

appendix C

Transit Investment Analysis Methodology

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Transit Investment Analysis Methodology

The Transit Economic Requirements Model (TERM), an analytical tool the Federal Transit Authority (FTA) developed, forecasts transit capital investment needs over a 20-year period. Using a broad array of transit-related data and research results, 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 model generates the forecasts that appear in the biennial C&P report.

This appendix provides a brief technical overview of TERM and describes the various methodologies used to generate the estimates for the 2015 C&P Report.

Transit Economic Requirements Model

TERM forecasts the level of annual capital expenditures required to attain specific physical condition and performance targets within a 20-year period. These annual expenditure estimates cover the following types of investment needs: (1) asset preservation (rehabilitation and replacement); and (2) asset expansion to support projected ridership growth.

TERM Database

The capital needs that TERM forecasts rely on a broad range of input data and user-defined parameters. Gathered from local transit agencies and the National Transit Database (NTD), the input data 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. The input data in TERM are used to draw an overall picture of the Nation's transit landscape; the most salient data tables that form the backbone of the TERM database are described below.

Asset Inventory Data Table

The asset inventory data table documents the asset holdings of the Nation's transit operators. Specifically, these records contain information on each asset's type, transit mode, age, and expected replacement cost. Because the 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 the current and future physical conditions, as required for each model run. These condition forecasts then are used to determine when each type of 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 way TERM estimates asset conditions are further explained later in this appendix.

The asset inventory data are derived from a variety of sources, including NTD, 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. Note that FTA does not currently require agencies to report on all asset types (with the exception of data for revenue vehicles, these data are provided only when requested). Furthermore, the transit industry has no standards for collecting or recording such data. Because of this, TERM analyses must rely on asset inventory data in the format and level of detail as provided by those agencies that respond to FTA's asset data requests. On July 2012, Congress passed the new Moving Ahead for Progress in the 21st Century (MAP-21) reauthorization act, which is the current law. The Act requires transit agencies to develop a capital asset report that inventories their capital assets and to evaluate the conditions of those assets. These data significantly enhance the consistency and availability of the Nation's asset base, resulting in greater accuracy of TERM's estimates of capital investment needs.

Urban Area Demographics Data Table

This data table stores demographic information on nearly 500 large, medium-sized, and small urbanized areas and for 10 regional groupings of rural operators. TERM uses fundamental demographic data, such as current and anticipated population, in addition to more transit-oriented information, such as current levels of vehicle miles traveled and transit passenger miles, to predict future transit asset expansion needs.

Agency-Mode Statistics Data Table

The agency-mode statistics table contains operations and maintenance data on each mode operated by approximately 725 urbanized transit agencies and more than 1,700 rural operators. Specifically, TERM uses the agency-mode data on annual ridership, passenger miles, operating and maintenance costs, mode speed, and average fare data 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). All data in this portion of the TERM database come from the most recently published NTD reporting year. When reported separately, directly operated services 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 the Nation's public transit systems use in support of transit service delivery (either directly or indirectly). Each record in this table documents each asset's type, unit replacement cost, and 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 more in the next section of this appendix.

Benefit-Cost Parameters Data Table

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

Mode Types Data Table

The mode types data table provides generic data on all 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 nontransit modes, such as private automobile and taxi costs. The data in this table are used to support TERM's benefit-cost analysis.

The input tables described above form the foundation of TERM but are not the sole source of information used when modeling investment forecasts. In combination with the input data, which are static—meaning that the model user does not manipulate them from one model run to the next—TERM contains user-defined parameters to facilitate its capital expenditure forecasts.

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 20 years. These condition forecasts are then used to determine when each individual asset identified in the asset inventory table is due for rehabilitation or replacement. The investment policy parameters data table enables the model user to set the physical condition ratings at which rehabilitation or replacement investments are scheduled to occur (although the actual timing of rehabilitation and replacement events might be deferred if the analysis is budget constrained). Unique replacement condition thresholds can be chosen for the following asset categories: guideway elements, facilities, systems, stations, and vehicles. For the 2015 C&P Report, all of TERM's replacement condition thresholds have been set to trigger asset replacement at condition 2.5 (under the Sustain 2012 Spending scenario, many of these replacements would be deferred due to insufficient funding capacity).

