TRB TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

March 29, 2013

Mr. Vincent Valdes
Associate Administrator for Research,
Demonstration, and Innovation
Federal Transit Administration
U.S. Department of Transportation
1200 New Jersey Avenue, SE
Washington, DC 20590

Dear Mr. Valdes:

At the request of the Federal Transit Administration, a committee of the National Research Council's Transportation Research Board (TRB) has reviewed the Transit Economic Requirements Model. The committee's statement of task was as follows:

> This project will review the assumptions, data inputs, and logic of the Federal Transit Administration's Transit Economic Requirements Model (TERM) to assess whether it provides reasonable and appropriate estimates of condition and investment needs for its intended purposes. The project will also assess whether the model's reliance on a backlog of capital investments is an appropriate basis for developing future capital funding requirements.

The enclosed report of the committee presents its assessment of TERM and proposes directions for improvements to the model. Also enclosed are three resource papers commissioned by TRB on behalf of the committee to support its review. The committee drew on the resource papers in preparing the report; however, the papers are the responsibility of their respective authors and do not necessarily reflect the conclusions of the committee. The committee roster also is enclosed.

Very truly yours,

Robert E. Skinner, Jr.
Executive Director

Enclosures:
Report of the committee
Commissioned papers (3)
Committee roster

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Review of the Federal Transit Administration's
Transit Economic Requirements Model

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SUMMARY

The Federal Transit Administration's (FTA's) Transit Economic Requirements Model (TERM) is a tool for estimating the nation's transit capital expenditure needs over a 20-year period. TERM's primary use is in the preparation of the U.S. Department of Transportation's biennial reports to Congress on the conditions and performance of U.S. highways, bridges, and public transit systems. FTA asked a committee of the Transportation Research Board (TRB) to review TERM with respect to whether (*a*) TERM provides reasonable and appropriate estimates of condition and investment needs for its intended purposes and (*b*) TERM's reliance on a backlog of capital investments is an appropriate basis for developing future capital funding requirements. The responses of the TRB committee that conducted the review are below, followed by the committee's proposals for improvements in TERM.

Task Statement Questions

1. *Whether TERM Provides Reasonable and Appropriate Estimates of Condition and Investment Needs for Its Intended Purposes*

TERM's estimates of the state of good repair (SGR) backlog and of the annual capital expenditures required to eliminate the backlog and maintain SGR over a 20-year period, as presented in the SGR benchmark scenario in the 2010 *Conditions and Performance* report, are a useful indication of the level of capital spending required to meet the objective of attaining SGR, provided that users of the estimates understand the key assumptions underlying them: (*a*) assets that fall below the minimum physical condition standard that FTA has selected as the definition of SGR for the first time in each year are replaced or rehabilitated in that year, (*b*) assets in the backlog (i.e., already below the SGR standard in the initial year) are replaced gradually over 20 years, (*c*) no capacity expansions are included, and (*d*)

spending is not constrained by a benefit–cost test. In addition, the estimates are useful for revealing the nature of transit capital stock and spending needs, for example, the distribution of needs among modes.

The committee also reviewed TERM estimates of capital expenditure requirements for capacity expansions but was unable to assess their reasonableness. The capacity expansion projections depend on ridership projections, the assumed relationship between ridership and expansion needs, and benefit–cost calculations. These elements of TERM require testing before the expansion projection can be assessed.

2. Whether TERM's Reliance on a Backlog of Capital Investments Is an Appropriate Basis for Developing Future Capital Funding Requirements

TERM projects the costs of meeting targets for the condition of transit assets and appropriately includes the backlog as part of these costs. However, FTA's reporting of TERM results does not make clear the relationship between these targets and transit system performance or compare the performance benefits of alternative targets. Therefore, TERM does not provide sufficient guidance on capital requirements for meeting the federal transit program's objectives of safety, mobility, and environmental protection.

To increase TERM's usefulness for projecting capital funding requirements, two capabilities are needed. First, TERM should be able to relate asset physical condition to transit system performance, as measured by travel times, delays, distance between failures, ridership, and accident frequency. Second, it should be able to estimate the impact of improved asset management on capital expenditure requirements.

Directions for Improvement

Systematic assessment: FTA should systematically assess TERM's methodology through sensitivity analyses, construction of hypothetical examples, and case studies from actual transit operations to develop a quantitative understanding of how the model's structure and data limitations affect its estimates.

Validation using trend analysis: FTA should consider developing simple methods for projecting capital expenditure requirements to validate and supplement TERM. Projections using trend analysis and independent data could serve as validity checks on TERM projections and clarify connections between data inputs and capital expenditure outputs.

Sampling: FTA should consider following the example of the Highway Economic Requirements System asset inventory methodology by developing a scientifically designed sampling approach to data collection to replace present methods. This approach would improve data quality, provide a quantitative basis for estimating the reliability of the data, and likely reduce the data collection burden on transit agencies.

Refinements of TERM: FTA should consider refinements of TERM to make its capital expenditure requirements projections more accurate and defensible. The committee recommends several refinements that might prove practical and worthwhile:

- Estimate the performance consequences of attaining SGR;
- Improve ridership projections;
- Revise TERM's application of benefit–cost analysis;
- Incorporate simulation of management strategies to improve efficiency of asset use; and
- Incorporate additional refinements concerning replacement criteria, planning horizons, and asset category definitions to improve reliability of projections.

Long-run development: FTA's goals for TERM should be to refine the agency's ability to provide information useful to Congress in monitoring federal transit capital funding programs and planning future programs. The information should include estimates of the performance consequences of alternative levels of capital spending and identification of opportunities for improving the cost-effectiveness of capital spending and of federal aid.

