CHAPTER 9: Sensitivity Analysis

Sensitivity Analysis – Highways

Sound practice in investment modeling includes analyzing the sensitivity of key results to changes in the underlying assumptions. This section analyzes how changes in some of the assumptions would affect the estimate of the average annual levels of highway investment for two scenarios presented in Chapter 7.

KEY TAKEAWAYS

- The Improve Conditions and Performance scenario is highly sensitive to the real discount rate assumed in the analysis. Substituting a 3-percent discount rate for the 7-percent discount rate assumed in the baseline would increase its average annual investment requirements by 20.0 percent.
- Both HERS and NBIAS are more sensitive to changes in the assumed value of time than to the assumed value of a statistical life. Substituting a high or low value of a statistical life changes by only 1 percent the estimate of average annual investment requirements, in part because neither model evaluates the need for improvements that are primarily safety-focused.
- Reducing projected average annual VMT growth from 1.2 percent per year to 0.9 percent per year would reduce the average annual investment levels for both scenarios by 7.2 percent for the Maintain Conditions and Performance scenario and by 8.1 percent for the Improve Conditions and Performance scenario.

Scenarios Analyzed

The Improve Conditions and Performance scenario is defined in terms of the level of investment estimated to be cost-beneficial (i.e., all potential projects with a benefit-cost ratio greater than or equal to 1.0 are implemented). For this scenario, any change in assumptions that increases the value of benefits (or decreases costs) will result in a higher average annual investment level. Conversely, any change in assumptions that reduces the value of benefits (or increases costs) will result in a lower average annual investment level.

The situation for the Maintain Conditions and Performance scenario is a little more complicated, as it is defined in terms of the level of investment needed to maintain certain specific performance indicators in 2036 at 2016 levels. The Highway Economic Requirements System (HERS) inputs to this scenario identify the lowest level of investment at which the 2036 projections for each of two measures—the average International Roughness Index (IRI) and average delay per vehicle miles traveled (VMT)—indicate conditions and performance that match (or are better than) those in the 2016 base year. In practice, the binding constraint was maintaining average IRI; average delay improved (i.e., was reduced) under this scenario. Because system rehabilitation spending has a larger impact on average IRI than does system expansion spending, changes to assumptions that cause HERS to increase the share of investment directed toward system rehabilitation relative to system expansion will tend to reduce the level of investment needed to achieve the goals of this scenario. Conversely, changes to assumptions that cause HERS to place more value on system expansion relative to system rehabilitation will tend to increase the level of investment needed to maintain average IRI.

The National Bridge Investment Analysis (NBIAS) inputs to this scenario identify the lowest level of investment at which the percentage of bridges in poor condition (weighted by deck area) in 2036 matches that in 2016. This indicator is influenced by the relative level of investment directed toward bridge replacement vs. bridge rehabilitation, which can affect the investment level needed to achieve the goals of the scenario.

Alternative Economic Analysis Assumptions

The U.S. Department of Transportation (DOT) periodically issues guidance on valuing changes in travel time and traveler safety for use in benefit-cost analysis; the Office of Management and Budget (OMB) provides guidance on the choice of discount rate. Recognizing the uncertainty regarding these values, the guidance documents include both specific recommended values and ranges of values to be tested. The analyses presented in Chapters 7 and 10 of this report are based on the primary recommendations in DOT and OMB guidance for these economic inputs, whereas the analyses presented in this chapter rely on recommended alternative values to be used for sensitivity testing.

Value of Travel Time Savings

The value of travel time savings is a key parameter in benefit-cost analysis of transportation investments. For HERS and NBIAS, the Federal Highway Administration (FHWA) estimates average values per vehicle hour traveled by vehicle type. Primarily, these values reflect the benefits from savings in the time spent by travelers in vehicles, also taking into account that vehicles can have multiple occupants. Time used for travel represents a cost to society and the economy because that time could be used for other more enjoyable or productive purposes. For heavy trucks, FHWA makes additional allowances for the benefits from freight arriving at its destination faster and from the opportunities for more intensive vehicle utilization when trips can be accomplished in less time. Even for these types of vehicles, however, the value of travel time savings estimated by FHWA primarily reflects the benefits from the freeing of travelers' time—the time of the truck driver and other vehicle occupants.

For valuation of traveler time, the analysis in this report follows DOT's guidance on valuing travel time saved in 2016. In the analyses presented in Chapters 7 and 10, traveler time savings are valued per person hour at $14.20 for personal travel and between $27.56 and $34.96 for business travel (Appendix A, Valuation of Travel Time Savings section). The value for personal travel is set in the guidance at 50 percent of hourly household income, calculated as median annual household income divided by 2,080, the annual work hours of someone working 40 hours every week. The values for business travel are set at the relevant estimate of average hourly labor compensation (wages plus supplements). The variation in these values by vehicle type indicates, for example, that truck drivers typically earn less than business travelers in light-duty vehicles.

