CHAPTER 10

Sensitivity Analysis

Highway Sensitivity Analysis

In any modeling effort, it is critical to evaluate the validity of the underlying assumptions and determine the degree to which projected outcomes could be affected by changes to these assumptions. This section demonstrates how the average annual highway investment requirements associated with the **Maintain Conditions and Performance** scenario and the **Improve Conditions and Performance** scenario presented in Chapter 8 would be affected by changes in some of the underlying assumptions in the Highway Economic Requirements System (HERS) and the National Bridge Investment Analysis System (NBIAS). To simplify the presentation of results, these sensitivity tests were applied only to the systemwide versions of these scenarios based on HPMS-derived future growth in vehicle miles traveled (VMT), rather than to the full range of subscenarios presented in Chapter 8.

This section begins with sensitivity tests on economic inputs to the models, varying the assumptions about the value that travelers attach to travel time and crash risk, and the discount rate used to convert future costs and benefits into present equivalents. The effects of assuming growth in the value of travel time and price of fuel are also discussed. This is followed by tests relating to investment strategies, including the impact of applying some alternative Maintenance, Repair, and Rehabilitation (MR&R) strategies built into NBIAS, and the impact of alternative assumptions about future Operations/Intelligent Transportation System (ITS) deployment strategies in HERS. A subsequent section within this chapter explores information regarding the assumptions underlying the analyses developed using the Transit Economic Requirements Model (TERM).

Alternative Economic Analysis Assumptions

The U.S. Department of Transportation (DOT) periodically issues guidance on the valuation of travel time and the economic value of a statistical life, while the Office of Management and Budget (OMB) provides guidance to Federal agencies on the discount rate to be applied in benefit-cost analysis. 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 Chapter 7 and 8 of this report are based on the primary recommendations from the OMB and U.S. DOT guidance for these economic inputs, whereas the analyses presented in this chapter rely on recommended alternative values to be used for sensitivity testing.

The HERS analyses presented in Chapter 7 and 8 assume future changes in fuel prices consistent with forecasts from the U.S. Department of Energy's Annual Energy Outlook (AEO) publication. This publication presents a range of potential alternative forecasts. One such alternative assuming higher fuel prices is explored in this section.

Value of Travel Time

The value of travel time is a critical component of benefit-cost analysis of transportation investments. It is often the largest component of the benefits estimated. 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. There is much debate on the appropriate value of travel time. Studies show that the value of time can vary by income, time of day and type of trip. The U.S. DOT's *Revised Departmental Guidance on the Value of Travel Time in Economic Analysis, 2011* recommends values of time to use for economic analysis developed from the findings of current research and the values used in other countries (see http://www.dot.gov/sites/dot.dev/files/docs/vot_guidance_092811c_0.pdf). The value of time is tied to specified percentages of the median annual household income for personal travel and the median gross wage for business travel, which vary

Why conduct a sensitivity analysis for the assumed value of travel time savings?

Sensitivity analysis is done to test the results of models using information that is uncertain, such as the value of travel time saved.

The U.S. DOT based its guidance for valuing travel time on a review of the research literature, which reflects estimates that vary widely even after attempts to standardize them. Particularly for personal travel (including commuting), the evidence is hard to synthesize. Internationally, common practice among transportation government agencies is to assume that the average value of personal travel time bears a fixed ratio to a measure of economy-wide average wages (or some similar measure).

For local personal travel, the value of travel time savings is estimated to be 50 percent of hourly median household income, derived by dividing the nationwide median annual household income by 2,080 hours to yield an hourly income. For business travel, the value of travel time savings is assumed to be equal to a nationwide median gross wage, defined as the sum of the median hourly wage and estimated hourly benefits.

The U.S. DOT recognizes the uncertainty in the recommended values and therefore recommends that alternative calculations be done using the range of high and low dollar values. For personal auto travel, the low value is 35 percent of the estimated hourly median household income and the high value is about 60 percent. For business travel, 80 percent of the median wage is used for the low dollar value and 120 percent is used for the high value.

depending on the mode of travel. Within the HERS and NBIAS models, the per-person-hour estimates of travel time savings based on this guidance are converted to average values of time per vehicle-hour for different types of vehicle classes, drawing upon estimates of average vehicle occupancy; time-related vehicle depreciation cost; and, for trucks, the inventory cost of freight in transit. For 2010, the average values per vehicle-hour ranged from $16.89 for small autos to $31.44 for five-axle combination trucks. (For the passenger vehicle classes, the averages are weighted means of a value for personal travel and a higher value for business travel.) The U.S. DOT guidance recommends sensitivity analyses using a lower and a higher value of travel time savings given the uncertainty of the values recommended; these alternative values are based on different valuations of travel time savings per person hour as a percentage of hourly earnings. *Exhibit 10-1* shows the results of applying these alternative travel time values to the average annual investment levels

Exhibit 10-1 Impact of Alternative Value of Time Assumptions on Highway Investment Scenario Average Annual Investment Levels

Alternative Assumptions About the Valuation of Travel Time Savings per Hour as a Percentage of Hourly Earnings, for Personal and Business Travel	Maintain Conditions and Performance Scenario		Improve Conditions and Performance Scenario	
	Billions of 2010 Dollars	Percent Change From Baseline	Billions of 2010 Dollars	Percent Change From Baseline
Baseline* (Personal–50%; Business–100%)	**$86.3**		**$145.9**	
HERS-Derived Component	$51.1		$86.9	
NBIAS-Derived Component	$12.2		$20.2	
Other (Non-modeled) Component	$23.0		$38.8	
Lower (Personal–35%; Business–80%)	**$89.2**	**3.3%**	**$134.9**	**-7.6%**
HERS-Derived Component	$53.2	4.0%	$78.9	-9.2%
NBIAS-Derived Component	$12.2	0.4%	$20.1	-0.5%
Other (Nonmodeled) Component	$23.7	3.3%	$35.9	-7.6%
Higher (Personal–60%; Business–120%)	**$84.9**	**-1.6%**	**$153.3**	**5.1%**
HERS-Derived Component	$50.1	-2.0%	$92.3	6.2%
NBIAS-Derived Component	$12.2	0.1%	$20.2	0.1%
Other (Nonmodeled) Component	$22.6	-1.6%	$40.8	5.1%

** The Baseline levels shown correspond to the systemwide scenarios presented in Chapter 8 that applied higher, HPMS-derived VMT growth forecasts. The investment levels shown are average annual values for the period from 2011 through 2030.*

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

associated with the **Maintain Conditions and Performance** scenario and the **Improve Conditions and Performance** scenario. Results are shown separately for the portions of these scenarios derived from HERS and NBIAS because their sensitivity to these inputs is very different. As discussed in Chapter 8, each scenario includes non-modeled investment components reflecting types of investments not modeled in HERS or NBIAS, which varies proportionally based on the model results.