Review of the Federal Transit Administration's Transit Economic Requirements Model

At the request of the Federal Transit Administration (FTA), a committee of the Transportation Research Board (TRB) has reviewed the Transit Economic Requirements Model (TERM). The committee's statement of task, proposed by FTA and approved by the National Research Council, is as follows:

> This project will review the assumptions, data inputs, and logic of the Federal Transit Administration's Transit Economic Requirements Model (TERM) to assess whether it provides reasonable and appropriate estimates of condition and investment needs for its intended purposes. The project will also assess whether the model's reliance on a backlog of capital investments is an appropriate basis for developing future capital funding requirements.

The first section below provides an overview of TERM, its history and legislative requirement, and the basis for the committee's analysis of the model. The second section responds to the questions in the statement of task, and the third identifies directions for improvement in TERM.

INTRODUCTION

TERM History: Legislative Requirement; *Conditions and Performance* Reports

TERM is a tool for estimating the nation's transit capital expenditure needs over a 20-year period. The model estimates the total annual capital expenditures required to maintain or improve the physical condition of the nation's transit infrastructure and to serve projected levels of transit ridership. Since 1995, TERM has been used primarily to support preparation of the transit component of the U.S. Department of Transportation's (U.S. DOT's) biennial *Status of the Nation's Highways, Bridges, and*

Transit: Conditions and Performance: Report to Congress (U.S. DOT 2012a). It also has been used in other analyses of national transit infrastructure condition.

Congress in 1965 directed the Federal Highway Administration (FHWA) to report biennially on the conditions, performance, and future highway investment needs of the nation's street and highway systems. At that time, no systematic national data on highway condition existed. To respond to the congressional directive, FHWA conducted several special national studies. Then in 1978, FHWA implemented the Highway Performance Monitoring System (HPMS), a continuing, sample-based monitoring program requiring each state to report annually on the condition of its highway system (Mueller 1995). In 1996, FHWA introduced the Highway Economic Requirements System (HERS), a model for estimating the economically justified level of highway capital expenditure. HERS uses the HPMS data on the condition of the federal-aid highway system. The National Bridge Investment Analysis System was developed later to analyze bridge capital expenditure needs by using a data set describing all U.S. highway bridges.

TERM was developed in 1995 as a system analogous to HERS but focused on the nation's public transit needs. In contrast to HERS, TERM is not supported by mandatory periodic reporting of asset data by transit operators. Like HERS, TERM is used primarily in the preparation of the biennial *Conditions and Performance* reports, which include highway and bridge information required by 23 U.S.C. §502(h) as well as transit system information required by 49 U.S.C. §308(e):

> (1) The Secretary shall submit to Congress in March 1998, and in March of each even-numbered year thereafter, a report of estimates by the Secretary on the current performance and condition of public mass transportation systems with recommendations for necessary administrative or legislative changes.
>
> (2) In reporting to Congress under this subsection, the Secretary shall prepare a complete assessment of public transportation facilities in the United States. The Secretary also shall assess future needs for

those facilities and estimate future capital requirements and operation and maintenance requirements for one-year, 5-year, and 10-year periods at specified levels of service.

Committee Activities and Sources of Information

To respond to FTA's request for a National Research Council assessment of TERM, TRB appointed the Committee for Review of the Federal Transit Administration's Transit Economic Requirements Model. Members were selected on the basis of expertise in transit system management, asset management, economics, or public policy. The committee convened four times in 2012 and early 2013, twice in person and then twice by telephone conference call. During the first meeting, FTA staff and contractors involved in the development of TERM presented the model's methodology (FTA 2012b). At a public session during the second committee meeting, authors of three resource papers commissioned by TRB on behalf of the committee presented their results: (*a*) the relationship between asset condition and system performance (Cohen 2012), (*b*) a comparison of TERM's capital needs estimates with estimates developed by a sample of large transit agencies (Zarembski 2012), and (*c*) a proposal for longer-term revision of the model (Pozdena 2012). The papers are available on TRB's website at http://www.trb.org/Main/Blurbs/168691.aspx. The committee drew on the resource papers in preparing this report; however, the papers are the responsibility of their respective authors and do not necessarily reflect the conclusions of the committee.

Other information sources included the TERM user's guide (Booz Allen Hamilton 2011) and the *Conditions and Performance* reports.

This report was subject to an independent review according to the procedures of the National Research Council, as described in Appendix B.

Description of TERM

TERM is made up of three modules that generate estimates of requirements in three categories of capital expenditure: (*a*) rehabilitation and replacement of assets existing at the beginning of the forecast period, (*b*) expansion of assets to accommodate expected future ridership growth, and (*c*) expansion of assets to improve levels of service.

TERM draws on an asset database that records the quantities and ages of every physical asset held by every transit agency that receives FTA funding. Many of the data elements are imputed by FTA on the basis of more aggregate information. FTA describes the data sources as follows (U.S. DOT 2012a, C-2):

> The asset inventory data are derived from a variety of sources including the [National Transit Database], responses by local transit agencies to FTA data requests, and special FTA studies. . . . Note that FTA does not currently require agencies to report on all asset types. . . . 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.

The National Transit Database is a compilation of required annual reports from about 660 transit systems that receive FTA grants. It contains limited asset data: numbers and average ages of vehicles and route miles of fixed guideways. FTA staff recognize that questionable asset data quality is a weakness of TERM. The federal transit aid program enacted in 2012 contains new transit asset data reporting requirements, which are described in the next section. They are expected to enable replacement of the present piecemeal method of assembling the TERM database with more systematic and uniform procedures.

TERM estimates the physical condition of the nation's transit assets, for the current year and for a 20-year forecast period, on a 5-point asset condition scale ranging from poor (scored as 1) to excellent (scored as 5). Asset condition forecasts are based on empirically derived decay curves relating physical condition to asset age and are generated for each transit mode (e.g., local bus, urban rail, commuter rail, light rail, paratransit) operated by each agency. Once these agency–mode estimates have been developed, they can be summed by agency, mode, or other characteristics.