For personal travel, the values per person hour of travel are estimates subject to considerable uncertainty. Estimating an average value of travel time is complicated by substantial variation in the value of travel time among individuals and, even for a given individual, among trips. Contributing to such variation are differences in incomes, employment status and earnings, attitudes, conditions of travel (e.g., the level of traffic congestion), and other factors. Moreover, studies that estimate values of travel time often are difficult to compare because of differences in data and methodology.

In view of these uncertainties, the present analysis includes sensitivity tests that set values of personal travel time savings lower or higher than the baseline. In line with DOT guidance, these values are 35 percent and 60 percent of median hourly household income, respectively.

Exhibit 9-1 shows the effects of these variations on spending levels in the two scenarios reexamined in this chapter. Assuming lower values of time reduces the average annual investment level for the Maintain Conditions and Performance scenario by 4.2 percent and for the Improve Conditions and Performance scenario by 3.8 percent. Conversely, assuming higher values of time increases the average annual investment level for both scenarios.

For the NBIAS-derived component of the scenarios, the effects of changing the assumed value of time are small (at most, a 1.1-percent change in average annual investment levels), consistent with bridge capacity expansion being outside the model's scope. The bridge preservation actions evaluated by NBIAS would have minimal effect on travel times, except where they would eliminate long detours caused by vehicle weight restrictions on a bridge.

Exhibit 9-1 ■ Impact of Alternative Value of Time Assumptions for Personal Travel on Highway Investment Scenario Average Annual Investment Levels

Alternative Time Valuation Assumptions for Personal Travel as Percentage of Hourly Earnings	Maintain Conditions and Performance Scenario		Improve Conditions and Performance Scenario	
	Billions of 2016 Dollars	Percent Change from Baseline	Billions of 2016 Dollars	Percent Change from Baseline
Baseline[1] (50% of Hourly Earnings)	**$98.0**		**$165.9**	
HERS-derived Component	$54.7		$91.7	
NBIAS-derived Component	$14.3		$25.1	
Other (Nonmodeled) Component	$29.1		$49.2	
Lower (35% of Hourly Earnings)	**$93.9**	**-4.2%**	**$159.6**	**-3.8%**
HERS-derived Component	$51.9	-5.1%	$87.5	-4.5%
NBIAS-derived Component	$14.2	-0.8%	$24.8	-1.1%
Other (Nonmodeled) Component	$27.9	-4.2%	$47.3	-3.8%
Higher (60% of Hourly Earnings)	**$100.2**	**2.2%**	**$169.8**	**2.4%**
HERS-derived Component	$56.1	2.6%	$94.2	2.8%
NBIAS-derived Component	$14.4	0.4%	$25.3	0.9%
Other (Nonmodeled) Component	$29.7	2.2%	$50.4	2.4%

[1]1The baseline levels shown correspond to the systemwide scenarios presented in Chapter 7. The investment levels shown are average annual values for the period from 2017 through 2036. Business travel is valued at 100% of hourly earnings for all three alternatives.

Note: HERS is Highway Economic Requirements System; NBIAS is National Bridge Investment Analysis System.

Sources: Highway Economic Requirements System; National Bridge Investment Analysis System.

Nonmodeled Highway Investments

The HERS-derived component of each scenario represents spending on pavement rehabilitation and capacity expansion on Federal-aid highways. The NBIAS-derived component represents rehabilitation spending on all bridges, including those off the Federal-aid highways. The nonmodeled component corresponds to system enhancement spending, plus pavement rehabilitation and capacity expansion on roads not classified as Federal-aid highways.

In the Sustain 2016 Spending scenario presented in Chapter 7, the values for these HERS and NBIAS components total $75.2 billion. In 2016, nonmodeled spending accounted for 29.7 percent of total investment and is assumed to form the same share in all scenarios presented in Chapter 7.

Likewise, the nonmodeled component is set at 29.7 percent of the total investment level in the sensitivity analysis for the Maintain Condition and Performance and the Improve Condition and Performance scenarios presented in this section. As the combined levels of the HERS-derived and NBIAS-derived scenario components increase or decrease, the nonmodeled component changes proportionally. Consequently, the percentage change in the nonmodeled component of each alternative scenario relative to the baseline always matches the percentage change in the total investment level for that scenario.

For the HERS-derived component of the Improve Conditions and Performance scenario, reducing the value of traveler time results in a 5.5-percent reduction in average annual investment levels, whereas increasing the value of traveler time results in a 4.2-percent increase. In the Improve Conditions and Performance scenario, the goal is to exploit all opportunities for cost-beneficial investments, which become fewer when the travel time savings are valued less (i.e., benefits decline) and more when traveler time savings are valued more (i.e., benefits increase).

For the HERS-derived component of the Maintain Conditions and Performance scenario, reducing the value of traveler time results in a 6.3-percent reduction in average annual investment levels.