Non-modeled 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 non-modeled component corresponds to system enhancement spending, plus pavement rehabilitation and capacity expansion on roads not classified as Federal-aid highways.

In the **Sustain 2010 Spending** scenario presented in Chapter 8, the values for these HERS and NBIAS components sum to $72.5 billion. In 2010, non-modeled spending accounted for 26.6 percent of total investment ($26.7 billion out of $100.2 billion) and is assumed to form the same share in all scenarios presented in Chapter 8.

Similarly for the sensitivity analysis for the **Maintain Condition and Performance** scenario and the **Improve Condition and Performance** scenario presented in this section, the non-modeled component is set at 26.6 percent of the total investment level. As the combined levels of the HERS-derived and NBIAS-derived scenario components rise or fall, the non-modeled component changes proportionally. Consequently, the percent change in the non-modeled component of each alternative scenario relative to the baseline always matches the percent change in the total investment level for that scenario.

Impact on Improve Conditions and Performance Scenario

As shown in *Exhibit 10-1*, applying a lower value of travel time reduces the average annual investment level for the **Improve Conditions and Performance** scenario from $145.9 billion to $134.9 billion (-7.6 percent). The HERS-derived component of the scenario declines by 9.0 percent from $86.9 billion to $78.9 billion, whereas the NBIAS-derived component declines by only 0.5 percent. Applying a higher value of time would increase the average annual investment level associated with this scenario by 5.5 percent in total, again with HERS investments being more sensitive, increasing by 6.2 percent.

The HERS investments are more sensitive to the value of travel time savings because the HERS model evaluates a mix of system rehabilitation and system expansion investments, and system expansion investments tend to be more sensitive to changes in travel time savings. NBIAS only considers system rehabilitation investments, which tend to have a much smaller impact on travel time, except to the extent that they address situations where weight restrictions had been imposed on a bridge requiring long detours for trucks.

As described in Chapter 8, the **Improve Conditions and Performance** scenario is defined to include all investments that would be cost-beneficial (i.e., with a benefit-cost ratio [BCR] greater than or equal to 1.00). The change in the value of travel time saved affects the benefits estimated. A reduction in the value of travel time saved is likely to reduce the magnitude of the benefits estimated from the time savings, thus reducing the BCR for individual projects under consideration. To the extent that the estimated BCR for some of these projects falls below 1.00, they would no longer qualify for inclusion under this scenario. Conversely, applying a higher value of time increases the estimated benefits and, hence, the BCR, causing more projects to appear to be cost-beneficial.

Impact on Maintain Conditions and Performance Scenario

As described in Chapter 8, the **Maintain Conditions and Performance** scenario is intended to keep overall system conditions and performance in 2030 at roughly the same level as in 2010. The NBIAS-derived portion of this scenario is based on maintaining the average bridge sufficiency rating (see Chapter 7 for a discussion of this measure). The HERS-derived portion represents the average of two investment levels: (1) the amount of total HERS investment in system rehabilitation and system expansion that results in average pavement roughness (as measured by the International Roughness Index [IRI]) being maintained; and (2) an investment level which results in average delay per VMT being maintained. Generally, this approach results in one of these two indicators (IRI in the baseline analysis) improving a little over the 20-year period, while the other (delay in the baseline analysis) gets a little worse.

For the **Maintain Condition and Performance** scenario, applying a lower value of travel time savings increases the average annual investment level for HERS-derived component by 4.0 percent, from $51.1 billion to $53.2 billion. This change is primarily driven by changes in the mix of investments selected by HERS; reducing the value of time makes capacity projects less attractive, so that HERS will direct a greater share of investment towards pavement rehabilitation. This has the effect of reducing the level of total HERS investment required to maintain average pavement roughness, while increasing the level of total HERS investment required to maintain average delay. In this case, these changes were not proportional, causing the average of these two HERS investment levels to rise. The opposite is true applying a higher value of travel time savings, which brings the investment level associated with maintaining average pavement roughness closer to the investment level associated with maintaining average delay, and reduces their average by 2.0 percent relative to the baseline.

The NBIAS-derived component of the **Maintain Condition and Performance** scenario rounds to $12.2 billion regardless of which set of travel time assumptions is applied. The overall investment level associated with this scenario would increase by 3.3 percent, from $86.3 billion to $89.2 billion, assuming a lower value of time, and decline by 1.6 percent to $84.9 billion assuming a higher value of time.

Growth in the Value of Time

Benefit cost analysis is generally done in constant base year dollars, assuming no change in the value of the parameters used in the analysis. The implicit assumption of this approach is that all values will experience the same rate of growth in the future, therefore not changing the relative values. U.S. DOT guidance recommended value for travel time savings is based on the median national gross hourly wage for business travel and the median hourly household income for personal travel. The guidance also recognizes the need to increase the value of travel time savings in line with the growth in income adjusted for inflation. It assumes income elasticity equal to one for scaling the value of travel time savings, based on time series estimates of income elasticity. The recommendation is that the value of travel time savings increases annually by 1.6 percent based on Congressional Budget Office assumption of future annual growth in real median household income.

This poses a few challenges on how to appropriately include the increase in the real value of time. The value of time will affect both the demand for travel and the value of the benefits estimated. Since the real value of time increases due to an increase in income, this would increase the demand for travel given income elasticity of demand for travel, possibly in addition to the other changes. However, as HERS is currently configured, the base year value of time is factored into the implicit baseline price that the model assumes is consistent with the HPMS-derived VMT growth forecast. If the value of time is increased over time, the HERS model will interpret the resulting increase in travel time costs relative to the base year the same way it would if this increase in costs were related to increased congestion. Consequently, the travel demand elasticity feature in HERS will cause some of the HPMS-derived future VMT growth to be suppressed.

What are some examples of the types of behavior that the travel demand elasticity features in HERS represent?