Finally, TERM also estimates both the current and the projected changes in the deferred expenditures that constitute the state of good repair (SGR) backlog. This backlog represents the capital expenditures required to bring the nation's transit assets to a state of good repair, which FTA defines as a condition rating of 2.5 on the 5-point rating scale. The SGR backlog is the sum of the estimated cost of replacing all assets predicted to have exceeded their useful life and the cost of all rehabilitation activities known to be past due. TERM's design allows the user to control many of the model input parameters, such as asset replacement and rehabilitation assumptions, financial assumptions, and benefit–cost parameters, to facilitate the analysis of a wide range of investment scenarios.

FTA staff identified concerns with TERM's methodology in their presentation at the first committee meeting (FTA 2012b). Among them are the reliability of the model's decay curves, the relationship between TERM's SGR definition and actual transit system performance, ridership projections in TERM's expansion module, methods used in assessing the need for improvements at transit system bottlenecks, and the model's approach to benefit–cost analysis.

Federal Surface Transportation Program Asset Management Requirements: Relationship to TERM

In July 2012, after the committee had begun the task of evaluating TERM, Congress passed a 2-year transportation funding reauthorization bill entitled Moving Ahead for Progress in the 21st Century (MAP-21). The bill contains new requirements for asset management by federal transit claimants and

new reporting requirements for all FTA grantees (see 49 U.S.C. Section 5326/MAP-21 Section 20019). According to this section of the bill, the "goal of improved transit asset management is to implement a strategic approach for assessing needs and prioritizing investments for bringing the nation's public transit systems into a state of good repair."

Under MAP-21 (Section 20019), FTA is to establish a national transit asset management system. To do this, FTA is to issue regulations that define SGR, set objective standards for measuring the condition of capital assets (including equipment, rolling stock, infrastructure, and facilities), and establish performance measures for SGR. Grantees will be required to develop transit asset management plans that include capital asset inventories and condition assessments as well as investment priorities. Each recipient of FTA formula funding is also required to establish performance targets for attaining an SGR. Each recipient of formula funding will be required to report periodically on the condition of its system, condition changes since the previous report, performance targets, and progress toward meeting the targets (FTA 2012a). FTA is to support this effort through technical assistance. In particular, FTA is to develop an analytical process or decision support tool for estimating capital investment needs over time and assisting with investment prioritization (FTA 2012a).

The MAP-21 asset management requirements create an opportunity for FTA to improve its transit asset inventory data and thereby to improve the reliability of TERM. The analysis and model development that FTA undertakes to support transit agency asset management may lead to refinements in the TERM methodology.

TASK STATEMENT QUESTIONS

The task statement addresses two questions to the committee: first, whether TERM provides reasonable and appropriate estimates of condition and investment needs for its intended purposes, and second, whether TERM's reliance on a backlog of capital investments is an appropriate basis for developing future capital funding requirements. The committee's responses to these questions are given below.

1. Whether TERM Provides Reasonable and Appropriate Estimates of Condition and Investment Needs for Its Intended Purposes

The committee understands that the primary purpose of TERM is to inform Congress, policy makers, and interested parties on the state of the nation's public transit assets and the consequences of alternative levels of federal funding for transit capital expenditures.

TERM's estimates of the SGR backlog and of the annual capital expenditures required to eliminate the backlog and maintain SGR over a 20-year period, as presented in the SGR benchmark scenario in the 2010 *Conditions and Performance* report, give a useful indication of the level of capital spending required to meet the SGR objective, provided that users of the estimates understand the key assumptions underlying the estimates: (*a*) assets that fall below the minimum physical condition standard that FTA has selected as the definition of SGR for the first time in each year are replaced or rehabilitated in that year, (*b*) assets in the backlog (i.e., already below the SGR standard in the initial year) are replaced or rehabilitated gradually over 20 years, (*c*) no capacity expansions are included, and (*d*) spending is not constrained by a benefit–cost test.

In addition, the TERM estimates are useful for revealing the nature of the nation's transit capital stock and of the capital spending required to attain SGR. For example, the TERM estimates show the distribution of capital needs among modes, between large and small systems, and between older and newer systems.

Evidence of Credibility of the Estimates

FTA has attempted to assess the accuracy of the TERM estimates by comparing model projections with actual transit agency experience (U.S. DOT 2012a, 9-41–9-47). The comparison showed that total capital expenditures on existing facilities during the 7-year period between 2003 and 2009 were 14 percent below the TERM projection in the 2004 *Conditions and Performance* report ($10.5 billion actual versus $12.1

billion projected) and within 40 percent of the TERM projections for five of six major asset categories. Moreover, in five of the six major asset categories, the direction of change of the actual condition rating over the period was consistent with the difference between the TERM-projected spending need and actual spending. In other words, if actual agency spending was less than the TERM-projected need, the condition rating reported by the transit agency examined declined over time. Likewise, if actual spending exceeded the TERM-projected need, the condition rating improved.

A second assessment of the accuracy of TERM forecasts is discussed in the paper commissioned by the committee that compares TERM's estimated backlog and 20-year capital spending requirements with transit agency estimates for three systems: the rail systems of Atlanta, Georgia, and New York City and the bus and rail systems of Boston, Massachusetts (Zarembski 2012). The comparison showed that the three transit agencies' projections of total capital spending requirements were close to, but consistently lower than, the TERM projections.[1] For some individual asset categories, TERM and agency estimates were close, but the estimates diverged substantially in other categories.[2]

Reasonableness of TERM Expansion Capital Expenditures Projections

Twenty percent of capital expenditure needs reported in the 2010 *Conditions and Performance* report low-growth scenario, and 30 percent in the high-growth scenario, are for expansion (U.S. DOT 2012a, 8-29). In the TERM projections of the low-growth and high-growth scenarios in the 2010 *Conditions and Performance* report, transit agencies are assumed to make capital expenditures so as to expand capacity to

[1] Agency projections were 4 percent lower than those of TERM for Atlanta and 17 percent lower for New York. The Boston agency's projection was 21 percent lower than that of TERM, although much of this difference may reflect inflation and a difference in the time period covered, because the available Boston agency projection was for 2005 to 2024 and the TERM projection was for 2010 to 2029.

