CHAPTER 10

Sensitivity Analysis

Summary

This chapter explores the effects of varying some of the assumptions that were used to develop the investment requirement projections in Chapter 7. In any modeling effort, evaluating the validity of the underlying assumptions is critical. The results produced by the Highway Economic Requirements System (HERS) and the Transit Economic Requirements Model (TERM) are strongly affected by the values they are supplied for certain key variables. This chapter was first added to the 1999 C&P report to open up more of the modeling process and to make the report more useful for supplementary analysis efforts.

One of the most significant enhancements to the HERS modeling process in this report is the consideration of the effects of operations strategies and improvements. The analyses in Chapter 7 incorporated a baseline scenario for future operations deployments based on existing trends. The impact of this scenario is illustrated by reporting results from HERS that do not take such deployments into account. An alternative scenario assuming a more aggressive deployment of operations improvements is also analyzed.

There is some uncertainty about the 20-year travel growth forecasts on which HERS and TERM rely. The highway and transit sections both show the impact of changing assumptions about growth rates on investment requirement projections. Alternative estimates of highway investment requirements are shown for a scenario in which baseline constant-price future highway travel growth rates match those observed over the last 20 years. The sensitivity of the estimated transit investment requirements to the growth rate forecast is analyzed by allowing three alternative growth rate inputs: 50 percent higher than the forecast, 50 percent below the forecast, and 100 percent below the forecast (i.e., zero transit passenger-mile growth).

The chapter also includes other sensitivity analyses that show the impact of using alternative values for certain key model parameters (whose estimated values may be subject to some uncertainty). Both the highway and transit sections analyze the impact of increasing the unit improvement costs in HERS and TERM by 25 percent and the effects of variations in the value of time and travel demand elasticity. The highway section also considers alternative values for additional parameters, including the value of statistical life and truck volume shares.

Highway Sensitivity Analysis

The accuracy of the investment requirements reported in Chapter 7 depends on the validity of the underlying assumptions used to develop the analysis. This section explores the effects that varying several key assumptions in the highway investment requirement analytical process would have on the Maximum Economic Investment (Cost to Improve Highways and Bridges) and the Cost to Maintain Highways and Bridges. While not discussed directly in this chapter, any changes in the projected investment requirements would also affect the gaps identified in Chapter 8 between projected spending and the investment requirement scenarios.

Alternative Operations/ ITS Deployment Scenarios

As described in Chapter 7, one of the key additions to the HERS analysis for this edition of the C&P report is the ability to consider the impact of current and future intelligent transportation system (ITS) deployments and operations strategies on highway conditions and performance, with resulting implications for the projected investment requirements. The analyses of Chapters 7, 8, and 9 used a baseline scenario for future deployments based on existing trends. *Exhibit 10-1* shows the impact on the results of two alternative deployment scenarios: one with more aggressive assumptions about future deployments and one that excludes operations from the analysis entirely. Chapter 7 and Appendix A include more information on the types of strategies and investments reflected in both the existing trends and aggressive operations deployment scenarios, which include those targeted at freeway management (ramp metering, electronic monitoring, variable message signs, and traffic management centers), incident management (incident detection, verification, and response), and arterial management (upgraded signal control, electronic monitoring, variable message signs, and emergency vehicle signal preemption).

Exhibit 10-1 *Impact of Alternate Operations/ITS Deployment Assumptions on Investment Requirements*

	Cost to Maintain Highways & Bridges		Maximum Economic Investment for Highways & Bridges	
	($Billions)	Percent Change	($Billions)	Percent Change
Chapter 7 Baseline	$73.8		$118.9	
No Operations Impacts	$76.0	3.0%	$120.7	1.5%
Aggressive Deployment	$71.4	-3.3%	$118.7	-0.2%

Source: Highway Economic Requirements System (HERS).

