Average Operating Speed

The Average Speed Improvement component is designed to identify urbanized areas 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 transit expansion investment. This module operates on the premise that average operating speeds for rail and bus rapid transit (BRT) are higher than for standard bus service. Hence, the substitution of rail transit capacity or BRT in place of existing bus capacity is made to increase the average operating speed for the entire urbanized area.

Minimum Service Standard: This component calculates the average urbanized areas transit operating speed as the weighted average speed across existing rail and bus service (excluding commuter rail) within the urbanized areas, weighted by vehicle miles. The values were calculated using data obtained from the NTD. The minimum service standard for average urbanized areas operating speed is then calculated as the national average transit operating speed, less one standard deviation, calculated across all urbanized areas with greater than 500,000 population (see Figure 10).

Mode Selection: The selection of which mode to invest in is determined first by the mode types already existing in each urbanized area and second by the population size of that urbanized area. Specifically, this component will first look to invest in the fastest existing rail mode within an urban area (excluding commuter rail) and hence will select heavy rail over light rail if both are already present. Commuter rail is not included as an option here as the intent is to focus speed improvements on operating speeds toward the urban core, and these systems typically extend well beyond the urban core. If the urban area does not currently have existing heavy rail, light rail, or BRT service, this component will select light rail for urbanized areas over 1 million in population and BRT for urbanized areas between 500,000 and 1 million in population.

Figure 10. National Distribution of Average Transit Operating Speeds



Source: Transit Economic Requirements Model User's Guide

Expansion Asset Investments: Having identified urbanized areas with average operating speeds below the minimum service standard, this component then estimates the number of additional miles of rail or BRT service require to attain that standard for each individual urbanized area. Depending on mode, this includes investment in guideway track and structures, stations, vehicles, maintenance facilities, systems assets, right-of-way acquisition, design, project mobilization, and project management costs. Investment costs and quantities are based on as-built costs for CIG projects as documented in FTA's Capital Cost Database.

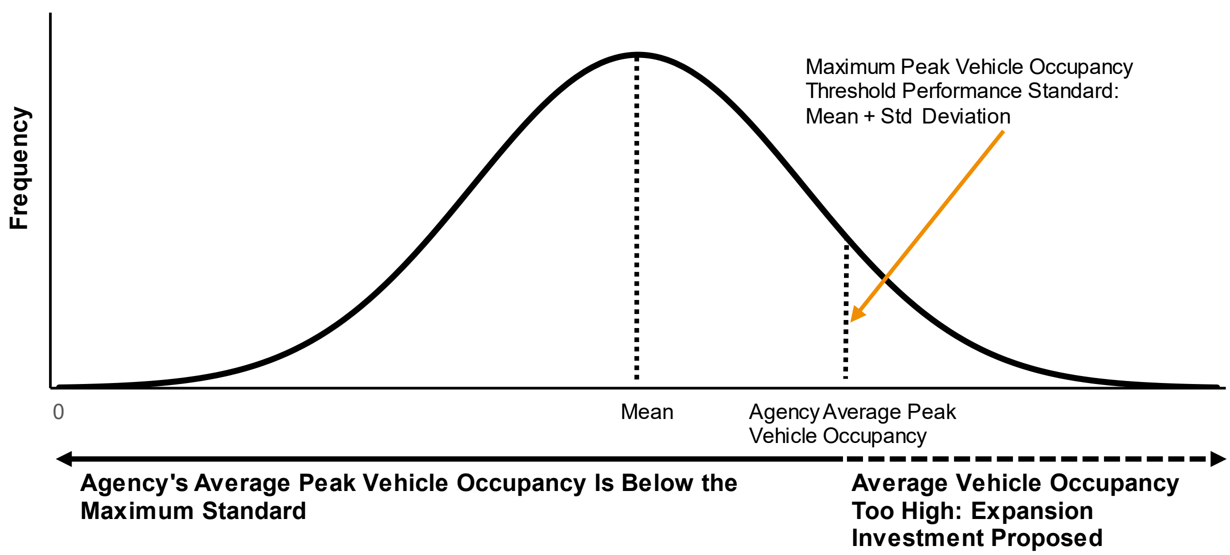
Asset Record Development: The Improve Average Speed component is designed to generate asset TERM records both for replaceable assets and for one-time (nonrecurring) acquisition costs (e.g., project design, construction management, and purchases). This component first determines the total miles of guideway required to improve average urbanized area operating speeds to the minimum-performance standard, which is set to the national average less one standard deviation (based on data from the NTD). The component then determines the levels of investment in other asset types (e.g., train control, traction power, track, vehicles) as required to support the service expansion. TERM then uses these asset records to estimate the costs of asset acquisition, rehabilitation, and replacement, as well as asset condition, for the specified forecast horizon.

