Chapter 10

Sensitivity Analysis

Highway Sensitivity Analysis

The results produced by the Highway Economic Requirements System (HERS), the National Bridge Investment Analysis System (NBIAS), and the Transit Economic Requirements Model (TERM) are strongly affected by the values that are supplied to them for certain key variables. In any modeling effort, evaluating the validity of the underlying assumptions is critical. The accuracy of the investment scenario estimates reported in Chapter 8 depends on the validity of the underlying assumptions used to develop the analysis.

This section explores the effects of varying some of the assumptions in the HERS and NBIAS analyses that were used to develop the projections of the potential impacts of highway capital investment presented in Chapter 7, which were used as input to the selected capital investment scenario estimates reported in Chapter 8. Subsequent sections within this chapter explore comparable information regarding the assumptions underlying the analyses developed using TERM.

The first part of this section considers the potential impacts that new technology could have on changing the baseline highway investment/performance relationships described in Chapter 7. This includes an analysis of the potential impacts of alternative deployment rates for selected operations strategies and intelligent transportation systems (ITS). The potential impacts of modifying pavement technologies and management practices to significantly extend the expected lives of reconstruction and resurfacing improvements is also explored. The second part of this section analyzes the potential impacts of alternative assumptions regarding future highway travel volumes, both in terms of highway travel demand and the elasticity of that demand with respect to changes in user costs. The third part of this section explores the effects of various economic assumptions, including fuel prices, the costs associated with different types of capital improvements, and the rate at which future benefits are discounted in constant dollar terms. This is followed by a discussion of the valuation of non-monetary benefits, including those associated with saving lives, saving time, and improving reliability. The last part of this section considers the potential impact of aging bridges on long term bridge rehabilitation and replacement needs.

It is important to note that the alternative investment levels identified in this section only consider those types of capital investments that are currently modeled in either HERS or NBIAS, which are reflected in the analyses presented in Chapter 7. These estimates do not reflect the full range of investments considered in the selected highway and bridge capital investment scenarios presented in Chapter 8, which combine estimates for HERS-derived, NBIAS-derived, and non-modeled components.

Each of the exhibits presented in this section reflects the results of alternative analyses developed using either HERS or NBIAS; the results obtained from the two models are not combined, even in cases where the comparable sensitivity analyses were performed in both models. In order to fully reconstruct a Chapter 8 scenario using input from this section, it would be necessary to combine a modified HERS-derived component with an NBIAS-derived component, and to re-estimate the non-modeled component of the scenario in the manner described in Chapter 8.

Potential Impacts of Technological Advances

As described in Chapter 7, the HERS analysis considers the potential impact of current and future ITS deployments and operations strategies on highway conditions and performance. Appendix A includes more information on the types of strategies considered, including those targeted at arterial management (upgraded

What are the costs associated with the alternative deployment strategies identified in this section?

Q&A

The alternative deployment strategies 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 average annual capital cost of new deployments associated with the baseline existing deployment trends scenario is $142 million (in 2006 dollars). The estimated average annual operating and maintenance cost relating to these new deployments is $271 million. The average annual capital and operating costs related to existing infrastructure (including traffic signal replacement) over the 2007 to 2026 period are estimated to be $1.8 billion and $2.4 billion, respectively. These costs are not included in the alternative HERS-related spending levels described in Chapter 7, or the HERS-derived components of the capital investment scenarios presented in Chapter 8; the capital portion of these costs were assumed to be captured in by the adjustment for non-modeled improvement types described in Chapter 8.

The alternative strategy assuming **no additional deployments** was analyzed by increasing the funding targets analyzed in HERS by the amount of the capital and operating costs related to new deployments identified above as part of the baseline scenario. For each alternative funding level analyzed in HERS, the budget for capacity expansion and system rehabilitation was increased by an amount equating to $413 million annually, stated in constant 2006 dollars.

The estimated average annual capital costs of new deployments associated with both the **aggressive deployment** strategy is $1.9 billion stated in 2006 dollars. Taking into account the additional operating and maintenance costs related to these new deployments less savings associated with existing infrastructure that would be replaced, the average annual cost associated with this strategy is $3.4 billion higher than the baseline strategy. To analyze this strategy, the budget in HERS for capacity expansion and system rehabilitation was reduced by this amount.

The **full deployment** strategy assumes the same deployments as the aggressive deployment strategy, but assumes they would be implemented immediately, rather than spread out over 20 years. This would increase the total operating and maintenance costs within the 2007 to 2006 period, so that the estimated average annual cost associated with this strategy would be $4.5 billion higher than the baseline strategy, stated in constant 2006 dollars. These costs were deducted from the budget in HERS for capacity expansion and system rehabilitation in order to analyze this strategy.