Q&A

If highway congestion worsens in an area, this increases travel time costs on the road network. In response, some highway users might shift their trips to mass transit or perhaps forgo some personal trips that they might ordinarily make. For example, they might be more likely to combine multiple errands into a single trip because the time spent in traffic discourages them from making a trip unless it is absolutely necessary. Increases in fuel prices also increase the cost of driving and would have a similar impact.

In the longer term, people might make additional adjustments to their lifestyles in response to changes in user costs that would impact their travel demand. For example, if travel time in an area is reduced substantially for an extended period of time, some people may make different choices about where to purchase a home. If congestion is reduced, purchasing a home far out in the suburbs might become more attractive because commuters would be able to travel farther in a shorter period of time.

Exhibit 10-2 illustrates the effect of including an increase in the real value of time in HERS as it is currently configured. Under the **Improve Conditions and Performance** scenario, the growth in the value of time increases the HERS-modeled component of the average annual investment level from $86.9 billion to $87.7 billion, a 0.9 percent change. Projected 2030 Federal-aid highway VMT would be 3.544 trillion under this alternative, rather than the 3.629 trillion predicted for 2030 in the baseline analysis. The reduction in travel demand reduces the net time savings and pavement improvements resulting from the investments, while the value of time estimate increases. The two countervailing impacts have a very small effect on the estimated benefits, and hence the resulting investment needs.

Exhibit 10-2 Impact of Alternative Assumptions About Growth in the Real Value of Time on Highway Investment Scenario Average Annual Investment Levels

Alternative Assumptions About Growth in Value of Time in Response to Projected Increases in Real Median Household Income	Maintain Conditions and Performance Scenario		Improve Conditions and Performance Scenario	
	Billions of 2010 Dollars	Percent Change From Baseline	Billions of 2010 Dollars	Percent Change From Baseline
Baseline* (No change)	**$86.3**		**$145.9**	
HERS-Derived Component	$51.1		$86.9	
Alternative (1.6 % increase per year)	**$77.8**	**-9.8%**	**$147.0**	**0.8%**
HERS-Derived Component	$44.9	-12.2%	$87.7	0.9%

** The Baseline levels shown correspond to the systemwide scenarios presented in Chapter 8 that applied higher, HPMS-derived VMT growth forecasts. The investment levels shown are average annual values for the period from 2011 through 2030.*

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

For the **Maintain Conditions and Performance** scenario, the average annual investment level associated with the HERS-derived component would fall from $51.1 billion to $44.9 billion under this alternative, a 12.2 percent decline. The investment associated both with maintaining average pavement roughness and average delay per VMT would be lower under this alternative—projected 2030 Federal-aid highway VMT would be 3.489 trillion, down from 3.584 trillion in the baseline analysis. The increased value of time tends to increase the BCR associated with some projects, which has an impact on the prioritized ranking of potential projects, but this effect is swamped by the HERS perception that any increase in travel time costs equates to a higher implicit price and, consequently, less travel.

The initial plans for this report had been to factor in an increasing value of time into the baseline analysis, as directed by U.S. DOT guidance. However, as a result of HERS testing similar to that presented above, this increased value was not included in the analysis for this report, and instead to work on alternative approaches that would better capture the impacts of higher incomes without unintentionally suppressing travel growth. The NBIAS model does not currently have the capability to process changes to the value of time during its analysis period.

Value of a Statistical Life

One of the most challenging issues in benefit-cost analysis is how to best determine the monetary cost to place on injuries of various severities. Few people would consider any amount of money to be adequate compensation for a person being seriously injured, much less killed. On the other hand, people can attach a value to changes in their risk of suffering an injury, and indeed such valuations are implicit in their everyday choices. For example, a traveler may face a choice between two travel options that are equivalent except that one carries a lower risk of fatal injury but costs more. If the additional cost is $1, then a traveler who selects the safer option is manifestly willing to pay at least $1 for the added safety—what economists call "revealed preference." Moreover, if the difference in risk is, say, one in a million, then a million travelers who select the safer option are collectively willing to pay at least $1 million for a risk reduction that statistically can be expected to save one of their lives. In this sense, the "value of a statistical life" among this population is at least $1 million.

Based on the results of various studies of individual choices involving money versus safety trade-offs, some government agencies estimate an average value of a statistical life (VSL) for use in their regulatory and investment analyses. The U.S. DOT issued guidance in 2008 (Revised Departmental Guidance: Treatment of the Value of Preventing Fatalities and Injuries in Preparing Economic Analyses) recommending a value of $5.8 million per statistical life, to be updated annually by the changes in prices and income. The 2010 inflated VSL is $6.2 million. (Subsequent to the analysis undertaken for this report, guidance issued by the DOT in 2013 increased the VSL to $9.1 million for analyses with a base year of 2012 [Guidance on Treatment of the Economic Value of a Statistical Life in U.S. Department of Transportation Analyses, http://www.dot.gov/office-policy/transportation-policy/guidance-treatment-economic-value-statistical-life].) For nonfatal injuries, the DOT retained from its 1993 guidance the practice of setting values per statistical injury as percentages of the value of a statistical life; these vary according to the level of severity, from 0.2 percent for a "minor" injury to 76.3 percent for a "critical" injury. (The injury levels are from the Maximum Abbreviated Injury Scale.) In view of the uncertainty surrounding the average value of a statistical life, the Department also required that regulatory and investments analyses include sensitivity tests using alternative values; alternative values of $3.4 million as the lower bound and $9.0 million as the upper bound are presented.

Impact of Alternatives on HERS Results

The HERS model contains for each highway functional class equations to predict crash rates per VMT and parameters to determine the number of fatalities and nonfatal injuries per crash. The model assigns to crashes involving fatalities and other injuries an average cost consistent with the guidance in the U.S. DOT memorandum. *Exhibit 10-3* demonstrates that the results from the HERS simulations are nevertheless relatively insensitive to the use of alternative values of a statistical life. This is consistent with the observations from Chapter 7 that crash costs: (1) form a small share of highway user cost (13.6 percent in 2010); and (2) are much less sensitive than travel time and vehicle operating costs to changes in the level of total investment within the scope of HERS, which excludes targeted safety-oriented investments due to data limitations. Replacing the baseline value of a statistical life with a figure of $9.0 million slightly raises the BCR for potential improvements and increases the estimate of the amount of potentially cost-beneficial investment (the HERS component of the **Improve Conditions and Performance** scenario) by 0.9 percent, from $86.9 billion to $87.7 billion. Conversely, assuming a value of statistical life of $3.4 million would reduce the average annual investment level associated with the HERS-derived component of the scenario by 0.7 percent.