In addition to varying the replacement condition, users can also vary other key input assumptions intended to reflect better 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 shut down. Users can also assume assets are replaced either by agency (force-account) or by contracted labor. Each affects the cost of asset replacement for rail assets.

Financial Parameters

TERM also includes two key financial parameters. First, the model enables the user to establish the rate of inflation used to escalate the cost of asset replacements for TERM's needs forecasts.

Note that this feature is not used for the C&P report, which reports all needs in current dollars. Second, users can adjust the discount rate used for TERM’s benefit-cost analysis.

Investment Categories

The data tables described above enable TERM to estimate different types of capital investments, including rehabilitation and replacement expenditures, expansion investments, and capital projects aimed at performance improvements. These three different investment categories are described below.

Asset Rehabilitation and Replacement Investments

TERM’s asset rehabilitation and replacement forecasts are designed to estimate annual funding needs for the ongoing rehabilitation and replacement of the Nation’s existing transit assets. Specifically, these needs include the normal replacement of assets reaching the end of their useful lives, mid-life rehabilitations, and annual “capital expenditures” to cover the cost of smaller capital reinvestment amounts not included as part of asset replacement or rehabilitation activities.

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 20-year forecast. These projected condition values then are 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 alternative 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 *Exhibit C-1* for a description of the scale.

TERM currently allows an asset to be rehabilitated up to five times throughout its life cycle before being replaced. During a lifecycle simulation, TERM records the cost and timing of each reinvestment event as a model output and adds it to the tally of national investment needs (provided they pass a benefit-cost test, if applied).

TERM’s process of estimating rehabilitation and replacement needs is represented conceptually for a generic asset in *Exhibit*

C-2. 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

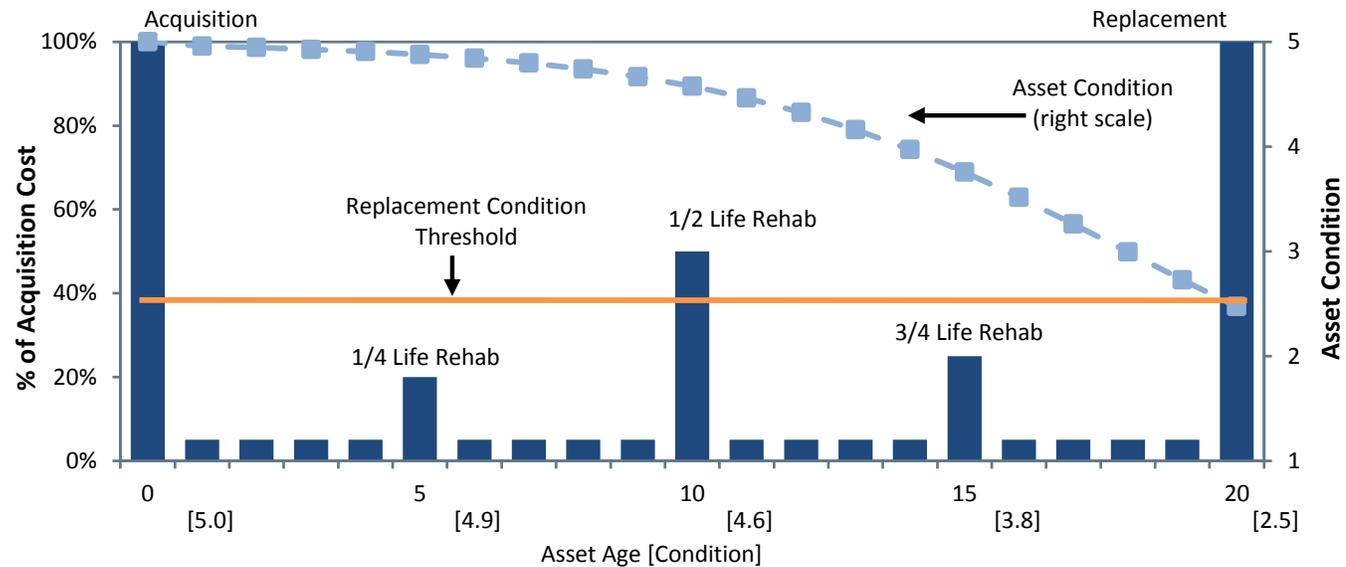
Exhibit C-1 Definitions of Transit Asset Conditions

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.

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.