Reduce Crowding

The Reduce Crowding component (formerly known as the Vehicle Occupancy Improvement component) is designed to identify those U.S. transit agency-modes with vehicle occupancy rates that are well above the national average. The component then seeks to reduce crowding for these high-occupancy agency-modes to a maximum occupancy threshold by investing in expansion vehicles and related support assets. These needs are assessed on an agency-mode basis (i.e., individual transit modes are treated separately for each transit agency identified in NTD) (Figure 11).

Service Standard: This component calculates vehicle occupancy at the agency-mode level as riders per vehicle operated in maximum service (VOMS). The values are calculated using data obtained from the NTD. The maximum service standard is calculated separately for each transit mode as the national average vehicle occupancy, plus one standard deviation, across all urbanized areas over 500,000 in population. Note here that the minimum service standard target is calculated at the start of the run and then remains fixed. The component continues to invest in expansion assets—from one year to the next—to attain those standards, subject to a maximum allowable annual investment level. This tends to spread investments across the period of analysis (versus making the entire investment in one period).

Figure 11. National Distribution of Peak Vehicle Occupancy



Source: Transit Economic Requirements Model User's Guide

Expansion Asset Investments: Having identified agency-modes with vehicle occupancy levels above the maximum service standard, this component then estimates the number of additional vehicles required to attain that standard. Depending on the mode and the number of expansion vehicles identified, this component may also invest in additional supporting assets (e.g., maintenance facilities, passenger stations, systems assets, etc.), with the level of investment in other modes based on the size of the fleet investment (subject to minimum investment levels for these nonfleet asset types).

Asset Record Development: Like the Improve Average Speed component, the Improve Occupancy component is designed to generate asset TERM records at the subcategory level of detail. This includes records both for replaceable assets and for one-time (nonrecurring) acquisition costs (e.g., project design, construction management, and purchases). The Improve Occupancy component determines the level of fleet expansion required to reduce crowding to the maximum-performance standard, which is set to the national average plus one standard deviation (based on data from the NTD). TERM then uses these asset records to estimate the costs of asset acquisition, rehabilitation, and replacement, as well as asset condition, for the 20-year forecast horizon.

Double-counting Adjustment

The use of multiple components to estimate transit expansion investment levels leads to the possibility that two or more components will occasionally (and independently) look to make the same or similar expansion investment for the same agency (e.g., two or more components determine a specific agency would benefit from an expansion investment in the same rail mode). Where this occurs, there would be double counting of expansion investments. TERM has been modified to look for and correct this form of double counting.

In practice, each of the performance improvement expansion component analyses is performed in a predetermined order, starting with the Implement CIG Projects component, followed by the Service Coverage, Service Frequency, Average Speed Improvement, and the Reduce Crowding analyses in that order. As each successive component is run, TERM continually checks to determine if a preceding component analysis has already addressed any expansion investments identified by the component analysis currently underway. If prior components have indeed addressed some (or all) of the expansion investments identified by the subsequent component, the total investment levels for that subsequent component (e.g., miles of new guideway or number of expansion vehicles) are reduced or eliminated accordingly.

Ridership Growth

The ridership growth component, if enabled, increases an agency's fleet size directly in proportion with forecasted ridership growth based on historical NTD trends. For the 2023–24 update of TERM, historical NTD data from 2004 to 2019 was used to calculate compound annual growth rates for potential ridership growth. Ridership growth was capped at 4.9 percent for any given market, which is equal to the mean growth rate across all markets plus one standard deviation. For model runs assuming no ridership growth, the component is disabled.

No double-counting check is currently implemented between the Implement CIG Projects component investments and the ridership growth component. This is based on the assumption that CIG investments tend to address growth-related needs for the specific corridors served by those CIG investments, whereas expansion to address ongoing rider growth supports entire urbanized areas. Even with that assumption in place, potential double-counting between these components is small.