Reducing the value of travel time savings makes capacity expansion improvements relatively less attractive, causing HERS to make a larger share of funds available for the system rehabilitation improvements that more directly affect pavement roughness. This allows the criteria for the scenario to be met (maintaining average pavement roughness) at a lower overall cost. Conversely, increasing the value of time makes capacity expansion improvement relatively more attractive, reducing the share of investment available for system rehabilitation, and requiring a higher overall level of HERS investment to achieve the scenario objective of maintaining average pavement roughness.

Discount Rate

Benefit-cost analyses apply a discount rate to future streams of costs and benefits, which effectively weighs benefits and costs expected to arise further in the future less than those that would arise sooner. The baseline investment scenarios estimated by HERS, NBIAS, and the Transit Economic Requirements Model (TERM) use a discount rate of 7 percent; this means that deferring a benefit or cost for a year reduces its real value by approximately 6.5 percent (1/1.07). This choice of a real discount rate conforms to the "default position" in the 1992 OMB guidance on discount rates, in Circular A-94, for benefit-cost analyses of Federal programs or policies. The rationale is that for a potential Federal investment to be deemed cost-beneficial, the expected rate of return should be at least as high as the average before-tax rate of return on private-sector investments, which in the United States, has been about 7 percent in real dollars (net of inflation) over the long term. This approach to setting the discount rate is common in benefit-cost analyses of public investment in transportation infrastructure, in the United States and abroad.

In 2003, OMB's Circular A-4 recommended that regulatory analyses use both 3 percent and 7 percent as alternative discount rates.[27] The justifications for these recommendations also apply to benefit-cost analyses of public investments, so the sensitivity tests in this section include the use of the 3-percent discount rate as an alternative to the 7-percent rate used in the baseline simulations. Some governmental organizations use discount rates much closer to 3 percent than to 7 percent for benefit-cost analyses of transportation infrastructure investments. In the United States, examples include the discount rates of 1.7 percent and 4.0 percent reported to be used by the Minnesota Department of Transportation and the Florida Department of Transportation respectively.[28] For comparison, the sensitivity tests performed in this section also consider the use of a 10 percent discount rate, per the OMB policy prior to 1992.

For infrastructure improvements, including those that HERS and NBIAS consider, the normal sequence is for an initial period in which net benefits are negative, reflecting the costs of construction, followed by many years of positive net benefits, reflecting the benefits of improved infrastructure in place. Because the benefits from the use of the improved facilities materialize further in the future than do the costs of construction, a reduction in the discount rate increases the weight attached to those benefits relative to the construction costs, resulting in a higher benefit-cost ratio (BCR) for all potential projects. As a result, some potential projects that had a BCR below 1.0 (i.e., costs exceed benefits), based on a higher assumed discount rate, would have a BCR above 1.0 (i.e., benefits exceed costs) if a lower discount rate were assumed.

[27] https://obamawhitehouse.archives.gov/omb/circulars_a004_a-4/

[28] *Use of Benefit-Cost Analysis by State Departments of Transportation*, Federal Highway Administration, n.d., available at: https://www.fhwa.dot.gov/policy/otps/pubs/bca_report/. A relatively low discount rate was also recommended for use in the benefit-cost analyses conducted by Seattle public utilities; the document that developed this recommendation clearly delineates the issues in selecting a discount rate (see *Updating The Discount Rate for Benefit-Cost Analyses at Seattle Public Utilities,* Bruce Flory, n.d., available at http://mrsc.org/getmedia/9d05a8d7-b36d-4af4-8e1c-94491c351bb0/s42discrate.pdf.aspx.

Value of Traveler Safety

One of the most challenging questions in benefit-cost analysis is what monetary cost to place on injuries of various severities. The analysis in this report essentially follows DOT's guidance on the "value of a statistical life" saved in 2016, which recommends a base value of $9.6 million, but also requires that regulatory and investment analyses include sensitivity tests using alternative values of $5.2 million as the lower bound and $13.0 million for the upper bound.

As revealed in previous C&P reports, the HERS and NBIAS models are both much less sensitive to changes in the assumed value of a statistical life than they are to the assumed value of time. This is an artifact of the types of improvements captured by the models, which omit the types of targeted safety improvements that have the most direct impact on reducing crashes and fatalities. As noted in Part IV of this report, proposed changes to the HPMS include the addition of Model Inventory of Roadway Elements (MIRE) safety-related data into the HPMS framework. The future availability of such data would facilitate future analysis of targeted safety improvements in HERS.

Applying the recommended alternatives in HERS and NBIAS would increase both scenarios by approximately 1 percent, assuming a higher value of a statistical life, and reduce both scenarios by approximately 1 percent, assuming a lower value of a statistical life.

Since the Improve Conditions scenario is defined around exhausting all opportunities for implementing cost-beneficial projects, lowering the discount rate increases its average annual investment level. Accordingly, *Exhibit 9-2* shows that in the Improve Conditions and Performance scenario, a reduction in the assumed annual discount rate from 7 percent to 3 percent increases the total level of investment by 16.5 percent, due almost entirely to the 20.0 percent increase in the HERS component; the NBIAS component increases by only 3.5 percent. Conversely, raising the discount rate from the baseline value of 7 percent to 10 percent reduces the total level of investment in the Improve Conditions and Performance scenario by $20.0 billion.