Exhibit C-2 Scale for Determining Asset Condition Over Time, From Acquisition to Replacement



Asset Expansion Investments

In addition to devoting capital to the preservation of existing assets, most transit agencies invest in expansion assets to support ongoing growth in transit ridership. To simulate these expansion needs, TERM continually invests in new transit fleet capacity as required to maintain at current levels the ratio of peak vehicles to transit passenger miles. The rate of expansion is projected individually for each of the Nation’s roughly 500 urbanized areas (UZAs) (e.g., based on the UZA’s specific growth-rate projections or historic rates of transit passenger mile growth), while the expansion needs are determined at the individual agency-mode level. TERM will not invest in expansion assets for agency-modes with current ridership per peak vehicle levels that are well below the national average (these agency modes can become eligible for expansion during a 20-year model run if projected growth in ridership is sufficient for them to rise above the expansion investment threshold).

In addition to forecasting fleet expansion requirements to support the projected ridership increases, the model also forecasts expansion investments in other assets needed to support that fleet expansion. This includes investment in maintenance facilities and, in the case of rail systems, additional guideway miles, including guideway structure, track work, stations, train control, and traction power systems. Like other investments forecast by the model, TERM can subject all asset expansion investments to a benefit-cost analysis. Finally, as TERM adds the cost of newly acquired vehicles and supporting infrastructure to its tally of investment needs, it also ensures that the cost of rehabilitating and replacing the new assets is accounted for during the 20-year period of analysis.

TERM's estimates for capital expansion needs in the Low- and High-Growth scenarios are driven by the projected growth in passenger miles traveled (PMT). For this report, FTA has applied a new methodology for estimating growth in PMT, which is believed to be more accurate and provides greater consistency between the Low- and High-Growth scenarios.

In prior years, the Low-Growth scenario was driven by PMT projections obtained from metropolitan planning organizations (MPOs). Specially, UZA-level PMT growth projections were obtained from MPOs representing the Nation's 30 largest UZAs along with a sample of projections for MPOs representing smaller UZAs (less than 1 million population). These projections then were used to estimate transit capital expansion needs for the Low-Growth scenario (UZA growth rates for smaller UZAs not included in the sample were based on an average for UZAs of comparable size and region of the country). In contrast, the High-Growth scenario was driven by the historical (compound average annual) trend rate of growth, also at the UZA level, based on NTD data for the most recent 15 years.

For this report, the Low- and High-Growth scenarios now use a common, consistent approach that better reflects differences in PMT growth by mode. Specifically, these scenarios are now based on the trend rate of growth in PMT, now calculated as the compound average annual PMT growth by FTA region, UZA stratum, and mode over the most recent 15 years (hence, all bus operators located in the same FTA region in UZAs of the same population stratum are assigned the same growth rate). Use of the 10 FTA regions captures regional differences in PMT growth, while use of population strata (more than 1 million population; 1 million to 500,000; 500,000 to 250,000; and less than 250,000) capture differences in urban area size. Perhaps more importantly, the revised approach now recognizes differences in PMT growth trends by mode. Over the past decade, the rate of PMT growth has differed significantly across transit modes, being highest for heavy rail, vanpool, and demand response, and low to flat for motor bus. These differences are now recognized in the expansion needs projections for the Low- and High-Growth scenarios.

Asset-Decay Curves

Asset-decay curves were developed expressly for use within TERM and are comparable to asset-decay curves used in other modes of transportation, bridge, and pavement deterioration models. Although collecting 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 FTA collected at multiple U.S. transit properties specifically for this purpose.

TERM decay curves serve two primary functions: (1) to estimate the physical conditions of groups of transit assets and (2) to determine the timing of rehabilitation and replacement reinvestment.