Benefit-Cost Calculations

TERM uses a benefit-cost (B/C) module to assess which of a model run's capital investments are cost-effective and which are not. This module identifies and filters investments that are not cost-effective from the tally of national transit capital needs. TERM can filter all investments where the present value of investment costs exceeds investment benefits (B/C < 1). When the benefit-cost test is used, it is applied to all existing assets and all expansion components, with the exception of the CIG projects, which FTA assumes will be built. The other four expansion components (Expand Coverage, Improve Frequency, Improve Speeds, and Reduce Crowding) have the benefit-cost test applied, and the application of the benefit-cost test means that these components do not fully achieve their stated goals. For example, the Improve Speed expansion component will not ultimately raise all speeds to the identified minimum operating speed standard because some investments will be determined as not cost-beneficial and will not be included in the results.

The TERM B/C module conducts a systemwide business-case analysis to determine if the value generated by an existing agency-mode combination is sufficient to warrant the projected cost to operate, maintain, and potentially expand that agency-mode. Rather than assessing the benefits and costs for each individual investment need for each agency-mode (e.g., replacing a worn segment of track for a city's rail system), the module compares the stream of future benefits arising from continued future operation for an entire agency-mode against all capital (rehabilitation-replace and expansion) and operating costs required to keep that agency-mode in service. The benefits assessed in this analysis include user, agency, and social benefits of continued agency operations. If the discounted stream of benefits exceeds the costs, then TERM includes that agency-mode's capital needs in the tally of national investment needs. If the net present value of that agency-mode investment is negative (i.e., the benefit-cost ratio is less than 1), it will not include some or all of that agency-mode's identified reinvestment needs in the tally of national investment needs.

The specific calculations used by the TERM B/C module to compare the stream of investment benefits for agency-mode "j" against the stream of ongoing costs, calculated over the forecast analysis horizon is presented in this equation:

$$Benefit/Cost\ Ratio_{agency\ -mode j} = \left\{ \frac{\sum_{t=1}^{20} \left\{ \left(\left(User,\ Agency\ \&\ Social\ Benefits_{j,\ t=0} \right) * \left(1 + TPM\ Growth_j \right)^t \right) / (1+i)^t \right\}}{\sum_{t=1}^{20} \left\{ \left(ReplaceCost_{j,\ t} + ExpansionCost_{j,\ t} + \left(O\&M\ Costs_{j,\ t} * \left(1 + TPM\ Growth_j \right)^t \right) \right) / (1+i)^t \right\}} \right\}$$

Why Use a Systemwide Business-Case Approach?

TERM considers the benefit-cost ratio of the entire agency rail investment versus simply considering the replacement of a single rail car. Benefits and costs are grouped into an aggregated investment evaluation and not evaluated at the level of individual asset investment actions (e.g., replacement of a segment of track) for two primary reasons: (1) lack of empirical benefits data and (2) transit asset interrelationships.

Lack of Empirical Benefits Data: The marginal benefits of transit asset reinvestment are poorly understood for some asset types, such as vehicles, and nonexistent for others. For example, replacement of an aging motor bus will generate benefits in the form of reduced maintenance costs, improved reliability (fewer in-service failures and delays) and improved rider comfort, and potentially increased ridership in response to these benefits. The magnitude of each of these benefits will depend on the age of the vehicle retired, with benefits increasing with increasing age of the vehicle being replaced. Even though transit buses are the most numerous of all transit assets and a primary component of most transit operations, the relationship between bus vehicle age and O&M cost, reliability, and the value of rider comfort is not well understood. No industry standard metrics exist that tie bus age to reliability and related agency costs. The availability of reinvestment benefits for other transit asset types is even more limited (perhaps apart from rail cars, where the understanding is comparable to that of bus vehicles).

Transit Asset Interrelationships: The absence of empirical data on the benefits of transit asset replacement is further compounded by both the large number of transit assets that must work together to support transit service and the high level of interrelatedness between many of these assets. Consider the example of a rail car operating on trackwork equipped with train control circuits and power supply (running through the track), all supported by a central train control system and located on a foundation, such as an elevated structure, subway, or retained embankment. This situation represents a system that is dependent on the ongoing operation of multiple assets, each with differing costs, life cycles, and reinvestment needs, and interdependent on one another. The rail line benefits are dependent on ongoing reinvestment in all components of that rail line (track, structures, control systems, electrification, vehicles, and stations) rather than reinvestment in specific components.