For the Maintain Conditions and Performance scenario, the reduction in the discount rate has more complex effects within the models. At any given level of HERS-related spending, the model determines that allocating a slightly higher share to system preservation projects would be cost-beneficial; this is because, in HERS, benefits arising relatively late in the project life cycle tend to be more important for system rehabilitation projects than for system expansion projects. Because the preservation share of spending increases, the $53.4 billion of spending from the baseline (7 percent discount rate) would more than suffice to maintain IRI at the base-year level. Thus, a reduction in the discount rate leads the model to marginally reduce spending in the Maintain Conditions and Performance scenario. Conversely, an increase in the discount rate from the baseline value of 7 percent to 10 percent marginally increases spending in this scenario because the preservation share of spending decreases.

The NBIAS-derived component of spending in the Maintain Conditions and Performance scenario is somewhat more sensitive to the discount rate. Reducing the discount rate from 7 percent to 3 percent causes this component to decrease by 4.9 percent. The reduction in the discount rate expands the set of bridge improvement options that satisfy the NBIAS requirement that any selected improvements be cost-beneficial; with the choice set thus broadened, the model's estimate of the cost to maintain the deck-area weighted share of bridges rated poor at the base-year level decreases. When the discount rate is increased from the baseline value of 7 percent to 10 percent, the estimate of cost to maintain decreases by 1.7 percent. The explanation is that the increase in the discount rate favors projects that address functional deficiencies rather than structural deficiencies connected to bridge condition. Moreover, the target in the Maintain scenario is to keep unchanged from the base year level the percent of deck area in poor condition. Thus, since the increase in the discount rate reduces the share of spending that would address condition problems, the total amount of spending must increase to meet the condition target.

Exhibit 9-2 ■ Impact of Alternative Discount Rate Assumptions on Highway Investment Scenario Average Annual Investment Levels

Alternative Assumptions About Discount Rate	Maintain Conditions and Performance Scenario		Improve Conditions and Performance Scenario	
	Billions of 2016 Dollars	Percent Change from Baseline	Billions of 2016 Dollars	Percent Change from Baseline
Baseline[1] (7% Discount Rate)	**$98.0**		**$165.9**	
HERS-derived Component	$54.7		$91.7	
NBIAS-derived Component	$14.3		$25.1	
Other (Nonmodeled) Component	$29.1		$49.2	
Lower (3% Discount Rate)	**$95.2**	**-2.8%**	**$193.2**	**16.5%**
HERS-derived Component	$53.4	-2.3%	$110.0	20.0%
NBIAS-derived Component	$13.6	-4.9%	$25.9	3.5%
Other (Nonmodeled) Component	$28.2	-2.8%	$57.3	16.5%
Higher (10% Discount Rate)	**$98.6**	**0.6%**	**$145.9**	**-12.0%**
HERS-derived Component	$55.3	1.2%	$79.5	-13.3%
NBIAS-derived Component	$14.1	-1.7%	$23.2	-7.6%
Other (Nonmodeled) Component	$29.2	0.6%	$43.3	-12.0%

[1]The baseline levels shown correspond to the systemwide scenarios presented in Chapter 7. The investment levels shown are average annual values for the period from 2017 through 2036.

Note: HERS is Highway Economic Requirements System; NBIAS is National Bridge Investment Analysis System.

Sources: Highway Economic Requirements System and National Bridge Investment Analysis System.

Traffic Growth Projections

For each of the approximately 130,000 sections of highway in its sample, the Highway Performance Monitoring System (HPMS) requires from States an estimate of traffic volume in the base year and a forecast of traffic volume in a subsequent year, typically 20 years after the base year. The section-specificity of the forecasts allows States to factor in local conditions, constituting an advantage for their use in HERS, which evaluates highway improvement options on a section-by-section basis. The drawbacks to using these forecasts are: (a) the ambiguity as to how the forecasts are derived, which makes it difficult to evaluate them and to judge how to incorporate them within HERS; and (b) the apparent slowness of the States to adjust their forecasts for recent changes in the trend rate of national VMT growth (as discussed in the 2015 C&P Report, Chapter 9).

The modeling in this edition of the C&P Report thus supplements the section-level forecasts from the HPMS with national-level VMT forecasts from an FHWA econometric model. The Volpe National Transportation Systems Center developed this FHWA model, which forecasts future changes in passenger and freight VMT based on predicted changes in demographic and economic conditions. Built on economic theory, the national total VMT model establishes a separate but structurally similar econometric model for each of three vehicle categories—light-duty vehicles, single-unit trucks, and combination trucks—using time series data beginning in the 1960s. These econometric models include underlying factors that strongly influence user demand for travel, such as demographic characteristics, economic activity, employment, cost of driving, road miles, and transit service availability. The most recent documentation for the supporting model is available at http://www.fhwa.dot.gov/policyinformation/tables/vmt/vmt_model_dev.cfm.