[2] For example, TERM's estimate of 20-year capital expenditure requirements for rail transit vehicles was 110 percent higher than the agency estimate for Atlanta and 66 percent higher for New York. Part of the difference may be the inclusion of asset subcategories such as nonrevenue vehicles in the TERM estimates that are excluded from the agency estimates. In Atlanta, recent rehabilitations as well as agency maintenance practices have extended the life of the rail vehicle fleet beyond that assumed by TERM (Zarembski 2012, 15–16).

accommodate ridership growth while maintaining constant levels of service. Also, in these scenarios the total package of projected 20-year capital expenditures for each agency–mode combination is included in the capital expenditure requirements projections if the 20-year package passes TERM's benefit–cost test; otherwise, only a fraction of the total package is included (U.S. DOT 2012a, 8-28).

FTA's TERM accuracy assessment (U.S. DOT 2012a, 9-44–9-46) found that between 2003 and 2009, actual agency capital expenditures for expansion were substantially less than the TERM estimates of expenditures needed to maintain service level and that load factors (passengers per revenue vehicle mile of service) increased, consistent with the model's assumptions.

The committee understands the intended purpose of the expansion module and the 2010 *Conditions and Performance* report growth scenarios to be similar to the purpose of the SGR scenario projections. That is, the growth scenarios represent estimates of the cost of meeting a physical standard—maintaining a constant level of service (which is represented in the model by the average transit vehicle load factor) while accommodating patronage growth—under the implicit assumption that established agency practices concerning asset management and demand management will continue unchanged.

The committee considered three aspects of the TERM methodology for projecting expansion capital expenditures: ridership projections, TERM's assumed relationship between ridership growth and expansion needs, and TERM's benefit–cost calculation. Because of the concerns with aspects of the model identified below, the committee was unable to determine the credibility of the estimates of capital expenditure requirements for expansion.

Limitations of the TERM Methodology

The most basic limitation on the usefulness of TERM projections in guiding policy on capital spending is that they do not provide information on the public benefits of attaining the physical condition standards (defined as SGR and, in the growth scenarios, constant service level). That limitation is examined later in this report in the section on the appropriate basis for developing future capital funding requirements.

Within the scope of TERM's present use (i.e., to project the expenditures needed to attain transit asset physical condition and capacity standards), the reliability of TERM's estimates depends on the accuracy and timeliness of the asset inventory data and on the realism of the model parameters that define asset lives, replacement costs, and ridership growth. Because of gaps in data, TERM necessarily uses simplifying assumptions with regard to asset lives, costs, and other factors.

The committee did not review the quality of TERM's asset inventory database. The asset data reporting requirements of MAP-21 offer the opportunity for FTA to improve the asset data. The review concentrated instead on the structure and underlying logic of TERM.

The committee identified features of TERM's methodology that might diminish the reliability or usefulness of the model's projections. Four of them affect all TERM applications:

- Pooling of data for systems with differing management structures and efficiencies,
- Absence of explicit consideration of cost uncertainty,
- Information lost in aggregation of model estimates, and
- Lack of consideration of management alternatives to capital expenditure.

Three additional methodological concerns relate to the expansion module and the growth scenarios in the 2010 *Conditions and Performance* report:

- Ridership projections,
- Assumed linear relationship between ridership and capital stock requirements, and
- TERM's "business case" benefit–cost analysis.

The Appendix of this report explains the committee's concerns with regard to these features of the TERM methodology. The committee was unable to test whether the features are problematic in practice; rather,

they are listed here as areas that merit examination by FTA. The section below on directions for improvement proposes approaches for mitigating some of the concerns; these proposals would require testing by FTA to determine their viability.

2. Whether TERM's Reliance on a Backlog of Capital Investments Is an Appropriate Basis for Developing Future Capital Funding Requirements

TERM projects the costs of meeting targets for the condition of transit assets and appropriately includes the backlog as part of these costs. However, FTA's reporting of TERM results does not make clear the relationship between these targets and transit system performance or compare the performance benefits of alternative condition targets. Therefore, TERM does not provide sufficient guidance on capital funding requirements for meeting the federal transit program's fundamental objectives of safety, mobility, and environmental protection.

As described above, TERM calculates the present backlog of needed transit capital investments as the cost of replacing or rehabilitating all assets that in the present year are already below the 2.5 condition rating that defines SGR. In the SGR benchmark scenario in the 2010 *Conditions and Performance* report, capital funding requirements are the projected series of annual expenditures required to eliminate the backlog gradually by the end of the 20-year projection period, plus the annual expenditures required to replace the assets that fall below the 2.5 rating in each year in the projection period.

The model appears intended to simulate the spending decisions that transit agencies would be expected to make if funds at the level of TERM's estimates were available to each agency; it does not aim to project an economically justified or otherwise optimal level of capital spending. Interpreting the model as a simulation is consistent with the method of calibrating the asset decay curves that FTA described to the committee: the curves approximate the replacement decisions that agencies actually make, rather than economically optimal replacement decisions. The 2010 *Conditions and Performance* report growth scenarios apply a benefit–cost test, but only as a check to screen out expenditures that are least likely to

occur (because they have high costs or low ridership benefits, or both) rather than as a method for optimizing expenditures.

SGR, as defined in TERM, is a physical standard of unknown relationship to performance or benefits. As noted above, because asset replacement expenditures in TERM's estimated backlog are not determined on the basis of a benefit–cost calculation for the individual asset, the backlog will necessarily include some expenditures whose costs exceed their benefits and will exclude some expenditures that would yield a greater return than some expenditures that are included. Moreover, capital expenditure requirements depend on where the SGR threshold is set. A sensitivity analysis in the 2010 *Conditions and Performance* report demonstrates that raising the threshold increases the capital expenditures needed to meet SGR and lowering it causes the projection of required expenditures to decline (U.S. DOT 2012a, 10-25). If the SGR threshold condition rating is lowered, however, the asset replacements that drop out of the backlog will not necessarily be those with the lowest return on investment.