Estimating Physical Conditions

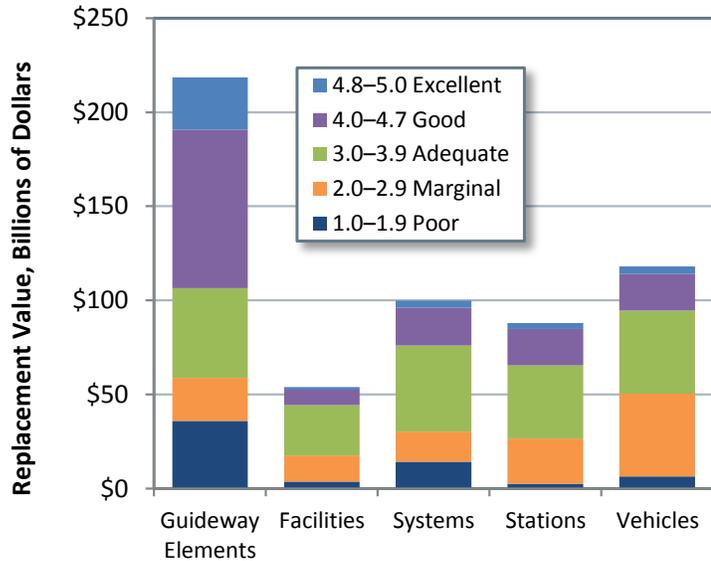
One use of the decay curves is to estimate the current and future physical conditions of transit asset groups. The groups can reflect all national transit assets or specific subsets, such as all assets

for a specific mode. For example, *Exhibit C-3* presents a TERM analysis of the distribution of transit asset conditions at the national level as of 2012.

Exhibit C-3 shows the proportion and replacement value of assets in each condition category (excellent, good, etc.), segmented by asset category. TERM produced this analysis by first using the decay curves to estimate the condition of individual assets identified in the inventory of the national transit assets and grouping these individual asset condition results by asset type.

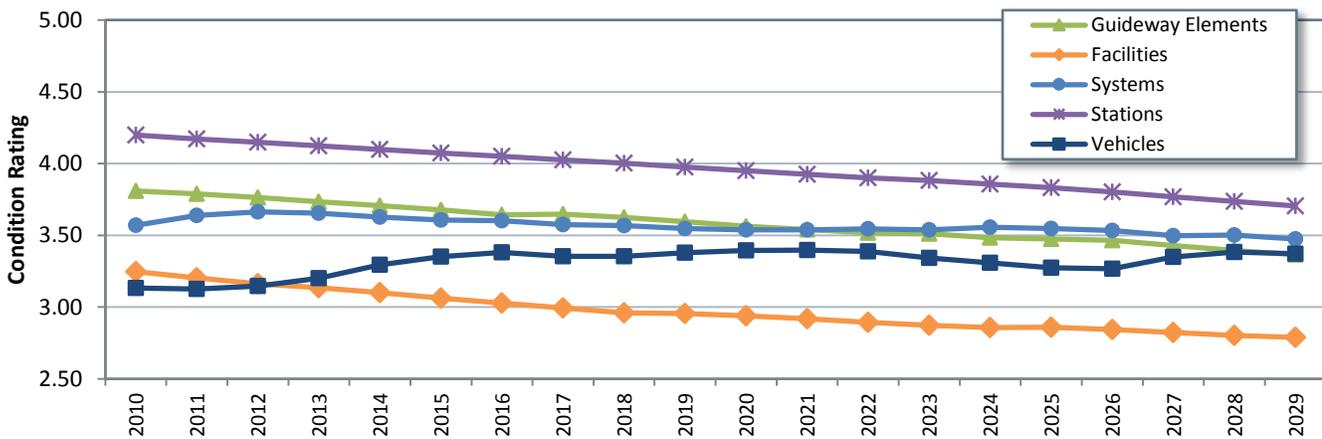
TERM also uses the decay curves to predict expected future asset conditions under differing capital reinvestment funding scenarios. An example of this type of analysis is presented in *Exhibits C-4* and *C-5*, which present TERM forecasts of the future condition of the national transit assets, assuming the national level of reinvestment remains unchanged. *Exhibit C-4* shows the future condition values estimated for each asset identified in the asset inventory (weighted by replacement value) to generate annual point estimates of average future conditions at the national level by asset category. *Exhibit C-5* presents a forecast of the proportion of assets in either marginal or poor condition, assuming limited reinvestment funding for a subset of the national transit assets.