The national forecasts used in the present analysis were published online as *FHWA Forecasts of Vehicle Miles Traveled (VMT): Spring 2018.*[29] For all vehicle types combined, VMT growth is forecast to average 1.2 percent annually over 20 years starting in 2017. This forecast is conditional on certain baseline projections for economic growth. In alternative scenarios where economic growth is projected to be higher or lower than in the baseline, VMT growth is forecast to average 0.9 percent or 1.3 percent. The highway investment scenarios presented in this C&P report (Chapter 7) use the baseline forecast of VMT growth, while the alternative forecasts are used in the sensitivity test presented in this section.

This report's modeling also uses the breakdown by vehicle category in the FHWA econometric forecasts (*Exhibit 9-3*). The National Bridge Inventory (NBI) includes State-supplied forecasts of traffic on each bridge, and the HPMS does likewise for each sampled highway section, but neither database disaggregates these forecasts by vehicle category. In this report, a scaling factor is applied for each vehicle category to produce forecasts that combine the strength of the HPMS and NBI forecasts (section- and bridge-level specificity that captures differences in growth prospects caused by local factors) with the strengths of the FHWA econometric forecasts (greater rigor and transparency, and breakdowns by vehicle category).[30]

Exhibit 9-3 ■ Projected Average Percent Growth per Year in VMT by Vehicle Class, 2017–2036

Vehicle Class	VMT Growth Rate		
	Baseline	From Low-economic Growth Forecast	From High-economic Growth Forecast
Passenger Vehicles	1.1	0.9	1.3
Single-unit Trucks	1.8	1.4	2.3
Combination Trucks	1.6	1.2	1.9
All Vehicles	**1.2**	**0.9**	**1.3**

Source: FHWA National Vehicle Miles Traveled Projection.

Alternative Growth Rates

In the Improve Conditions and Performance scenario, replacing the baseline traffic growth assumptions with the low-growth assumptions reduces by 9.6 percent the HERS component of the estimated investment level needed to achieve the scenario's objective of funding all cost-beneficial improvements (*Exhibit 9-4*). For all investment components of the Improve Conditions and Performance scenario, the change from baseline to low-growth assumptions reduces the NBIAS component by much less, 2.8 percent, making for an overall reduction (both model components) of 8.1 percent. For the Maintain Conditions and Performance scenario, this same sensitivity test has somewhat less effect on the required investment level: reductions of 8.7 percent (HERS component), 1.4 percent (NBIAS component), and 7.2 percent (both components).

Replacing the baseline traffic growth assumptions with the high-growth assumptions has a much smaller effect on the estimated investment requirements. This is consistent with the annual VMT growth rate under the high-growth assumptions, 1.3 percent, not much exceeding the 1.2 percent under the baseline assumptions. The percentage increase in the estimated investment requirement is 2.1 percent in the Improve Conditions and Performance scenario and 1.9 percent in the Maintain Conditions and Performance scenario. As in the sensitivity test discussed earlier in this section that

[29] https://www.fhwa.dot.gov/policyinformation/tables/vmt/vmt_forecast_sum.pdf

[30] In this calculation, the section-specific VMT growth rates in the State-supplied forecasts in the HPMS and NBI are initially assumed to apply to each vehicle category. The HPMS section-level forecasts are adjusted upward or downward proportionally, as needed to conform to the alternative value for nationwide VMT growth.

reduces the VMT growth rate, the percentage effect is again considerably larger for the HERS component of the investment requirement than for the NBIAS component.

An assumption of higher future VMT growth would increase the estimated benefits for both system expansion projects (higher demand translates into higher benefits for improvements that produce travel time savings) and system rehabilitation projects (higher VMT increases the rate of deterioration of existing assets). Increased rates of asset deterioration would also result in higher levels of investment needed to maintain assets in their current condition state.

Exhibit 9-4 ■ Impact of Alternative Travel Growth Forecasts on Highway Investment Scenario Average Annual Investment Levels

Alternative Assumptions About Future Annual VMT Growth[1]	Maintain Conditions and Performance Scenario		Improve Conditions and Performance Scenario	
	Billions of 2016 Dollars	Percent Change from Baseline	Billions of 2016 Dollars	Percent Change from Baseline
Baseline[2] (1.2% per Year, Tied to May 2018 Baseline Forecast)	**$98.0**		**$165.9**	
HERS-derived Component	$54.7		$91.7	
NBIAS-derived Component	$14.3		$25.1	
Other (Nonmodeled) Component	$29.1		$49.2	
Lower (0.9% per Year, Tied to May 2018 Low Economic Growth Forecast)	**$91.0**	**-7.2%**	**$152.5**	**-8.1%**
HERS-derived Component	$49.9	-8.7%	$82.9	-9.6%
NBIAS-derived Component	$14.1	-1.4%	$24.4	-2.8%
Other (Nonmodeled) Component	$27.0	-7.2%	$45.2	-8.1%
Higher (1.3% per Year, Tied to May 2018 High Economic Growth Forecast)	**$99.9**	**1.9%**	**$169.4**	**2.1%**
HERS-derived Component	$55.9	2.3%	$93.8	2.3%
NBIAS-derived Component	$14.3	0.3%	$25.3	1.1%
Other (Nonmodeled) Component	$29.6	1.9%	$50.2	2.1%

[1]The VMT growth rates identified represent the forecasts entered into the HERS and NBIAS models. The travel demand elasticity features in HERS modify these forecasts in response to changes in highway user costs resulting from future highway investment.