To increase the usefulness of TERM for projecting capital funding requirements, the model needs two capabilities it now lacks. Adding these would be consistent with U.S. DOT's congressional mandate concerning the content of the *Conditions and Performance* reports. First, TERM should be able to estimate the level of transit service the nation would be buying by attaining SGR or with any alternative level of future funding. That is, TERM should be able to relate asset physical condition to transit system performance as measured by travel times and delays, distance between failures, ridership, accident frequency, and ultimately, economic benefit. The objective of federal transit aid is to assist public transit operators in providing safe and convenient service to riders in a cost-effective manner (U.S. DOT 2012b). TERM does not provide sufficient guidance on the capital expenditure requirements for meeting these fundamental performance objectives.

Second, it would be valuable for TERM to have the capability to estimate potential gains in transit industry cost-effectiveness, and the consequent impact on capital expenditure requirements, that would result from better asset management as well as from other improvements in agency management and operating practices (such as demand management). TERM assumes that agency management

practices are fixed, but most transit agencies have opportunities to improve productivity, increase asset utilization, and reduce capital needs through improved operations and maintenance practices. Developing analysis methods that allow U.S. DOT to estimate how much opportunity there is for such productivity improvements would greatly increase the value of the *Conditions and Performance* reports.

Developing these two modeling capabilities—to relate asset physical condition to transit system performance and to estimate the effects of asset management practices—will be difficult and will require FTA commitment to a program of research and testing. The results of such research would have value beyond TERM as a source of information on the value of asset management.

Estimating capital funding requirements on the basis of the SGR standard may be defensible as a rule of thumb for estimating optimum spending because TERM's decay curves and SGR replacement thresholds are calibrated by analysis of transit agency practices. If agencies are collectively skilled at minimizing life-cycle asset costs, TERM's method may approximate optimum replacement decisions. However, if substantial opportunities exist to improve asset management practices, then the TERM capital expenditure projections may be obscuring the gap between current and optimal agency practices.

DIRECTIONS FOR IMPROVEMENT

The committee has identified opportunities in four areas to improve FTA's capability to estimate capital expenditure requirements: (*a*) practices for assessment of TERM, (*b*) validation using independent projections of capital expenditure requirements, (*c*) use of sampling in constructing the asset database, and (*d*) refinements of the TERM methodology.

Systematic Assessment

The 2010 *Conditions and Performance* report includes sensitivity analyses of TERM results, the TERM accuracy assessment described above, and discussions of possible weaknesses in TERM's methodology.

These efforts to validate and improve the model are laudable, but a more comprehensive assessment is needed.

FTA's ongoing review of TERM should involve a systematic assessment of the model's methodological assumptions by means of sensitivity analysis runs of TERM, construction of hypothetical examples, and case studies of individual transit operators' actual investment decisions and costs. The goal of this assessment would be to understand quantitatively how the model's structure and data limitations may affect the credibility of TERM's backlog estimates and projections of capital spending requirements. Assessment should include examination of the seven methodological concerns that are identified in the section above on limitations of the TERM methodology and described in the Appendix.

Validation Using Trend Analysis

As part of its assessment of TERM, FTA should consider developing simple methods of projecting future capital expenditure requirements to validate and possibly to supplement TERM. Projections using trend analysis and data at least partially independent of TERM's database could serve as validity checks on TERM outputs. Simple projection methods also could clarify the connections between the data inputs and assumptions and the needs projections and would be more transparent for users. Development of simple methods that were comparable in accuracy with TERM might be possible for aggregate categories of spending.

A method for tracking and projecting aggregate transit capital stock as a function of capital expenditures could be patterned on the method that the Bureau of Economic Analysis uses for developing its annual series of the stock of fixed assets for sectors of the U.S. economy, including public transit (BEA 2003; BEA 2012). These estimates use the perpetual inventory method whereby data are compiled on annual capital expenditures by industry and asset type (primarily from Census surveys), price indices for asset purchases, and service lives and depreciation rates for the asset types. The capital stock each year is calculated as the sum of all past capital expenditures less the sum of all past depreciation. The

future annual capital expenditures required to maintain or increase the capital stock can be estimated on the basis of the existing stock and the estimated service lives. FHWA has refined this method to produce estimates of highway capital stock (Fraumeni 2007), and the Congressional Budget Office has compiled annual series of public-sector transit capital expenditures (CBO 2010) that could serve as input to the calculation.

A second form of trend analysis would be to estimate TERM results by using high-level information about transit systems. A detailed assessment of capital expenditure requirements to attain SGR would be carried out for a small number of transit agencies using TERM or another approach. Then relationships would be estimated statistically between these requirements and aggregate measures of asset quantity and condition. For asset quantity, possible aggregate measures include the total number of vehicles, miles of fixed guideway, floor area (for facilities), and number of stations. For condition, aggregate measures might be average age of vehicles, percentage of vehicles older than some threshold, average age of the system, or equipment failure or road call rates. Finally, these relationships would be applied to estimate capital expenditure requirements for all transit agencies.

Sampling

The provisions of MAP-21 concerning transit asset management offer an opportunity for reforming the collection of the asset data that are the foundation of TERM. In implementing these provisions, FTA should consider following the example of the HERS asset inventory methodology by developing a scientifically designed sampling approach to data collection for TERM to replace the present methods. A sampling approach would improve data quality, provide a quantitative basis for estimating the reliability of the data, and reduce the data collection burden on transit agencies reporting data.