As shown in Exhibit 10-1, ignoring the impact of operations and ITS deployments in the analysis would result in higher estimates of the cost of the two investment scenarios. The impact is greater, proportionally, for the Cost to Maintain scenario than for the Maximum Economic Investment scenario. Without operations, additional infrastructure improvements would be needed to accommodate future travel growth in order to maintain the conditions and performance of the system, and more such improvements would be perceived as cost-beneficial in the absence of ITS deployments.

The aggressive operations/ITS deployment scenario assumes that existing trends in the adoption of ITS infrastructure and strategies would accelerate in the future. The impact of increasing the rate at which such technologies are adopted in the future would be to further decrease the estimated infrastructure investment necessary to maintain conditions and performance at current levels by approximately $2.4 billion per year under this particular scenario.

The aggressive scenario does not have as significant an impact on the Maximum Economic Investment relative to that based on existing trends. While in some cases, ITS deployments would reduce the benefit-cost ratio of certain potential widening projects below the 1.0 threshold imposed by this scenario, in other cases, both an ITS deployment and a widening project would be cost-beneficial. Consequently, the level of performance that HERS finds cost-beneficial to achieve would be greater under the aggressive scenario than under the baseline trends scenario. For example, average highway user costs would be 0.2 percent lower than under the existing trends scenario, and incident delay would be further reduced by nearly 3 percent, even though the overall level of investment is slightly lower.

Q. What are the costs associated with the aggressive deployment strategy analyzed here, relative to those for the baseline existing trends deployment strategy?

A. As described in Chapter 7, the costs of the new or increased operations deployments include both the capital costs of the equipment and infrastructure and the ongoing costs of operating and maintaining that infrastructure. The costs include those for both the basic infrastructure needed to support a given strategy (such as a traffic operations management center) and the incremental costs of increasing the coverage of that structure (such as additional ramp meters).

The estimated capital cost of new deployments under the aggressive deployment strategy used for these analyses is $7.5 billion over 20 years (in 2002 dollars). These costs are included in the capital investment requirements estimates based on the aggressive deployment strategy shown in Exhibit 10-1 for both the Cost to Maintain and Maximum Economic Investment scenarios. As described in Chapter 7, the comparable figure for the baseline existing trends deployment strategy was $1.5 billion over 20 years.

Estimated operating and maintenance costs for the aggressive deployment strategy over the same 2003 to 2022 time period are $25.1 billion (in 2002 dollars), including $17.1 billion for new deployments and $8.0 billion for the existing infrastructure. These costs are **not** included in the Cost to Maintain or the Maximum Economic Investment figures in Exhibit 10-1. As described in Chapter 7, the comparable figure associated with the baseline existing trends strategy was $10.9 billion, including $2.9 billion for new deployments and $8.0 billion for the existing infrastructure.

Historic Versus Projected Travel Growth

States provide forecasts of future vehicle miles traveled (VMT) for each individual Highway Performance Monitoring System (HPMS) sample highway section. As indicated in Chapter 7, HERS assumes that the forecast for each sample highway segment represents the level of travel that will occur if a constant level of service is maintained on that facility. This implies that VMT will only occur at this level if pavement and capacity improvements made on the segment over the 20-year analysis period are sufficient to maintain highway-user costs at 2002 levels. If HERS predicts that highway-user costs will deviate from baseline 2002 levels on a given highway segment, the model's travel demand elasticity features will modify the baseline VMT growth projections from HPMS.

Q. Does the accuracy of the investment requirements projected by HERS depend on how accurately the travel forecasts in HPMS predict what future VMT growth will be?

A. Not exactly. The HERS model assumes the travel forecasts in HPMS accurately predict what future VMT growth *would* be if highway-user costs remained constant, rather than what future growth *will* be. This is a critical distinction.

The accuracy of the investment requirements depends on the accuracy of the travel forecasts in HPMS as *modified by the travel demand elasticity features* in HERS. At current funding levels, HERS predicts that highway-user costs will increase over time, so VMT will grow more slowly than the HPMS baseline forecasts. This concept is discussed in more detail in Appendix A.