[2]The baseline levels shown correspond to the systemwide scenarios presented in Chapter 7. The investment levels shown are average annual values for the period from 2017 through 2036.

Note: HERS is Highway Economic Requirements System; NBIAS is National Bridge Investment Analysis System.

Sources: Highway Economic Requirements System; National Bridge Investment Analysis System.

What if Traffic Doesn't Grow?

Although VMT at the national level has sometimes decreased year-to-year, VMT has traditionally increased over the long run as population and the economy grew. However, exploring a no-growth analysis is of interest, both to serve as a conservative estimate of investment needs over the 20 years from 2015 through 2034 and to highlight the portion of the baseline analysis that is attributable to future traffic growth. Similar to the analyses presented in *Exhibit 9-4*, the HERS and NBIAS models were re-run under the assumption of zero growth in VMT over 20 years, with an adjustment made for other non-modeled capital spending types.

Eliminating the baseline assumption of 1.2-percent annual growth in VMT would reduce the average investment level under the Maintain Conditions and Performance scenario by 19.8 percent (to $78.6 billion) and would reduce the average annual investment level under the Improve Conditions and Performance scenario by 25.6 percent (to $123.4 billion). As in the other tests that varied the projected VMT growth, the estimate of investment needs for highway capacity expansion and pavement preservation (obtained from HERS) is much more sensitive to the assumed traffic growth rate than to the estimate of investment needs for bridge preservation (obtained from NBIAS).

Sensitivity Analysis – Transit

This section examines the sensitivity of estimated transit investment needs, as produced by the Transit Economic Requirements Model (TERM), to variations in key inputs, including:

- Asset replacement timing (condition threshold),
- Capital costs,
- Value of time, and
- Discount rate.

The alternative projections presented in this chapter assess how the estimates of baseline investment needs for the State of Good Repair (SGR) benchmark and the Low-Growth and High-Growth scenarios discussed in Chapter 7 vary in response to changes in the assumed values of these input variables. Note that, by definition, funding under the Sustain Recent Spending scenario does not vary with changes in any input variable, and thus this scenario is not considered in this sensitivity analysis.

KEY TAKEAWAYS

- TERM is sensitive to changes in replacement thresholds. A 0.5-point change in the condition scale results in up to a 34-percent change in replacement needs.
- Modeled changes in capital costs under different scenarios are as follows:
  - SGR (no benefit-cost analysis [BCA] test): the change in capital costs for preservation costs is comparable to the change in replacement investment costs.
  - High- and Low-Growth scenarios (applies to BCA test): a 25-percent increase in capital cost results in a 13- to 14-percent increase in investment.
- Preservation expenditures have low sensitivity to variations in value of time. Doubling the value of time cost (from $12.80 to $25.60) increases investment by 6–8 percent.
- TERM is relatively insensitive to changes in the discount rate. Dropping the discount rate from 7 percent to 3 percent leads to an increase of only 1 percent in investment levels.

Changes in Asset Replacement Timing (Condition Threshold)

Each of the three investment scenarios, as well as the SGR benchmark, examined in Chapter 9 assumes that assets are replaced at condition rating 2.5, as determined by TERM's asset condition decay curves. (In this context, 2.5 is referred to as the "replacement condition threshold.") TERM's condition rating scale runs from 5.0 for assets in "excellent" condition through 1.0 for assets in "poor" condition. Within this context, replacement at condition 2.5 assumes that assets are replaced close to or soon after they have attained their expected useful lives. Replacement at condition 2.5 can therefore be thought of as providing a replacement schedule that reflects asset life expectancy (the optimal time for asset replacement) but that is also potentially conservative, in the sense that many assets are replaced after their expected replacement age. Later replacement may be related to funding constraints (meaning some assets must be retained in service past their expected useful life) and to the time required to plan, fund, and procure replacement assets. Similarly, some assets can require replacement *before* attaining their expected life, for example due to premature asset failure, requirements for expanded asset capacity (e.g., a larger station), or other factors.

Importantly, the 2.5 replacement threshold only applies to *replaceable* assets. In contrast, nonreplaceable assets are subject only to ongoing maintenance and rehabilitation activities that help preserve these asset types and are inexpensive compared with the assets' initial acquisition cost. Unlike replaceable assets, nonreplaceable assets are not subject to the 2.5 replacement threshold, and their condition continues to decay beyond that point (at a very slow rate of decline). Examples of nonreplaceable assets include assets with very long useful lives such as elevated structures, subway stations, and tunnels.