The appropriate design may be a multistage sample—for example, first sampling among transit agencies and then sampling assets within each asset class at each selected agency. The agency sample would include 100 percent sampling of the largest agencies. (One hundred percent sampling of assets

within each of the largest agencies would not be necessary.) Data collection would need to be consistent with the asset management provisions of MAP-21. FTA would continue to collect basic data for all transit agencies in the National Transit Database.

Refinements of TERM

FTA should consider refinements of TERM to make its projections of capital expenditure requirements more accurate and defensible. The refinements outlined below may, under further investigation, prove feasible, practical, and worthwhile.

Estimate Performance Consequences of SGR

FTA should develop the capability of quantifying the relationship between transit asset physical condition ratings projected in TERM and transit performance measures such as service reliability, passenger delay, accident risk, and agency expenses. Estimates of the performance impact of alternative levels of capital spending or of alternative SGR condition rating targets would increase the value of the *Conditions and Performance* reports as a source of guidance on capital spending requirements.

The Cohen (2012) resource paper commissioned for this review outlines a possible approach to research and data collection that FTA could undertake to quantify condition–performance relationships in four areas: travel time and reliability (using lost passenger hours as the performance metric), safety (using expected casualties as the metric), environmental and other nonuser costs (measured as TERM now quantifies social costs), and transit agency operating expenses. Operating expenses should be considered a performance metric because, if a transit agency chooses to maintain its assets to an SGR standard, the standard selected will affect the life-cycle cost of providing a specified level of transit service.

Research will be necessary to specify and estimate models relating asset condition to performance measures. For example, models would be required to predict the probability of failure of an asset as a function of age and condition and to estimate passenger delay caused by failure of the asset as a function of system characteristics. Initially, the research objective would be to develop models that could be applied in TERM using data on system characteristics available in the National Transit Database (Cohen 2012, 5). Separate models would be needed for each major category of equipment and infrastructure (e.g., vehicles, track, escalators, and control systems). Examples of such a model are the procedure proposed for estimating bus passenger delays described in *Transit Cooperative Research Program Report 157* (Spy Pond Partners et al. 2012, 114) and the estimate of service disruptions as a function of vehicle age distribution in the 2010 *Conditions and Performance* report (U.S. DOT 2012a, 2-36).

The proposed model development should not lead to the imposition of expanded general data reporting requirements on transit agencies. Instead, the committee envisions that the models relating condition to performance would be developed analogously to FTA's approach in developing TERM's asset decay curves: data for calibrating the curves were collected from voluntarily cooperating transit agencies as part of a special research project of limited duration.

In interpreting and reporting the results of a model relating condition to performance, users of the model should keep in mind that service reliability and other performance measures for any particular transit system will depend on factors beyond the system's asset condition ratings, and especially on the system's operating environment, maintenance and operating practices, and performance monitoring procedures.

Improve Ridership Projections

The committee's concerns with the ridership projections used for the growth scenarios presented in the 2010 *Conditions and Performance* report are described in the Appendix. To ensure that the projections are adequate for the model's intended purposes, FTA should take the following actions:

- Test the historical accuracy of projections from the local metropolitan planning organization projections and trend extrapolations currently used and compare the current projections with those used by transit agencies in grant applications to FTA;
- Analyze the sensitivity of TERM's capital expenditure projections to the ridership projections;
- Explore development of ridership projections that reflect nationally consistent assumptions about economic, demographic, and urban form trends; and
- Explore the possibility of incorporating supply-sensitive ridership projections in TERM.

Revise Benefit–Cost Analysis

As explained in the Appendix, the implications of TERM's business case benefit–cost analysis (i.e., applying a benefit–cost test only to 20-year packages of agency–mode expenditures rather than to individual expenditure decisions) are unclear. The resulting capital expenditure projections do not indicate economically optimal investment decisions and may not be realistic simulations of transit agency decision making. To rationalize the application of benefit–cost analysis in TERM, FTA should undertake four steps:

- Define more clearly the intended interpretation of the business case benefit–cost test. It is not evident whether the purpose now is simulation (i.e., eliminating from the estimates expenditures that agencies would be unlikely to undertake) or optimization (i.e., projecting the level of capital expenditures that would be economically justified).
- Assess, through sensitivity analyses and historical comparisons, how the present benefit–cost test affects the realism and the economic value of projected capital expenditures. In particular, FTA should assess the prevalence in TERM projections of uneconomic replacement and expansion

expenditures within agency–mode combinations that pass the business case benefit–cost test. (As explained in the Appendix, individual asset replacement and capacity expansion expenditures in TERM's projections of requirements are not subjected to a benefit–cost test.)

- Explore methods for applying a benefit–cost test for individual asset replacement decisions in TERM. The Cohen (2012) resource paper proposes a method for this calculation.
- Subject the internal assumptions and data of the TERM benefit–cost analysis to review. FTA should check whether unit cost and benefit values are consistent with recent research and should test the significance of assumptions concerning next-best alternatives to transit. [TERM estimates benefits by comparing riders' costs on a transit mode with their costs on an alternative transportation mode but does not consider the same mode with a lower level of service as an alternative (U.S. DOT 2012a, C-6).]

The first goal of revisions to the use of benefit–cost analysis in TERM should be to avoid including uneconomic capital expenditures in TERM's needs projections (or alternatively, to enable TERM to produce an estimate of the fraction of expenditures in a needs projection that would be uneconomic).

The key to refining the use of benefit–cost analysis will be implementation of models relating asset physical condition to transit system performance, as described above. By using these relationships, provided that they can be meaningfully measured, TERM could estimate how replacing (or not replacing) a particular asset in a particular year would affect performance. The incremental benefit of replacing the asset in a year is the value of the improvement in performance over the year that would be gained by the replacement. Then the method outlined by Cohen (2012, 11–12) or another life-cycle cost minimization technique could be used to determine whether to replace or defer replacement of the asset.

FTA also should examine the prevalence of uneconomic expenditures in the needs estimate of the SGR benchmark scenario. Reporting the aggregate benefits of the entire set of capital expenditures included in the SGR scenario needs estimate would align the transit analysis more closely with the analyses of highway and bridge needs in the *Conditions and Performance* reports.