The HERS model utilizes VMT growth projections to predict future conditions and performance of individual highway segments and to calculate future investment requirements. If the HPMS VMT forecasts *as modified by the HERS travel demand elasticity features* are overstated, the investment requirement projections may be too high. If travel growth is underestimated, the investment requirement projections may be too low.

The effective VMT growth rates predicted by the HERS model could be off target if (1) the HPMS forecasts don't precisely represent the travel that will occur if a constant level of service is maintained or (2) the travel demand elasticity procedures in HERS don't accurately predict how highway users will respond to changes in costs. The latter effect is addressed in the next section by varying the values of the elasticity parameters used in the model. This section explores the impacts of the former case by modifying the estimates of future travel found in the HPMS sample data.

As indicated in Chapter 9, the State-supplied VMT growth projections in HPMS for 2002 to 2022 average 2.07 percent per year, well below the 2.96 percent average annual VMT growth rate observed from 1982 to 2002. The HERS model assumes that the 2.07 percent composite VMT growth projection in HPMS represents the growth that will occur at a constant level of service. As noted in Chapter 4, however, the level of service on highways in the United States has generally been declining over the past two decades. If States expect this trend to continue and factor this into their projections, then the HPMS forecasts might represent a declining level of service as well, and would thus understate future *constant price* growth, causing HERS to likewise underestimate the level of investment that would be needed to achieve a given level of performance. It is thus prudent to consider the impact of such a circumstance on the Chapter 7 projections, and the historic growth rate provides a useful benchmark for comparison.

Exhibit 9-6 shows the impact of different levels of future investment on the average annual VMT growth rate, if one assumes that the baseline travel growth forecasts in HPMS represent a constant level of service. *Exhibit 10-2* shows the impact on investment requirements of assuming that the 20-year future growth in VMT that would occur at a constant level of service matches the growth over the previous 20 years, rather than using the baseline assumption that the constant-price growth would be in line with the HPMS forecasts (this was done by adjusting the travel forecasts entered into HERS for each section accordingly). Modifying the travel growth projections in this fashion would increase the Cost to Maintain Highway and Bridges by 65.0 percent. Increased VMT would increase the rate of pavement deterioration, as well as increase the share of resources that HERS would recommend using for capacity expansion, to over 50 percent of total spending. Both of these factors would tend to increase the investment required to maintain user costs at 2002 levels. The Maximum Economic Investment for Highways and Bridges would increase by 30.8 percent based on this change in assumptions. The increased travel would increase the number of pavement and capacity projects that HERS would find cost-beneficial.

Exhibit 10-2 *Impact of Alternate Constant-Price Travel Growth Assumptions on Investment Requirements*

	Cost to Maintain Highways & Bridges		Maximum Economic Investment for Highways & Bridges	
	($Billions)	Percent Change	($Billions)	Percent Change
Chapter 7 Baseline	$73.8		$118.9	
Historic VMT Growth Rates	$121.8	65.0%	$155.4	30.8%

Source: Highway Economic Requirements System (HERS).

Q. Can Exhibit 10-2 be used to analyze the impact that travel demand management policies (such as pricing) on the investment requirements estimates?

A. No. Travel demand management policies such as road pricing are intended to actively reduce the amount of highway usage in congested periods. Such policies accomplish this goal by directly or indirectly raising the cost of highway travel to users in order to alleviate excess demand and are often used as a means of addressing inefficiencies in the pricing of highway use (see the discussion in the Introduction to Part II). As is discussed in Chapter 7, the travel demand elasticity feature of HERS is intended to capture the effect of increases or decreases in the price of travel on travel demand. This is not what the figures shown in Exhibit 10-2 represent, however. Rather, they simply convey the impact that different assumptions about future *constant-price* travel growth would have on the investment estimates and should thus not be used to make inferences about changes in VMT growth rates explicitly induced by pricing policies.