For the **Maintain Conditions and Performance** scenario, increasing (to $9.0 million) or lowering (to $3.4 million) the average value of a statistical life would change the average annual investment level by negative 0.8 percent or positive 0.5 percent respectively.

Exhibit 10-3 Impact of Alternative Value of Life Assumptions on Highway Investment Scenario Average Annual Investment Levels

Alternative Value of a Statistical Life Assumption, in 2010 Dollars	Maintain Conditions and Performance Scenario		Improve Conditions and Performance Scenario	
	Billions of 2010 Dollars	Percent Change From Baseline	Billions of 2010 Dollars	Percent Change From Baseline
Baseline* ($6.2 Million)	**$86.3**		**$145.9**	
HERS-Derived Component	$51.1		$86.9	
NBIAS-Derived Component	$12.2		$20.2	
Other (Non-modeled) Component	$23.0		$38.8	
Lower ($3.4 Million)	**$84.5**	**-2.1%**	**$142.4**	**-2.4%**
HERS-Derived Component	$50.7	-0.8%	$86.3	-0.7%
NBIAS-Derived Component	$11.3	-7.6%	$18.2	-9.8%
Other (Non-modeled) Component	$22.5	-2.1%	$37.9	-2.4%
Higher ($9.0 Million)	**$87.7**	**1.7%**	**$148.9**	**2.0%**
HERS-Derived Component	$51.4	0.5%	$87.7	0.9%
NBIAS-Derived Component	$13.0	6.5%	$21.5	6.7%
Other (Non-modeled) Component	$23.4	1.7%	$39.6	2.0%

** The Baseline levels shown correspond to the systemwide scenarios presented in Chapter 8 that applied higher, HPMS-derived VMT growth forecasts. The investment levels shown are average annual values for the period from 2011 through 2030.*

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

Impact of Alternatives on NBIAS Results

Exhibit 10-3 also shows that increasing the assumed value of a statistical life to $9.0 million raises the NBIAS estimate of the average annual investment in bridges that would be needed over the following 20 years to fund all cost-beneficial projects by 2030 (the NBIAS component of the **Improve Conditions and Performance** scenario) by 6.7 percent, from $20.2 billion to $21.5 billion. Assuming a higher value of life increases the benefits associated with projects that reduce crash rates, causing additional projects to have a BCR above 1.0. Conversely, reducing the statistical value of life to $3.4 million reduces the NBIAS-derived component of the **Improve Conditions and Performance** scenario by 9.8 percent, indicating that there are a number of projects with BCRs not far above 1.0 in the baseline analysis that derived benefits from reducing crash rates.

At any given level of investment, increasing the value of statistical life shifts investment toward producing significant safety benefits to bridge users (by reducing crash rates) and away from projects that may be more focused on addressing issues with the physical conditions of bridges. Consequently, the overall level of NBIAS investment associated with maintaining the average bridge sufficiency rating is 6.5 percent higher ($13.0 billion versus $12.2 billion per year) assuming a $9.0 million value of a statistical life than in the baseline analysis. Assuming a $3.4 million value of a statistical life reduces the average annual NBIAS-derived component of the **Maintain Conditions and Performance** scenario by 7.6 percent, because a greater share of this spending is directed towards projects that would more directly impact the sufficiency rating.

Discount Rate

Benefit-cost analyses use a discount rate that scales down benefits and costs arising in the future relative to those arising in the base year. To this point, the real discount rate has been 7 percent in this report's applications of HERS, NBIAS, and TERM; 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 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 public investment and regulatory programs. Subsequently, in 2003, OMB's Circular A-4 recommended that

Could the discount rate be higher than 7 percent?

The 2003 OMB guidance calls for the use of a discount rate higher than 7 percent as a further sensitivity test in some instances. In the context of public investment, this recommendation applies when there is a fair likelihood that: (1) much of the investment's opportunity cost will take the form of crowding out private investment, and (2) the displaced investment would have generated an average real rate of return exceeding 7 percent annually. Although the first of these conditions could be valid for some public investments in highways and transit systems, the expectation that displaced private investments will average rates of return above 7 percent annually could be difficult to justify. In 2003, the OMB referred to its own recent estimate that the average real rate of return on private investment remained near the 7 percent that the OMB had estimated in 1992. Although the OMB also noted that the average real rate of return on corporate capital in the United States was approximately 10 percent in the 1990s, it is by no means clear whether the current economic outlook could justify the expectation of a rate of return averaging above 7 percent during this report's analysis period.

regulatory analyses use both 3 percent and 7 percent as alternative discount rates (http://www.whitehouse.gov/sites/default/files/omb/assets/omb/circulars/a004/a-4.pdf). The justifications for these recommendations apply equally 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.

Alternative Discount Rates—HERS

When the goal is to select all cost-beneficial improvements, as is the case for the **Improve Conditions and Performance** scenario, changing the discount rate from 7 percent to 3 percent increases the amount of investment in HERS programs by 21.6 percent, with the annual average amount increasing from $86.9 billion to $105.7 billion over the period from 2011 to 2030 *Exhibit 10-4*). This increase in investment dollars results in more favorable projections for highway conditions and performance in 2030. The lowering of the discount rate improves the projection for average pavement roughness by 5.8 percentage points (from a 26.4 percent reduction to a 32.2 percent reduction) and average delay by 3.7 percentage points (from an 8.0 percent reduction to an 11.7 percent reduction).

In addition to increasing the amount of investment that can be economically justified, the reduction in assumed discount rate shifts the HERS allocation of any given investment, in particular toward improvements that produce relatively long streams of future benefits. This shift in investment patterns would result in a small (2.7 percent) increase in the HERS-derived component of the **Maintain Conditions and Performance** scenario.