Exhibit C-3 Distribution of Asset Physical Condition by Asset Type for All Modes



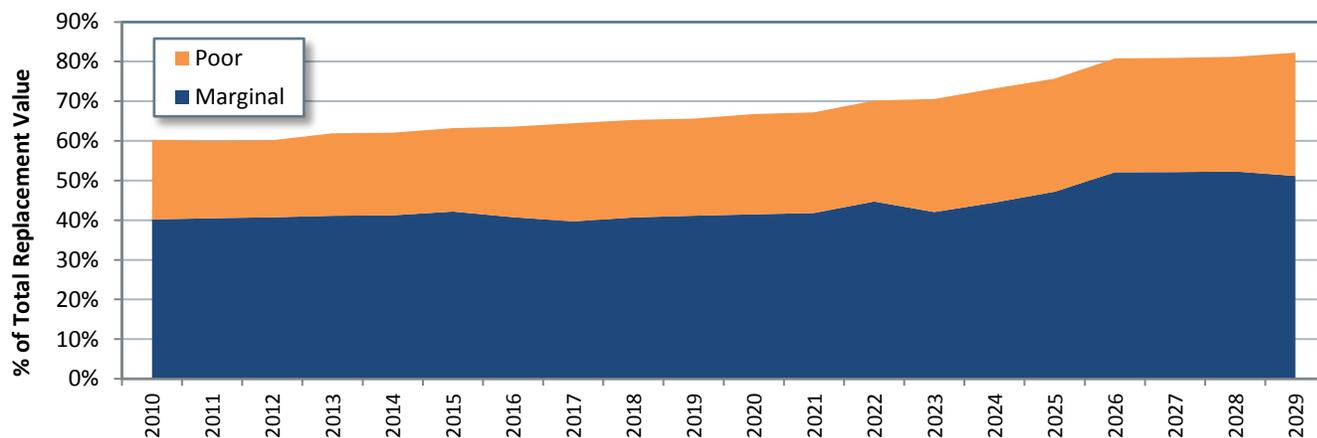
Source: *Transit Economics Requirements Model*.

Exhibit C-4 Weighted Average by Asset Category, 2010–2029



Source: *TERM, Sustain 2010 Spending*.

Exhibit C-5 Assets in Marginal or Poor Condition, 2010–2029



Source: TERM, Sustain 2010 Spending (Excludes Unreplaceable Assets).

Determine the Timing of Reinvestment

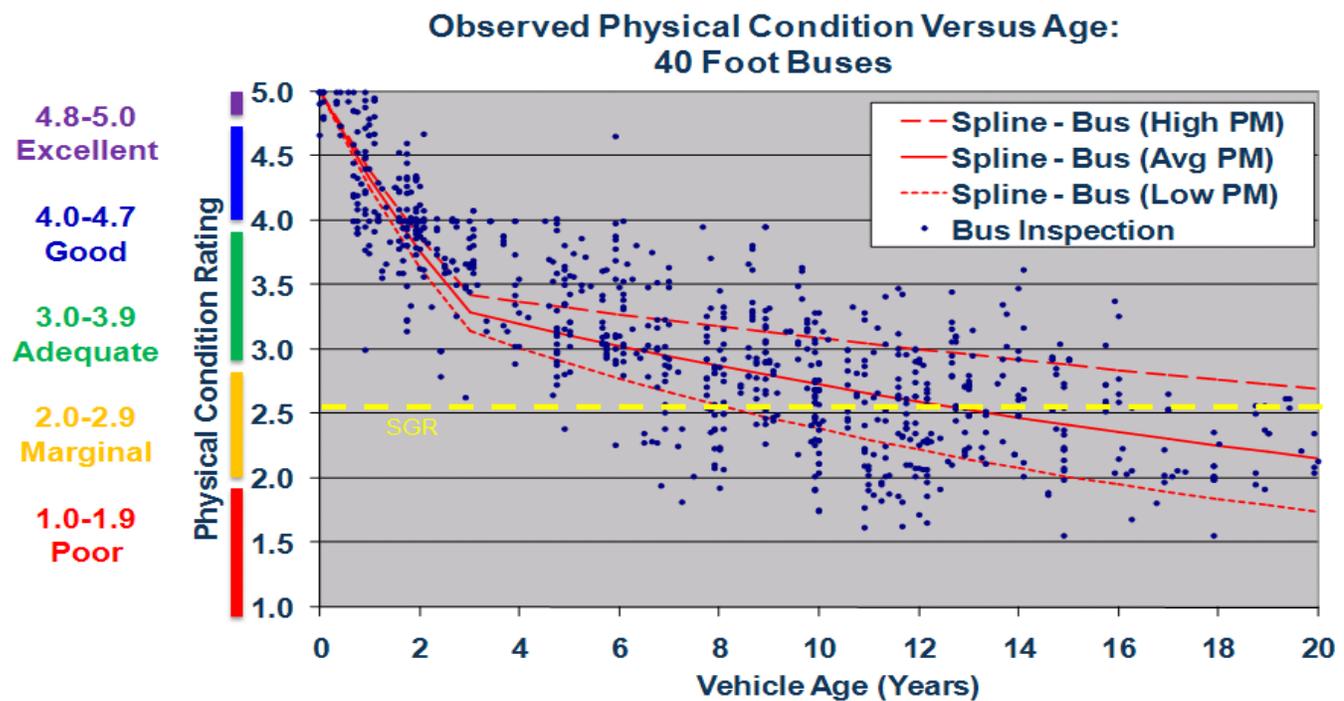
Another key use of the TERM asset-decay curves is to determine when the individual assets identified in the asset inventory will require rehabilitation or replacement, with the ultimate objective of estimating replacement needs and the size of the state of good repair backlog. Over the 20-year period covered by a typical TERM simulation, the model uses the decay curves to monitor the declining condition of individual transit assets continually as they age. As an asset's estimated condition value falls below predefined threshold levels (known as "rehabilitation condition threshold" and "replacement condition threshold"), TERM will seek to rehabilitate or replace that asset accordingly. If sufficient funding is available to address the need, TERM will record this investment action as a need for the specific period in which it occurs. If insufficient funding remains to address a need, that need will be added to the state of good repair backlog. These rehabilitation and replacement condition thresholds are controlled by asset type and can be changed by the user. Some asset types, such as maintenance facilities, undergo periodic rehabilitation, while others, such as radios, do not.