More generally, Exhibit 10-2 should not be used to infer a direct linear relationship between a certain level of future VMT and future highway investment requirements. This relationship is not linear, and the overall level of future travel nationwide is less critical than the spatial distribution of future travel growth. For example, large increases in VMT on uncongested highway sections would not impact future investment requirements as much as smaller increases in VMT on severely congested highway sections.

Alternative Model Parameters

The HERS model uses several key input parameters whose values may be subject to considerable uncertainty or debate, but whose values can affect the costs and benefits of investment strategies estimated within the model. To assess the importance of such uncertainty, the estimates of future investment requirements were recomputed using different values for some of these parameters, including improvement costs, the value of a statistical life, the value of reductions in incident delay, the value of ordinary travel time, short-run and long-run elasticity, and truck volume growth. *Exhibit 10-3* shows the impacts of the alternative parameter values on the Maximum Economic Investment for Highways and Bridges.

Improvement Costs

The unit improvement costs used in HERS to calculate total investment costs, though recently updated, may themselves be subject to uncertainty. For example, currently unforeseen circumstances may cause highway construction costs to increase faster than the general rate of inflation in the future. It is therefore prudent to consider the impact of higher-than-expected capital improvement costs in order to ensure that non-cost-beneficial projects are not mistakenly included in the investment requirements estimated by HERS.

Exhibit 10-3 shows the impact of inflating all the improvement costs used by HERS by 25 percent on the Maximum Economic Investment level. The increase in investment requirements due to higher unit values for the improvement costs is largely offset by the elimination of some projects that would no longer be considered cost-beneficial by HERS. The net result is an increase of 6.6 percent in the estimated investment requirements.

Exhibit 10-3 *Impact of Alternate Model Features and Parameters on Investment Requirements*

Maximum Economic Investment for Highways & Bridges	($Billions)	Percent Change
Chapter 7 Baseline	**$118.9**	
Improvement Costs		
Increase 25 percent	$126.7	6.6%
Value of a Statistical Life		
Reduce 50 percent	$118.2	-0.6%
Increase 100 percent	$119.9	0.8%
Value of Incident Delay Reduction		
Equal to value of ordinary travel time	$111.8	-5.9%
3 times value of ordinary travel time	$124.0	4.4%
Value of Ordinary Travel Time		
Increase 25 percent	$127.8	7.6%
Reduce 25 percent	$108.8	-8.4%
Elasticity Values		
Reduced 50 percent	$128.8	8.4%
Truck Volumes		
Based on Freight Analysis Framework	$83.0	1.9%

Source: Highway Economic Requirements System (HERS).

Value of a Statistical Life

HERS uses $3.0 million for the value of a statistical life, which is the U.S. Department of Transportation's (DOT's) standard value for use in benefit-cost analyses. As with the value of time, there is a great deal of debate about the appropriate value; and no single dollar figure has been uniformly accepted by the academic community or within the Federal government.

Doubling the value would increase the Maximum Economic Investment for Highways and Bridges by 0.8 percent. HERS would find a few more projects to implement on the basis of their increased safety benefits if the value of life were increased. Reducing the value of a statistical life by 50 percent would reduce the Maximum Economic Investment level by 0.6 percent. A few marginal projects that were justified based on potential reductions in crash rates would not be implemented if the value of life used in the analysis were reduced.

Changing the value of a statistical life in HERS does not have a significant impact on the estimates of annual investment requirements. The model is not currently equipped to consider all the safety benefits of highway improvements, nor does it model safety-oriented enhancement projects (such as improved crash barriers or protected turning lanes). The Afterword in Part V of this report includes a discussion of future research options for improving the HERS model's capabilities in this area.

Value of Incident Delay Reduction

As noted in Appendix A and elsewhere in this report, HERS calculates the delay associated with traffic incidents in addition to that caused by recurring congestion and traffic signals. Research has indicated that such unpredictable delay is perceived by highway users as more onerous (and thus more "costly" on a per-hour basis) than is the predictable, routine delay typically associated with peak traffic volumes. The HERS model accounts for this by allowing for a user-specified parameter for the "reliability premium" associated with reductions in incident delay, which is expressed as a multiple of the value of ordinary travel time.