Exhibit 10-4 Impact of Alternative Discount Rate Assumption 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 2010 Dollars	Percent Change From Baseline	Billions of 2010 Dollars	Percent Change From Baseline
Baseline* (7% discount rate)	**$86.3**		**$145.9**	
HERS-Derived Component	$51.1		$86.9	
NBIAS-Derived Component	$12.2		$20.2	
Other (Non-modeled) Component	$23.0		$38.8	
Alternative (3% discount rate)	**$88.1**	**2.1%**	**$177.3**	**21.5%**
HERS-Derived Component	$52.5	2.7%	$105.7	21.6%
NBIAS-Derived Component	$12.2	-0.3%	$24.4	20.7%
Other (Non-modeled) Component	$23.5	2.1%	$47.2	21.5%

** The Baseline levels shown correspond to the systemwide scenarios presented in Chapter 8 that applied higher, HPMS-derived VMT growth forecasts. The investment levels shown are average annual values for the period from 2011 through 2030.*

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

Alternative Discount Rates—NBIAS

Since many of the bridge improvements evaluated in NBIAS are relatively long-lived, the choice of discount rate can significantly affect the model's estimate of investments necessary to maintain or improve the condition and performance of the system. Reducing the discount rate increases the number of potential investments that pass the benefit cost test. *Exhibit 10-4* shows that reducing the real discount rate in NBIAS from the baseline 7 percent to 3 percent would increase the NBIAS-derived component of the **Improve Conditions and Performance** scenario by 20.7 percent, from $20.2 billion to $24.4 billion, annually.

For the maintain scenario, the BCR is not the limiting factor or the goal. Many projects that pass the benefit test will not be included under the maintain scenario, so increasing the number of eligible projects does not significantly affect the needs estimated. The change in discount rate would change the composition of investments implemented in NBIAS, which would result in a 0.3 percent reduction in the NBIAS-derived component for the **Maintain Conditions and Performance** scenario.

Alternative Future Fuel Price Assumptions

In this edition of the C&P report, the price of oil used in the baseline analyses presented in Chapters 7 and 8 is the AEO reference forecast. This is a change from the 2010 C&P report where price of oil was held constant at the base year level. From 2008 to 2010 the price of fuel (both gasoline and diesel) declined by 38.5 percent. AEO projects oil prices to increase above the rate of inflation and anticipates that, after recovering in 2011, fuel prices will ease up for a few years and then start to increase above the rate of inflation, resulting in an increase of 28.2 percent over the first 5 years of the C&P analysis period, and a 45.0 percent increase over the 20-year period.

The sensitivity analysis presented in *Exhibit 10-5* compares the changes in investment needs using AEO's projections assuming a more aggressive rate of growth in prices. Under this projection, the oil prices continue to increase, resulting in 93.1 percent growth in the first 5 years, with a total increase of 162.6 percent over the 20-year period. *Exhibit 10-5* shows the results of using a more aggressive rate of growth in oil prices. For the **Improve Conditions and Performance** scenario, the average annual investment level would decline by 14.7 percent, driven by a decline in the HERS-modeled component of 18.1 percent. For the **Maintain Conditions and Performance** scenario, the average annual investment level would decline from $86.3 billion to $72.8 billion, a reduction of 15.7 percent, driven by a decline in the HERS-modeled component of 19.4 percent. Under both scenarios, the reduction in investments results primarily from reduced spending on system expansion. This sensitivity test was not applied to NBIAS, as it does not include fuel prices as a separate discrete model input.

Exhibit 10-5 Impact of Alternative Future Fuel Price Assumption on Highway Investment Scenario Average Annual Investment Levels

Alternative Assumptions About Future Fuel Prices	Maintain Conditions and Performance Scenario		Improve Conditions and Performance Scenario	
	Billions of 2010 Dollars	Percent Change From Baseline	Billions of 2010 Dollars	Percent Change From Baseline
Baseline* (AEO Reference Case)	**$86.3**		**$145.9**	
HERS-Derived Component	$51.1		$86.9	
Alternative (AEO High Oil Price Case)	**$72.8**	**-15.7%**	**$124.5**	**-14.7%**
HERS-Derived Component	$41.2	-19.4%	$71.2	-18.1%

** The Baseline levels shown correspond to the systemwide scenarios presented in Chapter 8 that applied higher, HPMS-derived VMT growth forecasts. The investment levels shown are average annual values for the period from 2011 through 2030.*

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

Assuming a higher rate of growth in oil prices increases the user costs by increasing the cost of driving. As discussed in Chapter 7, an increase in user costs lead to reduced miles of travel. Under the **Maintain Conditions and Performance** scenario, projected 2030 VMT on Federal-aid highways would be 8.1 percent lower (3.293 trillion vs. 3.584 trillion) relative to the baseline assumption. Under the **Improve Conditions and Performance** scenario, VMT would be 8.2 percent lower assuming higher fuel prices than in the baseline.

Alternative Strategies

In addition to analyses based on alternative technical assumptions, the HERS and NBIAS models are capable of analyzing selected policy alternatives as well. Two such alternatives pertain to strategies for bridge MR&R (modeled in NBIAS), and accelerating the future rate of deployment of Operations/ITS strategies.

Alternative Bridge Maintenance, Repair, and Rehabilitation Strategies

As discussed in Appendix B, the NBIAS model has been adapted to consider four alternative strategies for the MR&R actions simulated in NBIAS. The State of Good Repair MR&R strategy is the most aggressive, and seeks to bring all bridges to a relatively high condition level that can be sustained via ongoing investment, and involves heavy frontloading of MR&R spending. The Sustain Steady State MR&R strategy is somewhat less aggressive, and is aimed toward identifying and implementing a pattern of MR&R improvements that would reach and achieve an improved steady state in terms of overall bridge system conditions without frontloading MR&R investment. The Maximize Average Returns strategy is even less aggressive, seeking to maximize the degree of bridge system performance improved per dollar of MR&R expenditure. The least aggressive alternative is the Minimize MR&R Costs strategy, which seeks to minimize MR&R costs only, without regard to the implications for other types of NBIAS-modeled spending. The baseline analyses presented in Chapters 7 and 8 applied the Sustain Steady State MR&R strategy; previous C&P reports relied on the Minimize MR&R Costs strategy.

As discussed in Chapter 7, the NBIAS model considers bridge deficiencies at the level of individual bridge elements based on engineering criteria and computes an initial value for the cost of a set of corrective actions that would address all such deficiencies. The economic bridge investment backlog represents the combined cost of these corrective actions in those cases where NBIAS estimates that it would be cost-beneficial to implement them. Assuming the Sustain Steady State MR&R strategy, the economic backlog for year 2010, as reported in Chapter 7, was estimated to be $106.4 billion. *Exhibit 10-6* shows that, if less-aggressive MR&R strategies are assumed, the size of the initial backlog would be smaller. Reducing the set of MR&R actions considered results in an estimated 2010 backlog of $93.4 billion assuming the Minimize MR&R Costs strategy and $100.8 assuming the Maximize Average Return strategy. Assuming the more aggressive State of Good Repair MR&R strategy would increase the 2010 backlog computed by NBIAS to $114.3 billion.