Incorporate Management Strategies to Improve Efficiency of Asset Use

Given the wide variations in asset lives across transit agencies, there is reason to believe that many public transit operators can reduce life-cycle costs through better asset management. In addition, Congress mandated in MAP-21 that agencies improve their asset management practices. FTA projections of capital spending requirements should be able to estimate and articulate the payoffs from better asset management.

As noted above, estimating the effects of asset management will be difficult. Most agencies have only recently begun to develop formal asset management programs, so data derived from experience with asset management are limited. As a first step, FTA should assess the effect of improved asset management on capital spending required to maintain SGR through a study of agency best practices, determining the advantages each agency receives from its various strategies and benchmarking other agencies to the best practices. The results of this analysis could guide refinements of TERM.

Practices other than asset management, such as maintenance and demand management, affect transit agency costs of maintaining SGR and of accommodating ridership growth. A long-term goal for FTA analysis of capital spending requirements should be to develop estimates of the potential of improved management practices to optimize capital expenditures and reduce long-term capital, operating, and maintenance costs. As a methodological precedent, FHWA has developed a procedure to estimate how highway operations improvements would affect highway capital expenditure requirements projected by HERS.

Additional Refinements

The following refinements would not be as fundamental as those proposed above, but they could improve the reliability of TERM's projections of capital expenditure requirements.

Use Condition-Based Replacement Criteria Several large transit agencies have shifted to using condition-based replacement criteria instead of age-based criteria for their asset management and planning. Condition-based assessments use information obtained in routine inspections and have generally been found to be more effective than age-based criteria in optimizing asset replacement. In light of these moves, FTA should reexamine the current asset life criteria used in TERM to match current agency practices more closely and should consider shifting to condition-based replacement criteria in the model. The commissioned paper comparing TERM and agency projections (Zarembski 2012) showed that such a revision would be likely to bring TERM's estimates more in line with spending needs estimated by transit agency managers.

Reexamine Planning Horizons TERM's accuracy would benefit from extending its planning horizon. Many transit assets have long lives when properly maintained, longer than the 20 years considered by TERM. As a result, significant asset replacement needs may fall just outside of TERM's planning horizon, skewing the needs estimates. Longer planning horizons would account for the replacement needs of a larger fraction of agencies' assets, particularly for agencies managing relatively new systems. Zarembski (2012) illustrates the potential for distortion of TERM projections through use of planning periods shorter than asset lives.

Standardize Asset Categories TERM and transit agency staff categorize assets differently, complicating comparison of assets and spending needs across agencies. Standardization of asset categories for reporting purposes would improve TERM's ability to develop reliable aggregate estimates for the many hundreds of transit systems nationwide. These categories are likely to be determined by FTA's implementation of the MAP-21 asset management provisions.

Long-Run Development

FTA's goals for TERM should be to refine the agency's ability to provide information useful to Congress in monitoring federal transit capital funding programs and planning future programs. The information should include estimates of the performance consequences of alternative levels of capital spending and identification of opportunities for improving the cost-effectiveness of capital spending and of federal aid. Meeting this goal will require continuing improvements in data collection, forecasting, and communication of results. To supplement its analytical capabilities, FTA should investigate alternative model structures to project capital spending requirements. For example, the Pozdena (2012) resource paper commissioned for this review outlines a possible econometric approach to estimation of optimal transit capital expenditures.

CONCLUSION

TERM is the product of decades of rigorous and creative development by FTA, and its use in the *Conditions and Performance* reports has provided important insights into the long-term consequences of transit funding decisions. The committee recognizes that the proposed improvements—relating condition to performance, estimating the effect of asset management on capital expenditure needs, and estimating incremental benefits of individual asset replacement decisions—will be challenging to incorporate in TERM, since each will require substantial research and testing. Initially, FTA could present assessments of the performance impacts of asset condition and of the effect of asset management practices on capital needs as supplemental analyses, or even qualitative discussions, in the *Conditions and Performance* reports. It would be appropriate to start with simple methods to estimate orders of magnitude of the effects. Then FTA could decide whether building analyses into the simulation routines of TERM would be worthwhile. Whatever approach FTA adopts, the committee believes that informing Congress and the public about how asset condition affects transit performance and about opportunities for controlling

capital expenditure needs through management improvements is essential in fulfilling FTA's objective of producing meaningful projections of capital funding requirements and in complying with the MAP-21 mandate for federal support and guidance on transit asset management.

APPENDIX A: TERM METHODOLOGY ISSUES

The features of TERM described below were cited in the section on limitations of the TERM methodology. They may be sources of inaccuracy in TERM's projections or create a risk of misunderstanding of the projections. Their influence on the projections merits examination by FTA.

Methodology Concerns Affecting All TERM Applications

Pooling of Data for Systems with Differing Management Structures and Efficiencies

TERM projects replacement needs on the basis of decay curves that assume fixed relationships between asset age and physical condition for each asset category. The curves are estimated on the basis of data from selected transit systems. Transit agencies differ, perhaps markedly, in their ability to minimize life-cycle costs by optimizing maintenance and replacement decisions. Agencies also differ substantially in external factors that influence asset lives, such as climate and geography. How these two aggregation steps (estimating a single decay curve on the basis of data from disparate agencies and projecting replacement needs as if all assets were part of a single transit system in a single operating environment) may affect the credibility of the backlog estimate is unclear.

Cost Uncertainty

Previous research has found that cost overruns are typical of major transit construction projects (Booz Allen Hamilton 2005, 27-24; Altshuler and Luberoff 2003). In addition, the "soft costs" of infrastructure projects for planning, design, project management, and starting up a new service vary widely. If TERM's unit cost data do not incorporate cost overrun risk and soft cost uncertainty, the capital expenditure requirements produced by TERM may underestimate actual project costs. Even if these two concerns are

accounted for in the data, the presentation of TERM results as point estimates of cost rather than as ranges that reflect known sources of uncertainty may communicate a misleading impression of precision.