The estimates of investment requirements in Chapters 7 and 8 used a baseline value of 2.0 times the value of ordinary travel time for the reliability premium, which was chosen on the basis of available research. Exhibit 10-3 shows the impact of setting this premium at a higher level (3.0 times the ordinary travel time) or eliminating it by setting the value of incident delay equal to ordinary travel time.

Changing the reliability premium associated with incident delay reductions has an effect similar to changing the value of ordinary travel time, though slightly smaller in magnitude. Increasing the reliability premium to 3.0 makes incident delay-reducing improvements relatively more valuable, thereby raising investment requirements by 4.4 percent at the Maximum Economic Investment level. Eliminating the premium results in a corresponding reduction of 5.9 percent in the investment estimate.

Q. Are any sensitivity analysis results available from the National Bridge Investment Analysis System (NBIAS) model?

A. Yes. NBIAS supports the ability to apply a swell factor to maintenance, repair, and rehabilitation (MR&R) needs to recognize that in some cases when bridge repair and rehabilitation projects are conducted to address deficiencies for some bridge components, other nondeficient components may be upgraded as well. This feature was utilized in the baseline scenarios for the 2002 edition of the C&P report, as the version of NBIAS used to develop that analysis analyzed bridges at an aggregate level, making it much more likely that its recommended improvements to bridge elements would not capture everything that would ordinarily occur as part of a real-world bridge project. As NBIAS now analyzes individual bridges, its recommended improvements are now much more inclusive, so that any ancillary bridge work that is not reflected should not be nearly as significant.

Had a swell factor of 1.25 been used, as was the case in the 2002 C&P report, then the bridge preservation component of the Cost to Maintain Highways and Bridges would have been approximately 15 percent higher. The bridge preservation component of the Maximum Economic Investment for Highways and Bridges would have been approximately 8 percent higher. The Maximum Economic Investment level is not affected to the same degree, because this adjustment would cause some potential bridge projects to fail the benefit-cost test imposed under this scenario, partially offsetting the increase in costs for the remaining projects.

Value of Ordinary Travel Time

The value of time in HERS was developed using a standard methodology adopted by DOT. This methodology provides consistency among different analyses performed within the Department. However, some debate remains about the appropriate way to value time, and no single methodology has been uniformly accepted either by the transportation community or within the Federal government.

Increasing the value of ordinary travel time in HERS by 25 percent would increase the Maximum Economic Investment by 7.6 percent. Increasing the value of time causes HERS to consider more widening projects (which reduce travel time costs) to be cost-beneficial. The proportion of capacity projects implemented as a percentage of total investment would increase to nearly 47 percent of total improvement costs. Reducing the value of time by 25 percent would have the opposite effect, resulting in an 8.4 percent reduction in the Maximum Economic Investment level.

Elasticity Values

As described in Appendix A, HERS applies both short-run and long-run travel demand elasticity procedures in its analysis, using assumed input values for these elasticities. There is considerable uncertainty, however, about what the appropriate values would be in this context. The elasticity values used in the analyses for this report (-0.6 for short-run elasticity and -1.2 for long-run elasticity) are considered by some to be on the high end for the type of highway user responses modeled by the travel demand procedures in HERS. Therefore, a sensitivity analysis was performed using elasticity values half the magnitude of those in the baseline.

The impact of such a change in these parameters is to increase the Maximum Economic Investment level for Highways and Bridges by 8.4 percent. Reducing the assumed amount of travel induced by reductions in user costs at higher investment levels serves to reduce the number of projects that would be cost-beneficial.

Truck Volumes

The HPMS sample data used in HERS include values for the percentage of single-unit and combination trucks in the current vehicle mix on each segment. Forecasts of future traffic, however, are not broken down by vehicle class, meaning that the data effectively assume no changes in truck shares. Many national forecasts of future VMT, however, indicate that truck travel is expected to grow faster than passenger auto travel.