Exhibit 9-5 shows the effect of varying the replacement condition threshold by increments of 0.25 on TERM's projected asset preservation needs for the SGR benchmark and the Low-Growth and High-Growth scenarios. Note that selection of a higher replacement condition threshold results in assets being replaced while in better condition (i.e., at an earlier age). This, in turn, reduces the length of each asset's service life, thus increasing the number of replacements over any given period of analysis and driving up scenario costs. Reducing the replacement condition threshold would have the opposite effect. As shown in *Exhibit 9-5*, each of these three scenarios shows significant changes to total estimated preservation needs from quarter-point changes in the replacement condition threshold. Relatively small changes in the replacement condition threshold frequently translate into significant changes in the expected useful life of some asset types; hence, small changes can also drive significant changes in replacement timing and replacement costs. Note that investment needs do not strictly increase with the replacement threshold in the High- and Low-Growth scenarios. As the replacement threshold increases, more assets begin to fail the benefit-cost test and are not replaced, resulting in lower total investment than at lower replacement thresholds.

Exhibit 9-5 ■ Impact of Alternative Replacement Condition Thresholds on Transit Preservation Investment Needs by Scenario (Excludes Expansion Impacts)

Replacement Condition Thresholds	SGR Benchmark		Low-Growth Scenario		High-Growth Scenario	
	Billions of 2016 Dollars	Percent Change from Baseline	Billions of 2016 Dollars	Percent Change from Baseline	Billions of 2016 Dollars	Percent Change from Baseline
Very Late Asset Replacement (2.00)	$11.9	-34%	$17.6	-24%	$19.1	-22%
Replace Assets Later (2.25)	$15.0	-17%	$20.5	-12%	$22.1	-10%
Baseline (2.50)	$18.1		$23.2		$24.7	
Replace Assets Earlier (2.75)	$21.1	17%	$26.0	12%	$26.6	8%
Replace Assets Much Earlier (3.00)	$23.3	29%	$27.1	17%	$27.6	12%

Source: Transit Economic Requirements Model.

Changes in Capital Costs

The asset costs used in TERM are based on actual prices paid by agencies for capital purchases. Sources of these data include the Federal Transit Administration's Capital Cost Database (which documents as-built costs for a sample of New Starts projects from 1980 through 2016), and ongoing sampling of agency asset inventory holdings and replacement costs. Asset prices in the current version of TERM have been converted from the dollar-year in which assets were acquired (which vary by agency and asset) to 2016 dollars using the RSMeans construction cost index. Given the uncertain nature of capital costs, a sensitivity analysis has been performed to examine the effect that higher capital costs would have on the dollar value of TERM's baseline projected transit investment.

As *Exhibit 9-6* shows, TERM projects that a 25-percent increase in capital costs (i.e., all costs are set to 125 percent of the value used in this C&P Report) would lead to proportional growth in the SGR benchmark, but would be only partially realized under the Low-Growth or High-Growth scenarios. This difference in sensitivity results is driven by the fact that investments are not subject to TERM's benefit-cost test in computing the SGR benchmark (i.e., increasing costs have no consequences in terms of which projects are carried out), whereas the two cost-constrained scenarios do employ this test. Hence, for the Low-Growth and High-Growth scenarios, any increase in capital costs (without a similar increase in the value of transit benefits) results in lower benefit-cost ratios and the failure of some investments to pass this test. For these latter two scenarios, a 25-percent increase in capital costs would yield roughly a 13- to 14-percent increase in needs that pass TERM's benefit-cost test.

Exhibit 9-6 ■ Impact of an Increase in Capital Costs on Transit Investment Estimates by Scenario

Capital Cost Increases	SGR Benchmark		Low-Growth Scenario		High-Growth Scenario	
	Billions of 2016 Dollars	Percent Change from Baseline	Billions of 2016 Dollars	Percent Change from Baseline	Billions of 2016 Dollars	Percent Change from Baseline
Baseline (No Change)	$18.1		$23.2		$24.7	
Increase Costs by 25%	$22.6	25%	$26.5	14%	$28.0	13%

Source: Transit Economic Requirements Model.

Changes in the Value of Time

The most significant source of transit investment benefits, as assessed by TERM's BCA, is the net cost savings to users of transit services, a key component of which is the value of travel time savings. Therefore, the per-hour value of travel time for transit riders is a key model input and a key driver of total investment benefits for those scenarios that use TERM's benefit-cost test. Readers interested in learning more about the measurement and use of the value of time for the BCAs performed by TERM, the Highway Economic Requirements System (HERS), and the National Bridge Investment Analysis System (NBIAS) should refer to the related discussion presented earlier in the highway section of this chapter.

For this C&P Report, the Low-Growth and High-Growth scenarios are the only scenarios with investment needs estimates that are sensitive to changes in the benefit-cost ratio. (Note that the Sustain Recent Spending scenario uses TERM's estimated benefit-cost ratios to allocate fixed levels of funding to preferred investments, whereas the computation of the SGR benchmark does not.)