Development of Asset-Decay Curves

Asset-decay curves are statistically estimated mathematical formulas that rate the physical condition of transit assets on a numeric scale of 5 (excellent) to 1 (poor).

Most TERM decay curves are based on empirical condition data obtained from a broad sample of U.S. transit operators; hence, they are considered representative of transit asset-decay processes at the national level. An example decay curve showing bus asset condition as a function of age and preventive maintenance based on observations of roughly 900 buses at 43 different transit operators is presented in *Exhibit C-6* below.

Exhibit C-6 TERM Asset Decay Curve for 40-Foot Buses



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

Benefit-Cost Calculations

TERM uses a benefit-cost (B/C) module to assess which of a scenario's capital investments are cost effective and which are not. The purpose of this module is to identify and filter investments that are not cost effective from the tally of national transit capital needs. Specifically, TERM can filter all investments where the present value of investment costs exceeds investment benefits ($B/C < 1$).

The TERM B/C module is a business case assessment of each agency-mode (e.g., "Metroville Bus" or "Urban City Rail") identified in NTD. Rather than assessing B/C for each investment need for each agency-mode (e.g., replacing a worn segment of track for Urban City Rail), the module compares the stream of future benefits arising from continued future operation for an entire agency-mode against all capital (rehab-replace and expansion) and operating costs required to keep that agency-mode in service. If the discounted stream of benefits exceeds the costs, 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 less than 1 ($B/C < 1$), TERM scales back these agency-mode needs until the benefits are equal to costs, as discussed below.

In effect, the TERM B/C module conducts a system-wide business case analysis to determine if the value generated by an existing agency-mode is sufficient to warrant the projected cost to operate, maintain, and potentially expand that agency-mode. If an agency-mode does not pass this system-wide business case assessment, TERM will not include some or all of that agency-mode's identified reinvestment needs in the tally of national investment needs. The benefits assessed in this analysis include user, agency, and social benefits of continued agency operations.

The specific calculations used by the TERM B/C module—comparing the stream of investment benefits for agency-mode “j” against the stream of ongoing costs calculated over the TERM 20-year analysis horizon—is presented below in Equation (1).

$$\text{Benefit - Cost Ratio}_{\text{investments for agency-mode } j} = \frac{\sum_{t=1}^{20} \left\{ \left(\text{User, Social Benefits}_{j,t=0} \right) * \left(1 + \text{TPM Growth}_j \right)^t \right\} / (1+i)^t}{\sum_{t=1}^{20} \left\{ \left(\text{Replacement Needs}_{j,t} + \text{Expansion}_{j,t} + \left(\text{O\&M Costs}_{j,t} * \left(1 + \text{TPM Growth}_j \right)^t \right) \right) \right\} / (1+i)^t}$$