Information Lost in Aggregation of Model Estimates

The 2010 *Conditions and Performance* report presents TERM projections summed for (*a*) all transit systems in the nation, (*b*) systems serving urbanized areas with populations greater than 1 million, and (*c*) systems serving areas with populations under 1 million. This aggregation of the projections is not a source of inaccuracy, but may not be the most informative way to communicate TERM's results. While TERM is intended to produce estimates only for aggregates of systems, reporting of results at lower levels of aggregation might provide greater insight into the nature of investment needs, as well as the sources of any systematic bias or error in TERM. For example, the *Conditions and Performance* reports might show estimates for rail–bus and bus-only systems, for older and newer rail systems, or for the six to 12 largest systems as a group.

Lack of Consideration of Management Alternatives to Capital Expenditures

TERM implicitly assumes that industry management practices with regard to maintenance, rehabilitation, and replacement of assets are fixed. However, some agencies are probably more successful than others at optimizing these decisions. Furthermore, agencies presumably change their practices in response to changes in costs, in federal-aid rules, and in funds available for capital expenditures and for maintenance. For example, federal aid that reduces the cost to transit agencies of asset replacement relative to the cost of maintenance may encourage earlier asset retirement. By comparing industry best practices with TERM's estimated asset decay curves, it may be possible to examine how relaxing TERM's assumption of fixed management practices would affect its investment needs estimates. Including estimates of how improved asset management practices industrywide would affect the capital expenditures required to

attain SGR in the *Conditions and Performance* reports would enhance the value of the reports to Congress and the public.

A second kind of management consideration may affect the reliability or usefulness of TERM projections. Agencies may decide that replacement of certain assets that fall below the SGR standard would be impractical because the disruption of service during the replacement work would be unacceptable. For agency–mode combinations that contained such assets, the TERM projection of the effect of an assumed future rate of capital expenditure on asset condition could be misleading because the asset would not be replaced even if funds were available.

Concerns with the TERM Expansion Module and *Conditions and Performance* Report Growth Scenarios

Ridership Projections

The TERM growth scenario projections of capital expenditure requirements for the 2010 *Conditions and Performance* report use two projections of ridership: projections by each transit agency's local metropolitan planning organization and trend extrapolations produced by FTA. These two projections represent the low and high ridership growth scenarios, respectively. The ridership projections are independent of TERM's projected level of capital expenditure for each agency and transit mode. The historical reliability of ridership projections from the sources used is unknown, and the sensitivity of TERM's capital needs and benefits projections to ridership assumptions has not been documented. Moreover, the local metropolitan planning organization projections may not be consistent in their underlying assumptions and sophistication and may not always represent a credible low-growth scenario.

Assumed Linear Relationship Between Ridership and Capital Stock Requirements

TERM's expansion module projects the increase in the stock of vehicles and infrastructure needed to serve an agency–mode combination's projected ridership growth by assuming that temporal and directional peaking of demand and vehicle occupancy rates at each system remain constant. In addition, the model assumes that the expansion of guideways and of maintenance facilities is proportional to projected increases in ridership. The rationale for holding the ridership-to-capital-stock ratio constant, according to the TERM documentation, is that doing so will maintain current levels of service performance (FTA 2012b, 54–56). However, the relationship between transit capital stock and patronage varies substantially from system to system and within a system over time and space. For example, adding midday bus or rail service on lines currently operating below capacity is unlikely to require additional vehicles or track. Yet TERM would assume proportional increases in both. On the other hand, adding even small amounts of peak-hour, peak-direction rail service on lines already operating at capacity may require capital investments far larger than the incremental service requirement proposed. Furthermore, transit managers can alter utilization rates while maintaining service by adjusting, for example, vehicle deployment practices and fare pricing. Thus, assuming a constant ratio of ridership to capital stock may yield misleading estimates of required capital expenditures.

TERM's Business Case Benefit–Cost Analysis

Benefit–cost analysis in TERM is performed for 20-year packages of proposed capital expenditures for each agency–mode combination in the database, rather than for individual spending decisions. If the total cost of maintaining and expanding the agency–mode combination exceeds the benefit of the transit service provided, TERM first deletes expansion expenditures for the agency–mode combination; it then deletes a portion of replacement expenditures from the capital expenditure requirements projection until the estimated benefit of the service exceeds the remaining projected cost. If an agency–mode

combination passes the overall 20-year benefit–cost test, TERM does not eliminate any individual expenditures from the capital expenditure requirement estimate for that combination.

Because inclusion of an asset's replacement expense in TERM's backlog estimates and future spending needs projections is not determined by a benefit–cost calculation for that asset, TERM capital requirements estimates likely include some expenditures whose benefits are less than their replacement costs and exclude some expenditures that would yield a greater return than expenditures that are included in the estimate. The scale and direction of these two possible errors are unknown. Therefore, the growth scenario projections do not represent economically optimum expansion decisions. Moreover, it is unclear whether the benefit–cost analysis produces realistic projections—that is, whether the analysis can predict which transit agencies are most likely to expand.

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Abbreviations

BEA	Bureau of Economic Analysis
CBO	Congressional Budget Office
FTA	Federal Transit Administration
U.S. DOT	U.S. Department of Transportation

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APPENDIX B: REVIEW OF THE DOCUMENT

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's (NRC) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that assist the authors and NRC in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The contents of the review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. The following individuals participated in the review of this report: Michael A. Allegra, Utah Transit Authority; Adjo A. Amekudzi, Georgia Institute of Technology; Jack M. Reilly, Rensselaer Polytechnic Institute; and G. Scott Rutherford, University of Washington. Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the committee's conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Susan Hanson, Clark University (emerita). Appointed by NRC, she was responsible for making certain that an independent examination of the report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

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