Although the Minimize MR&R Costs strategy has the lowest initial backlog from among the four alternatives, the average annual investment level associated with implementing all cost-beneficial NBIAS modeled investment within the **Improve Conditions and Performance** scenario is $31.6 billion, 56.3 percent higher than the $20.2 billion level estimated in the baseline. Even this level of investment is insufficient to maintain the average sufficiency rating at its 2010 level of 81.7 on a scale of zero to 100; the projected average sufficiency rating for 2030 would be only 75.4. Thus, it is not possible to achieve the objective of the **Maintain Conditions and Performance** scenario assuming a Minimize MR&R Cost strategy. The implications of these findings are that skimping on MR&R spending in the short term may make it necessary to conduct major bridge rehabilitation actions or bridge replacements sooner than would have been the case had MR&R spending been more robust.

Exhibit 10-6 shows similar results when the Maximize Average Returns MR&R strategy is applied. The criteria for the **Maintain Conditions and Performance** scenario cannot be met. Applying this strategy results in an average annual investment level of $31.7 billion for the NBIAS-derived component of the **Improve Conditions and Performance** scenario.

Exhibit 10-6 Impact of Alternative Bridge Maintenance, Repair, and Rehabilitation Strategies on the Economic Bridge Investment Backlog and Future Capital Investment Scenarios

Alternative Maintenance, Repair, and Rehabilitation (MR&R) Strategies	2010 Economic Bridge Investment Backlog[1]	Average Annual Highway Capital Investment, 2011 Through 2030 (Billions of 2010 Dollars)			
		Maintain Conditions and Performance Scenario[2]		Improve Conditions and Performance Scenario	
		NBIAS-Modeled	Total	NBIAS-Modeled	Total
Sustain Steady State (2013 C&P Baseline)	**$106.4**	**$12.2**	**$86.3**	**$20.2**	**$145.9**
Minimize MR&R Costs (2010 C&P Baseline)	$93.4	N/A	N/A	$31.6	$161.4
Maximize Average Returns	$100.8	N/A	N/A	$31.7	$161.6
State of Good Repair	$114.3	$10.0	$83.3	$20.8	$146.8

[1] When future MR&R strategies are assumed to be less aggressive, the MR&R-related component of the initial backlog is reduced.

*[2] N/A indicates that the maximum amount of cost-beneficial investment identified by NBIAS under the **Improve Conditions and Performance** scenario was insufficient to maintain the average sufficiency rating at its base-year level of 81.7; thus, the criteria for the **Maintain Conditions and Performance** scenario cannot be met.*

Source: National Bridge Investment Analysis System.

Applying the State of Good Repair MR&R strategy reduces the cost of maintaining the average sufficiency rating relative to the baseline, resulting in an average annual investment level of $10.0 billion over 20 years for the NBIAS component of the **Maintain Conditions and Performance** scenario. Use of this MR&R strategy would result in a small increase in the annual NBIAS component of the **Improve Conditions and Performance** scenario relative to the baseline ($20.8 billion versus $20.2 billion), but would result in a higher average sufficiency rating in 2030 relative to the baseline (86.0 versus 84.6).

Accelerating Operations/ITS Deployments

As described in Chapter 7, the HERS model considers the impacts on highway conditions and performance of various types of ITS and other operational enhancements to highways. Appendix A describes the types of strategies considered (including arterial management, freeway management, incident management, and traveler information systems) and three scenarios for future deployment. Although HERS incorporates assumptions about future deployment, it does not subject operational enhancements to benefit-cost analysis or to other economic evaluation; hence, the preceding chapters in this report referred to spending on these and other system enhancements as non-modeled. The only spending that HERS models in this sense is on highway pavement rehabilitation and capacity expansion, although spending on operational enhancements is represented.

Impact on Maintain Conditions and Performance Scenario

In the **Maintain Conditions and Performance** scenario, annual spending on HERS-modeled improvements averaged $51.1 billion under the baseline assumptions about future deployment of operational improvements. If HERS-modeled spending were held at that level while future deployment of operational improvements were assumed to be more aggressive, overall conditions and performance in 2030 relative to 2010 would be improved rather than maintained. To attain the scenario goal**,** HERS-modeled spending must therefore be lower when the alternative deployment assumptions replace the baseline.
For the "aggressive" deployment alternative, *Exhibit 10-7* shows the HERS-modeled capital spending to average $49.7 billion per year and spending on operational enhancements (including capital, operations

and maintenance costs) to be $4.6 billion per year more than in the baseline. The sum of these figures, $54.3 billion, indicates a $3.2 billion increase in total spending relative to the baseline value of $51.1 billion to achieve the objectives of the **Maintain Conditions and Performance** scenario. For the "full immediate deployment alternative," total spending is $55.1 billion, or $4.0 billion higher than the baseline value.

Exhibit 10-7 Impact of Alternative Operations Strategies Deployment Rate Assumptions on Selected Performance Indicators and Highway Investment Scenarios

Operations/ITS Deployments Assumption[1]	Average Annual Highway Investment, 2011 Through 2030 (Billions of 2010 Dollars)				Percent Change, 2030 Compared With 2010	
	HERS-Derived Component					
	HERS Modeled Spending	Additional Deployment Spending[2]	Total HERS	Total	Average Pavement Roughness (IRI)	Average Delay per VMT
Maintain Conditions and Performance Scenario						
Baseline[3] (continue existing trends)	**$51.1**	**N/A**	**$51.1**	**$86.3**	**-7.6%**	**4.3%**
Aggressive deployments alternative	$49.7	$4.6	$54.3	$90.6	-6.6%	3.3%
Full immediate deployments alternative	$45.0	$10.1	$55.1	$91.7	-1.9%	3.5%
Improve Conditions and Performance Scenario						
Baseline[3] (continue existing trends)	**$86.9**	**N/A**	**$86.9**	**$145.9**	**-26.7%**	**-8.0%**
Aggressive deployments alternative	$86.4	$4.6	$91.0	$151.5	-26.7%	-9.3%
Full immediate deployments alternative	$86.4	$10.1	$96.5	$159.0	-27.0%	-11.0%
Average Annual Spending $145.9 Billion						
Baseline[3] (continue existing trends)	**$86.9**	**N/A**	**$86.9**	**$145.9**	**-26.7%**	**-8.0%**
Aggressive deployments alternative	$82.3	$4.6	$86.9	$145.9	-25.3%	-8.1%
Full immediate deployments alternative	$76.8	$10.1	$86.9	$145.9	-22.8%	-8.7%