Q. What impacts do alternate parameter assumptions have on the Cost to Maintain Highways and Bridges?

A. The impacts of alternative model parameters and procedures on the estimated investment requirements are much more ambiguous and difficult to interpret for the Cost to Maintain Highways and Bridges than is the case for the Maximum Economic Investment scenario. This generally results from the definition of the Cost to Maintain Highways and Bridges used in this report (see Chapter 7). The HERS-modeled portion of this cost was based on the Maintain User Cost scenario, in which investment is sufficient to allow average highway user costs for 2022 as calculated by HERS to match the initial levels in 2002. The initial calculation of user costs, however, is directly affected by many of the parameters shown in Exhibit 10-3, including the values of time, incident delay, statistical life, and truck volume. As a result, the target average user cost that is maintained will be different for alternative values of these parameters, leaving the baseline and the alternatives less comparable to one another and making any such comparisons less meaningful. The impacts of alternative values on the Maximum Economic Investment level, however, are based on implementing all cost-beneficial projects and are thus not subject to this same caveat.

In the case of the ordinary travel time and reliability premium parameters, increasing their value also increases the initial calculated value of user costs. Less investment will then generally be required to maintain user costs at this higher, less "ambitious" level in the future. Increasing the share of trucks over time has the opposite effect: since trucks have higher travel time and vehicle operating costs than do passenger vehicles, an increasing truck share will cause average user costs to rise as well, thus requiring more investment to maintain user costs at the initial level. In both cases, the change is somewhat artificial and due solely to differences in the specification of the baseline and alternative scenarios. Changing the value of the statistical life parameter does not affect the estimate of the Cost to Maintain scenario to any significant degree.

Conceptually, the values of the elasticity parameters should not affect the investment if user costs are maintained at their current levels, since there would be no price response under such circumstances. However, this would only apply to the Maintain User Cost scenario if this were true for every section in every time period. In fact, the scenario definition is based on system-wide averages, in which user costs will rise on some sections and decline on others. The net effect of changing elasticity parameters thus depends on how such effects play out on individual sections, making it impossible to predict the net outcome. Also, if user costs are higher or lower than the baseline in the intermediate years between the base year and the end of the 20-year analysis period, then elasticity will have stronger or lesser impacts on overall travel growth and thus investment levels under the Maintain User Cost scenario, but this is not directly related to elasticity and the investment level required to reach the original user cost level in the final year.

Increasing the unit improvement costs in HERS by a given percentage has a straightforward impact on the investment needed to maintain user costs, but the impact is also less interesting analytically. Since the investments included in the Maintain User Cost scenario all have benefit-cost ratios well above 1.0, raising the improvement cost estimates does not cause HERS to forego any improvements on benefit-cost grounds. The increase in the portion of the Cost to Maintain Highways and Bridges will thus be directly proportional to the change in improvement costs. On the whole, the increase will be a less-than-proportional increase in the estimated Cost to Maintain Highways and Bridges simply due to the fact that bridge preservation investments modeled in the NBIAS, which are not affected by changes in HERS parameters, are also part of the cost of that investment scenario.

For this report, HERS has been adapted to accept alternate truck volume data and forecasts for sections in the HPMS data set. The source of this alternate data was FHWA's Freight Analysis Framework (FAF). The FAF forecasts generally show truck volumes increasing at a faster rate than general traffic levels. Exhibit 10-3 indicates that using the FAF forecasts for truck volume growth within the HERS estimation procedures would increase the Maximum Economic Investment by 1.9 percent. HERS finds a slightly larger number of additional projects to be cost-beneficial when the larger truck shares in FAF are accounted for.

Chapter 13 and Appendix A contain more information on the FAF and how its forecasts were used in HERS.

Transit Sensitivity Analysis

This section examines the sensitivity of projected transit investment requirements by the Transit Economic Requirements Model (TERM) to variations in the values of the following exogenously determined model inputs:

- Passenger miles traveled (PMT) on transit
- Capital costs
- Value of time
- User travel cost elasticities.