The Benefit-Cost Ratio equation above has the following parameters:

- j: Agency Mode (where costs and benefits are assessed by agency mode and summed across all agency modes reported to National Transit Database; e.g., NYCT Heavy Rail is an “Agency Mode”)
- t: time measured in years (year 1 to year 20)
- i: discount rate
- User Social Benefits: combination of user benefits and social benefits for users in Agency Mode j. User benefits consists of travel time saving and reduced auto costs. Social benefits is associated with reduced vehicle miles traveled, which results in reductions in air and noise emissions, roadway wear, and accidents.
- TPM Growth: recent growth in Total Passenger Miles for Agency Mode j (15 year)
- Replacement Needs: TERM’s projected reinvestment needs for Agency Mode j in year t
- Expansion: TERM’s projected expansion needs for Agency Mode j in year t
- O&M Costs: TERM’s projected operating and maintenance costs needs for Agency Mode j in year t

Why Use a System-Wide Business Case Approach?

TERM considers the cost-benefit of the entire agency rail investment versus simply considering the replacement of a single rail car. Costs and benefits are grouped into an aggregated investment evaluation and are not analyzed 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 very poorly understood for some asset types (e.g., vehicles) to nonexistent for others. Consider this 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 benefit will depend on the age of the vehicle retired (with benefits increasing with increasing age of the vehicle being replaced). However, what is the dollar value of these benefits? Despite the fact

that 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 operations and maintenance cost, reliability, and the value of rider comfort is poorly understood (no industry standard metrics tie bus age to reliability and related agency costs). The availability of reinvestment benefits for other transit asset types is even more limited (perhaps with the exception of rail cars, where the understanding is comparable to that of buses).

Transit asset interrelationships: The absence of empirical data on the benefits of transit asset replacement is compounded further 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 (1) rail car operating on (2) track work equipped with (3) train control circuits and (4) power supply (running through the track), all supported by (5) a central train control system and located on (6) a foundation, such as elevated structure, subway, retained embankment, etc. This situation represents a system that depends on the ongoing operation of multiple assets, each with differing costs, life cycles, and reinvestment needs—and yet completely interdependent. Now consider the benefits of replacing a segment of track that has failed. The cost of replacement (thousands of dollars) is insignificant compared to the benefits derived from all the riders that depend on that rail line for transit service in maintaining system operations. The fallacy in making this comparison is that the rail line benefits depend on ongoing reinvestment in all components of that rail line (track, structures, control systems, electrification, vehicles, and stations) and not just from reinvestment in specific components.

Incremental Benefit-Cost Assessment

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

- Step 1: TERM begins its benefit-cost assessment by considering the benefits 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, all assets for this agency-mode are assigned the same (passing) benefit-cost ratio. If not, the B/C module proceeds to Step 2.
- Step 2: Having "failed" the Step 1 B/C test, TERM repeats this B/C evaluation, 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 might generate enough benefits to warrant full reinvestment. If the agency-mode passes this test, 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.
- Step 3: The Step 3 B/C test provides a more realistic assessment of agency-mode benefits. Under this test, agency-mode benefits are assumed to exceed costs for at least some portion of that agency-mode's operations; hence, this portion of services is worth maintaining.

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 source of investment benefits (roughly 86 percent of total benefits) accrue 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 and station parking fee) and value of time costs (e.g., access time, wait time, and in-vehicle travel time).

Transit operator benefits: In general, the primary benefit to transit agencies of reinvestment in existing assets comes from the reduction in asset operations and maintenance 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 response costs of in-service failures (e.g., bus vehicle towing and substitution and bus for rail vehicle failures).

At present, none of these agency benefits is considered by TERM's B/C model. As noted above, little to no data are available to measure these cost savings. The available data relate primarily to fleet reinvestment and were not available at the time the B/C module was developed. FTA could incorporate some of these benefits in future versions of TERM.

Societal benefits: TERM assumes that investment in transit provides benefits to society by maintaining or expanding an alternative to travel by car. More specifically, reductions in vehicle miles traveled made possible by the existence or expansion of transit assets is assumed to generate benefits to society. Some of these benefits might include reductions in highway congestion, air and noise pollution, greenhouse gases, energy consumption, and automobile accidents. TERM's B/C module considers no societal benefits beyond those related to reducing vehicle miles traveled (hence, benefits such as improved access to work are not considered).