Incremental Benefit-Cost Assessment

TERM's B/C module assesses the benefits of incremental levels of reinvestment in each agency-mode in a three-step approach:

1. TERM begins its benefit-cost assessment by considering the benefits and costs derived from all of TERM's proposed capital investment actions for a given agency-mode—including all identified rehabilitation, replacement, and expansion investments. If the total stream of benefits from these investments exceeds the costs, then all assets for this agency-mode are assigned the same (passing) benefit-cost ratio. If not, then the B/C module proceeds to Step 2.

2. TERM repeats this B/C evaluation for projects that failed the Step 1 B/C test, but this time excludes all expansion investments. In effect, this test suggests that this agency-mode does not generate sufficient benefits to warrant expansion but may generate enough benefits to warrant full reinvestment. If the agency-mode passes this test, then all reinvestment actions are assigned the same, passing B/C ratio. Similarly, all expansion investments are assigned the same failing B/C ratio (as calculated in Step 1). If the agency-mode fails the Step 2 B/C test, the B/C module proceeds to Step 3.
3. The Step 3 B/C test provides a more realistic assessment of agency-mode benefits for agency-modes that fail the Step 2 B/C test. Under this "partial" cost-benefit test, it is assumed that agency-mode benefits exceed costs for at least some portion of that agency-mode's operations; hence, this portion of services is worth preserving (vs discontinuing any reinvestment in an entire agency-mode). This partial test focuses reinvestment actions (costs) on shorter useful-life, poorer condition assets, while simultaneously reducing service levels (benefits) until a B/C ratio of 1 is attained (with the relationship between assets renewed and supported service levels supported by high level empirical analysis). This partial benefit-cost test procedure represents a simple solution to this issue, although alternative approaches may be possible.

Investment Benefits

TERM's B/C module segments investment benefits into three groups of beneficiaries: transit riders (user benefits), transit operators, and society.

Rider Benefits

By far the largest individual share of investment benefits (roughly 86 percent of total benefits) accrues to transit riders. Moreover, as assessed by TERM, these benefits are measured as the difference in total trip cost between a trip made via the agency-mode under analysis versus the agency-mode user's next best alternative. The total trip cost includes both out-of-pocket costs (e.g., transit fare, station parking fee) and value of time costs (including access time, wait time, and in-vehicle travel time).

Transit Agency Benefits

In general, the primary benefit to transit agencies of reinvestment in existing assets comes from the reduction in asset O&M costs. In addition to fewer asset repair requirements, this benefit includes reductions of in-service failures (technically also a benefit to riders) and the associated costs of responding to those failures (e.g., bus vehicle towing and substitution, bus for rail vehicle failures).

At present, none of these agency benefits is considered by TERM's B/C model. As noted earlier, little to no data are available to measure these cost savings. That said, some data do exist that can be used to evaluate these benefits, mostly related to fleet reinvestment, but were not available at the time the B/C module was developed.

Societal Benefits

TERM assumes that investment in transit provides benefits to society by maintaining or expanding an alternative to travel by car. Reductions in VMT made possible by the existence or expansion of transit assets are assumed to generate benefits to society. Some of these benefits may include reductions in highway congestion, air and noise pollution, greenhouse gas emissions, energy consumption, and automobile accidents. TERM's B/C module does not consider any societal benefits beyond those related to reducing VMT (hence, benefits such as improved access to work are not considered).

TERM's Benefit-Cost Tests as Applied to the Model

The B/C test is an optional module in TERM that a user can opt in or out of activating for a given model run. When the B/C module is activated, it applies to almost all elements of the model run. The only exception to this is the CIG projects expansion component—all CIG projects are not included in the B/C test. In effect, this ensures that all CIG projects pass the test and are all included in the model run results. CIG projects are excluded from the benefit-cost analysis for policy purposes at FTA's discretion. The CIG projects are typically a small portion of the overall results for a given model run.

Additional Information

Additional information on TERM Federal and on TERM Lite, a tool for helping agencies plan long-term capital investment needs, is available at https://www.transit.dot.gov/TAM.