These alternative projections illustrate how investment requirements for transit vary according to different assumptions of these input values.

Sensitivity to Changes in PMT

TERM relies heavily on forecasts of PMTs in large urbanized areas. These forecasts are the primary driver behind TERM's estimates of the amount of investment that will be needed in the Nation's transit system to maintain performance, i.e., current levels of passenger travel speeds and vehicle utilization rates, as ridership increases. PMT forecasts are generally made by metropolitan planning organizations (MPOs) in conjunction with projections of vehicle miles traveled (VMT) as a part of the regional transportation planning process. These projections incorporate assumptions about the relative growth of travel on transit and in private vehicles in a metropolitan area. The average annual growth rate in PMT of 1.5 percent used in this report is a weighted average of the most recent, primarily 2000 to 2003, MPO forecasts available from 76 of the Nation's largest metropolitan areas. Investment requirements in the 2002 report were based on a projected PMT growth rate of 1.6 percent, based on a weighted average of the forecasts available from 33 of the Nation's largest metropolitan areas.

Future transit investment requirements have been estimated by TERM based on three alternative projected PMT scenarios to examine the sensitivity of transit investment needs to variations in PMT *[Exhibit 10-4].* These scenarios are as follows:

(1) PMT growth is 50 percent greater than the forecast levels.

(2) PMT growth is 50 percent less than the forecast levels.

(3) PMT remains unchanged (zero growth).

Varying the assumed rate of growth in PMT significantly affects estimated transit investment requirements. This effect is more pronounced under the Maintain Conditions and Performance scenario than under the Improve Conditions and Performance scenario, as PMT growth rates affect primarily asset expansion costs, which comprise a larger portion of total estimated Maintain Conditions and Performance needs than

Exhibit 10-4 *Impact of Alternative PMT Growth Rates on Transit Investment Requirements*

Annual PMT Growth Rate	Annual Cost to Maintain Conditions & Performance (Billions of 2002 Dollars)	Annual Cost to Maintain Conditions & Performance: Percent Change	Annual Cost to Improve Conditions & Performance (Billions of 2002 Dollars)	Annual Cost to Improve Conditions & Performance: Percent Change
Baseline (1.5%)	$15.55	–	$23.99	–
Increased 50% (to 2.25%)	$18.38	18.1%	$26.74	11.5%
Decreased 50% (to 0.75%)	$12.62	-18.7%	$20.95	-11.8%
Decreased 100% (to 0%)	$10.15	-33.6%	$18.49	-21.5%

*Investment requirements for rural and special service vehicles are included in the totals, but are not subject to the sensitivity analysis. They account for 5 percent or less of the total.

Source: Transit Economic Requirements Model and FTA staff estimates.

estimated Improve Conditions and Performance needs. A 50 percent increase/decrease in PMT growth will increase/decrease the cost to maintain conditions by 18 to 19 percent and the cost to improve conditions and performance by about 12 percent. Investment requirements to maintain conditions and performance decrease by 34 percent if PMT remains constant, although this is not a likely scenario.

Sensitivity to a 25 Percent Increase in Capital Costs

The capital costs used in TERM are based on actual prices paid by agencies for asset purchases as reported to FTA in TEAM (Transit Electronic Award and Management System) and in special surveys. Asset prices in the current version of TERM have been converted to 2002 dollars as necessary. 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 projected transit investment requirements.

As shown in *Exhibit 10-5,* a 25 percent increase in capital costs increases the costs to maintain conditions and performance by 14 percent and the costs to improve conditions and performance by 9 percent. With this increase in costs, fewer investments pass the benefit-cost hurtle under the Improve Conditions and Performance scenario than under the Maintain Conditions and Performance scenario.