Exhibit 9-7 shows the effect of varying the value of time on the needs estimates of the Low-Growth and High-Growth scenarios. TERM applies this amount to all in-vehicle travel, but then doubles it to $25.60 per hour when accounting for out-of-vehicle travel time, including time spent waiting at transit stops and stations. This multiplier reflects the observation that people view time in a transit vehicle as productive, whereas time spent waiting is viewed as "wasted."

Exhibit 9-7 ■ Impact of Alternative Value of Time Rates on Transit Investment Estimates by Scenario

Changes in Value of Time	Low-Growth Scenario		High-Growth Scenario	
	Billions of 2016 Dollars	Percent Change from Baseline	Billions of 2016 Dollars	Percent Change from Baseline
Reduce by 50% ($6.8)	$20.6	-11%	$22.1	-13%
Baseline ($13.6)	$23.2		$25.3	
Increase by 100% ($27.2)	$24.7	6%	$26.9	6%

Source: Transit Economic Requirements Model.

Given that value of time is a key driver of total investment benefits, doubling or halving this variable leads to changes in investment ranging from an increase of roughly 8 percent to a decrease of about 14 percent. The High-Growth scenario appears to be more sensitive to the value of time than the Low-Growth scenario. This is because the High-Growth scenario is associated with higher investment levels than is the Low-Growth scenario, so any changes in the value of time will be magnified accordingly.

Changes to the Discount Rate

TERM's benefit-cost module uses a discount rate of 7.0 percent, in accordance with guidance provided in OMB Circular A-94. Readers interested in learning more about the selection and use of discount rates for the BCAs performed by TERM, HERS, and NBIAS should refer to the related discussion presented earlier in the highway section of this chapter. For this sensitivity analysis, and for consistency with the discussion earlier on HERS and NBIAS discount rate sensitivity, TERM's needs estimates for the Low-Growth and High-Growth scenarios were re-estimated using a 3-percent discount rate. The results of this analysis, presented in *Exhibit 9-8*, show that this lower discount rate leads to a range in total investment needs (or changes in the proportion of needs passing TERM's benefit-cost test) amounting to a 1-percent increase.

Exhibit 9-8 ■ Impact of Alternative Discount Rates on Transit Investment Estimates by Scenario

	Low-Growth Scenario		High-Growth Scenario	
Discount Rates	Billions of 2016 Dollars	Percent Change from Baseline	Billions of 2016 Dollars	Percent Change from Baseline
7% (Baseline)	$23.2		$24.7	
3%	$23.4	1%	$25.0	1%

Source: Transit Economic Requirements Model.

Under this sensitivity test, investment needs are higher for the lower discount rate (3 percent) compared with the higher base rate (7 percent). This means that use of the lower rate allows more investments to pass TERM's benefit-cost test. This situation is primarily the result of differences in the timing of the flows of benefits vs. costs for the underlying scenario. Specifically, this test uses a fully (financially) unconstrained scenario that completely eliminates the large investment backlog at the start of the period of analysis and then invests incrementally as needed at a much lower rate to maintain this "SGR" for the remaining 20 years of analysis. In contrast, investment benefits tend to be more evenly distributed throughout the 20-year period of analysis. So, with a high proportion of costs concentrated very early in the period of analysis and evenly distributed benefits, the ratio of discounted benefits to discounted costs tends to decline as the discount rate increases.

No Ridership Growth

This analysis considers the impact of setting the level of ridership growth to 0 percent for both the Low- and High-Growth scenarios. This change effectively makes these two scenarios equivalent and limits scenario analysis to an assessment of 20-year reinvestment costs for existing transit assets. By definition, the SGR benchmark only considers reinvestment in existing transit assets and hence already assumes 0 percent ridership growth. In addition, the SGR benchmark, unlike the Low- and High-Growth scenarios, does not apply TERM's benefit-cost test.

The impact of reducing ridership growth to 0 percent is shown in Exhibit 9-9. As expected, there is no change in cost for the SGR benchmark. In contrast, the annual total cost of the Low- and High-Growth scenarios both decline to $16.6 billion (as both scenarios now assume the same 0-percent grow rate). Note further that the $16.6 billion annual cost of the Low- and High-Growth scenarios is less than the $18.1 billion for the SGR benchmark, as the latter does not apply TERM's benefit-cost scenario.

Exhibit 9-9 ■ Impact of 0% Rider Growth on Transit Investment Estimates by Scenario

	SGR Benchmark		Low-Growth Scenario		High-Growth Scenario	
No Ridership Growth	Billions of 2016 Dollars	Percent Change from Baseline	Billions of 2016 Dollars	Percent Change from Baseline	Billions of 2016 Dollars	Percent Change from Baseline
Baseline (No Change)	$18.1		$23.2		$24.7	
0% Ridership Growth	$18.1	0%	$16.6	-28%	$16.6	-33%

Source: Transit Economic Requirements Model.

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