[1] The analyses presented in this table assume one of the following: (1) existing trends in ITS deployments will continue for 20 years; (2) an aggressive pattern of deployment will occur over the next 20 years; or (3) all of the aggressive deployments will occur immediately, rather than being spread out over 20 years. The costs associated with the more aggressive deployments were deducted from the budget available in HERS for pavement and widening investments.

[2] Amounts reflect additional capital and operation and maintenance costs associated with the alternative Operations/ITS deployment strategies relative to the Baseline.

[3] The Baseline levels shown correspond to the systemwide scenarios presented in Chapter 8 that applied higher, HPMS-derived VMT growth forecasts.

Source: Highway Economic Requirements System.

By design, under any of the deployment assumptions, the **Maintain Conditions and Performance** scenario shows no unambiguous change in overall conditions and performance relative to the baseline. An improvement in one of the scenario's measures of conditions and performance must be accompanied by deterioration in the other measure. Under each deployment assumption, the measure which shows improvement happens to be average pavement roughness; at the same time, average delay per VMT worsens. Assuming aggressive rather than baseline deployment makes the projected change less favorable for average pavement roughness (-6.6 percent versus -7.6 percent) but more favorable for average delay (3.3 percent versus 4.3 percent). The projections for average delay are more favorable because the types of operational improvements represented are assumed to have direct impacts only on travel time and accident rates; direct impacts on pavement conditions are assumed to be negligible.

These findings suggest that at the particular investment level reflected in the Maintain Conditions and Performance scenario (which is 13.9 percent below the actual level of spending by all levels of government in 2010), diverting resources from pavement and capacity improvements towards more aggressive deployment of operational improvements would not produce better conditions and performance outcomes. It should be noted however, that some of the operational improvements being considered, such as incident management systems, have benefits in crash reductions that would not be reflected in the IRI and delay measures used as targets in the **Maintain Conditions and Performance** scenario**.**

Impact on Improve Conditions and Performance Scenario

In the **Improve Conditions and Performance** scenario**,** more aggressive deployment of operational enhancements marginally reduces the amount of highway rehabilitation and capacity investment that HERS finds to be cost-beneficial. HERS-modeled rehabilitation and capacity investment decreases from $86.9 billion per year assuming baseline deployment to $86.4 billion per year assuming either of the more aggressive deployment alternatives. Total spending represented in HERS increases, however, because of the extra spending on the operations deployments, from $86.9 billion per year in the baseline to $96.5 billion per year assuming full immediate deployments. After adding an allowance for capital spending on non-modeled improvements, *Exhibit 10-7* indicates the corresponding variation in total spending to be between $145.9 billion per year in the baseline and $159.0 billion per year assuming full immediate deployments.

Because of the increased spending on operational enhancements, projections for average delay are more favorable when deployment is more aggressive than when the baseline is assumed. Although the types of operational enhancements considered in these cases are assumed to have no direct impacts on pavement quality, the projections for average pavement roughness are also slightly better than in the baseline. One reason for this is that spending on pavement rehabilitation is slightly higher under more aggressive deployment even though total HERS-modeled spending is lower. Pavement rehabilitation receives $44.3 billion out of the total $86.4 billion in HERS-modeled spending under the full immediate deployment alternative, versus $43.9 billion out $86.9 billion in the baseline.

Although these findings suggest that adopting more aggressive Operations/ITS deployment strategies would be advantageous if overall highway spending levels were significantly increased, the different levels of investment associated with each of these alternatives under the **Improve Conditions and Performance** scenario make direct tradeoffs more difficult to assess. To address this issue, the bottom three rows in *Exhibit 10-7* present alternative allocations of fixed total spending between the HERS-modeled types of improvements and operational enhancements given a single fixed level of HERS investment, based on the $86.9 billion HERS-derived component of the **Improve Conditions and Performance** scenario. The additional spending on operational improvements in the more aggressive deployment alternatives is assumed to come out of this total, reducing dollar-for-dollar the HERS-modeled component of spending. The balance of this spending offset between pavement rehabilitation and highway capacity expansion is determined by the model's cost-benefit optimization.

Exhibit 10-7 indicates that such reallocation of spending would produce worse outcomes in 2030 for pavement roughness, but better outcomes for travel delay. For pavement roughness, this reflects reduced spending on pavement rehabilitation together with operational enhancements being assumed to have no direct effect. For average delay, the reduction from the additional spending on operational enhancements outweighs the effect of the offset to spending on highway capacity. With the full immediate deployment assumed, pavements are projected to become 22.8 percent smoother between 2010 and 2030, compared with 26.7 percent smoother with baseline deployment assumed. For average delay per VMT, the corresponding projections are for reductions of 8.7 percent versus 8.0 percent.

Transit Sensitivity Analysis

This section examines the sensitivity of the Transit Economic Requirements Model's (TERM's) transit investment needs estimates to variations in the values of these key inputs:

- Asset Replacement Timing (Condition Threshold)
- Capital Costs
- Value of Time
- Discount Rate.

Specifically, these alternative projections 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 8 vary in response to changes in the assumed values of these input variables. Note here that, by definition, funding under the **Sustain 2010 Spending Scenario** is invariant to changes in any input variable and, for this reason, that scenario is not considered in this sensitivity analysis.

Changes in Asset Replacement Timing (Condition Threshold)

Each of the four investment scenarios examined in Chapter 8 assume that assets are replaced at condition rating 2.50 as determined by TERM's asset condition decay curves (in this context, 2.50 is referred to as the "replacement condition threshold"). Recall here that TERM's condition rating scale runs from 5.0 for assets in "excellent" condition through 1.0 for assets in "poor" condition. In practice, this assumption implies replacement of assets within a short-term period (e.g., roughly 1 to 5 years depending on asset type) *after* they have attained their expected useful life. Replacement at condition 2.50 can therefore be thought of as providing a replacement schedule that is both realistic (in practice, few assets are replaced exactly at their expected useful life value due to a range of factors including the time to plan, fund, and procure an asset replacement) and potentially conservative (i.e., the needs estimates would be higher if all assets were assumed to be replaced at precisely the end of their expected useful life).