Exhibit 10-5 *Impact of a 25 Percent Increase in Capital Costs on Transit Investment Requirements**

	Annual Cost to Maintain Conditions & Performance (Billions of 2002 Dollars)	Annual Cost to Maintain Conditions & Performance: Percent Change	Annual Cost to Improve Conditions & Performance (Billions of 2002 Dollars)	Annual Cost to Improve Conditions & Performance: Percent Change
Baseline	$15.55	–	$23.99	–
Increase Costs 25%	$17.72	13.9%	$26.24	9.4%

*Investment requirements for rural and special service vehicles are included in the totals, but are not subject to the sensitivity analysis. They account for 5 percent or less of the total.

Source: Transit Economic Requirements Model and FTA staff estimates.

Sensitivity to Changes in the Value of Time

The value of time is a key input to TERM's benefit-cost analysis and is one of the factors used to determine the level of investment in capital assets under both the Maintain Performance and Improve Performance scenarios. The value of time is used to estimate changes in the total benefits accruing to transit users from investments in transit infrastructure that change the duration of passengers travel time.

Exhibit 10-6 shows the effect of varying the value of time. The baseline value of time is assumed to be $11.20, as recommended by the DOT Office of the Secretary for local travel in vehicles for all purposes, personal and business. TERM values waiting and transfer times at $22.40 per hour, double the value of in-vehicle travel time.

Overall, variations in the value of time have a very limited effect on investment needs. Increases in the value of time increase the benefits of investment in transit modes that offer passenger travel times that are faster than nontransit modes, such as the automobile, and decrease the benefits of investment in transit modes with passenger travel speeds that are slower than nontransit modes. Hence, an increase in the value of time reduces projected investment in modes with relatively slower transit services (and some travel shifts from transit to automobiles) and increases projected investment requirements in modes with relatively faster transit services (and some travel shifts from automobiles to transit). The opposite occurs in response to a decrease in the value of time.

Exhibit 10-6 *Impact of Change in the Value of Time on Transit Investment Requirements**

	Annual Cost to Maintain Conditions & Performance		Annual Cost to Improve Conditions & Performance	
Annual PMT Growth Rate	**(Billions of 2002 Dollars)**	**Percent Change**	**(Billions of 2002 Dollars)**	**Percent Change**
Baseline	$15.55	–	$23.99	–
Increase 100%	$15.21	-2.2%	$23.58	-1.7%
Decrease by 50%	$15.57	0.1%	$23.91	-0.4%

* Investment requirements for rural and special service vehicles are included in the totals, but are not subject to the sensitivity analysis. They account for 5 percent or less of the total.

Source: Transit Economic Requirements Model.

Sensitivity to Changes in User Cost Elasticities

"User cost" elasticity is the percentage change in ridership resulting from a 1 percent change is user costs. TERM uses user cost elasticities to estimate the changes in ridership that will result from changes in fare and travel time costs, due to infrastructure investment to increase speeds, decrease vehicle occupancy levels, and increase frequency. TERM assumes that these elasticities range from –0.22 to –0.40, depending on the mode. User cost elasticities are negative, reflecting an inverse relationship between ridership and costs. As ridership costs decrease, ridership increases. The larger the absolute value of the elasticity, the more responsive ridership will be to changes in user costs. As shown in *Exhibit 10-7*, a doubling or halving of these elasticities has almost no effect on projected investment requirements.

Exhibit 10-7 *Impact of Change in the Value of User Cost Elasticities on Transit Investment Requirements**

	Annual Cost to Maintain Conditions & Performance		Annual Cost to Improve Conditions & Performance	
User Cost Elasticities	**(Billions of 2002 Dollars)**	**Percent Change**	**(Billions of 2002 Dollars)**	**Percent Change**
Baseline	$15.55	-	$23.99	-
Increase 100%	$15.61	0.4%	$23.89	-0.4%
Decrease by 100%	$15.65	0.7%	$24.00	0.0%

* Investment requirements for rural and special service vehicles are included in the totals, but are not subject to the sensitivity analysis. They account for 5 percent or less of the total.

Source: Transit Economic Requirements Model.