Based on this background, *Exhibit 10-8* shows the impact 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**

Exhibit 10-8 Impact of Alternative Replacement Condition Thresholds on Transit Preservation Investment Needs by Scenario (Excludes Expansion Impacts)

	SGR Benchmark		Low Growth Scenario		High Growth Scenario	
Replacement Condition Thresholds	Billions of 2010 Dollars	Percent Change From Baseline	Billions of 2010 Dollars	Percent Change From Baseline	Billions of 2010 Dollars	Percent Change From Baseline
Very late asset replacement (2.00)	$15.57	-15.7%	$14.68	-13.7%	$14.77	-13.7%
Replace assets later (2.25)	$17.33	-6.1%	$16.00	-5.9%	$16.13	-5.8%
Baseline (2.50)	$18.46		$17.01		$17.12	
Replace assets earlier (2.75)	$22.07	19.6%	$20.16	18.5%	$20.41	19.2%
Very early asset replacement (3.00)	$26.03	41.0%	$23.28	36.9%	$23.49	37.2%

Source: Transit Economic Requirements Model.

Growth and **High Growth Scenarios**. It should be noted that selection of a higher replacement condition threshold results in assets being replaced at a higher condition (i.e., at an earlier age), which 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 will, of course, have the opposite effect. As shown in *Exhibit 10-8*, 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.

Changes in Capital Costs

The asset costs used in TERM are based on actual prices paid by agencies for capital purchases as reported to Federal Transit Administration (FTA) in the Transit Electronic Award Management (TEAM) System and in special surveys. Asset prices in the current version of TERM have been converted from the dollar year replacement costs in which assets were reported to FTA by local agencies (which vary by agency and asset) to 2010 dollars using 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 shown in *Exhibit 10-9,* TERM projects that a 25 percent increase in capital costs (i.e., beyond the 2010 level used for this report) would be fully reflected in the **SGR Benchmark,** but only partially realized under either 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 ratio in computing the **SGR Benchmark** (i.e., there are no consequences to increasing costs), whereas the two cost-constrained scenarios do employ this test. Hence, for the **Low Growth** or **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. Therefore, for these latter two scenarios, a 25 percent increase in capital costs would yield a range of roughly 19 to 20 percent increase in needs that pass TERM's benefit-cost test.

Exhibit 10-9 Impact of an Increase in Capital Costs on Transit Investment Estimates by Scenario

	SGR Benchmark		Low Growth Scenario		High Growth Scenario	
Capital Cost Increases	Billions of 2010 Dollars	Percent Change From Baseline	Billions of 2010 Dollars	Percent Change From Baseline	Billions of 2010 Dollars	Percent Change From Baseline
Baseline (no change)	$18.46		$21.96		$24.54	
Increase Costs 25%	$23.08	25.0%	$26.38	20.1%	$29.19	18.9%

Source: Transit Economic Requirements Model.

Changes in the Value of Time

The most significant source of transit investment benefits, as assessed by TERM's benefit-cost analysis, 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 employ TERM's benefit-cost test. Readers interested in learning more about the measurement and use of the value of time for the benefit-cost analyses performed by TERM, Highways Economic Requirements System (HERS), and 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: The **Sustain 2010 Spending Scenario** uses TERM's estimated benefit-cost ratios to allocate fixed levels of funding to preferred investments, while the computation of the **SGR Benchmark** does not employ TERM's benefit-cost test in any way.)

Exhibit 10-10 shows the effect of varying the value of time on the needs estimates of the **Low Growth** and **High Growth Scenarios**. The baseline value of time for transit users is currently $12.50 per hour, based on Department of Transportation (DOT) guidance. TERM applies this amount to all in-vehicle travel, but then doubles this amount to $25.00 per hour when accounting for out-of vehicle travel time, including time spent waiting at transit stops and stations.

Given that value of time is a key driver of total investment benefits, changes in this variable lead to changes in investment ranging from an increase of more than 10 percent to a decrease of more than 6 percent. The resulting different magnitudes of percent changes is because the absolute value of the changes from the baseline are different ($6.25 is a 50 percent change from baseline and $25 is a 100 percent change from baseline). In addition to this issue, we observe that the **High Growth Scenario** appears to be more sensitive to the value of time than the **Low Growth Scenario**. This is due to the fact that higher investment levels are associated with the **High Growth Scenario** than with the **Low Growth Scenario**; therefore, any changes in the value of time will be magnified accordingly.

Exhibit 10-10 Impact of Alternative Value of Time Rates on Transit Investment Estimates by Scenario

	Low Growth Scenario		High Growth Scenario	
Changes in Value of Time	Billions of 2010 Dollars	Percent Change From Baseline	Billions of 2010 Dollars	Percent Change From Baseline
Reduce 50% ($6.25)	$20.85	-5.1%	$22.98	-6.4%
Baseline ($12.50)	$21.96		$24.54	
Increase 100% ($25.00)	$23.40	6.6%	$27.04	10.2%

Source: Transit Economic Requirements Model.

Changes to the Discount Rate

Finally, TERM's benefit-cost module utilizes a discount rate of 7.1 percent in accordance with White House Office of Management and Budget (OMB) guidance. Readers interested in learning more about the selection and use of discount rates for the benefit-cost analyses 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 HERS and NBIAS discount rate sensitivity discussion above, 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 are presented in *Exhibit 10-11*. These results show that this approximately 58 percent reduction in the discount rate yields an increase in total investment needs (or an increase in the proportion of needs passing TERM's benefit-cost test) of 3.2 to 6.1 percent.

Exhibit 10-11 Impact of Alternative Discount Rates on Transit Investment Estimates by Scenario

	Low Growth Scenario		High Growth Scenario	
Discount Rates	Billions of 2010 Dollars	Percent Change From Baseline	Billions of 2010 Dollars	Percent Change From Baseline
7.10% (Baseline)	$21.96		$24.54	
3.00%	$22.67	3.2%	$26.03	6.1%

Source: Transit Economic Requirements Model.