Note that the costs shown above reflect only the particular types of improvements described in Appendix A, and thus represent a subset of total operations deployments that are expected to occur.

signal control, emergency vehicle signal preemption, electronic roadway monitoring, variable message signs), freeway management (ramp metering, electronic roadway monitoring, variable message signs, integrated corridor management, and variable speed limits), incident management (incident detection, verification, and response), and traveler information (511 systems and advanced in-vehicle navigation systems with real-time traveler information enabled by Vehicle-Infrastructure Integration deployment).

The assumptions reflected in the baseline analyses presented in Chapters 7 and 8 are consistent with those identified for the "Continuation of Existing Deployment Trends" scenario described in Appendix A. This section includes an analysis of the potential impacts of stopping all new deployments by examining the subset of this deployment scenario that focuses on the costs associated with existing deployments only. This section also includes analyses of more robust deployment strategies.

The "Aggressive Deployment" scenario described in Appendix A assumes an accelerated pace of deployment above existing trends, along with more advanced forms of operations strategies than are considered in the baseline. The "Full Deployment" scenario illustrates the maximum potential impact of the strategies and technologies modeled in HERS on highway operational performance.

The pavement performance and capital improvement cost assumptions reflected in the baseline HERS analyses in Chapters 7 and 8 are intended to be consistent with current pavement management practices, and do not make any explicit assumptions regarding changes in pavement technology. To the extent that technological improvements can extend the life of pavement improvements and/or reduce their life-cycle costs, this would benefit both highway agencies and system users. This section includes an analysis of the 20-year system performance implications of extending pavement lives by one-third.

The NBIAS model is not currently equipped to readily explore the potential impacts of new technologies.

Operations/ITS Deployments

While HERS can not currently directly compare the relative benefits and costs of increased operational deployments versus lane additions in a particular location, the model can be used to look at such tradeoffs on a systemwide basis by varying the amount of funding set aside to support the deployment of operations strategies and ITS within an overall fixed budget level. *Exhibit 10-1* compares the baseline assumption of a continuation of existing deployment trends with three alternatives scenarios: one assuming no additional deployments, an aggressive scenario assuming that the adoption of ITS infrastructure and operations strategies would accelerate in the future, and a hypothetical scenario that assumes full, immediate deployment of selected operations/ITS strategies in all urban areas. Appendix A includes more information on how these scenarios were defined. *Exhibit 10-1* uses adjusted average user costs as a proxy for changes in the overall performance of the highway system; as defined in Chapter 7, this measure excludes taxes and is normalized to offset the impacts of projected future changes in fuel economy.

No Additional Deployments Alternative

Exhibit 10-1 shows that, if no additional operations deployments were made, adjusted average user costs would be higher than the baseline values at all funding levels, regardless of whether these investments were supported by a fixed rate user financing mechanism or a variable rate financing mechanism. For example, while the baseline analyses assuming fixed rate user financing had projected a 2.9 percent reduction in adjusted average user costs if combined public and private highway capital investment were to grow by 7.45 percent annually in constant dollar terms, the alternative—no additional deployments—projects a reduction of only 2.7 percent. This suggests that highway users would be better off if existing operations/ITS deployment trends were to continue than if this funding were to be redirected toward the types of system expansion and pavement rehabilitation improvements modeled in HERS. It should be noted that, based on projected travel volumes for 2026, each 1-percent decline in user costs would generate savings of approximately $40 billion annually to system users.

Assuming fixed rate user financing and a suspension of further ITS deployments, HERS projects that a 3.30 percent annual constant dollar increase in spending would be required to maintain adjusted user costs at 2006 levels. This is higher than the 3.07 percent annual growth figure computed for the baseline to reach this target. *Exhibit 10-1* also shows that the spending level associated with maintaining adjusted average user costs in a variable rate user financing system would be higher if no additional operations deployments were to occur.

The minimum benefit-cost ratio cutoffs identified in *Exhibit 10-1* for each level of investment represent the benefit-cost ratio of the least attractive project that would be implemented at that level of investment. The benefit-cost ratios associated with the baseline analyses and the alternative analyses for no additional deployments were relatively close to one another. The spending levels associated with a minimum benefit-cost ratio of 1.0 for the types of capital improvements modeled in HERS were the same in both cases, $111.5 billion assuming fixed rate user financing and $79.5 billion assuming variable rate user financing. As noted earlier, these figures exclude the types of investments modeled in NBIAS, as well as capital improvement types that are not currently modeled.

Exhibit 10-1

Impact of Alternative Operations Strategies Deployment Rate Assumptions on Selected Indicators (for Different Possible Funding Levels and Financing Mechanisms)

Annual Percent Change Relative to 2006	Average Annual Spending Modeled in HERS (Billions of 2006 Dollars)*	Percent Change in Adjusted Average User Cost, 2026 Compared With 2006: Deployment Rate Assumption				Minimum Benefit-Cost Ratio Cutoff: Deployment Rate Assumption			
		Baseline	Alternative			Baseline	Alternative		
		Existing Trends	No Additional	Aggressive	Full	Existing Trends	No Additional	Aggressive	Full
Assuming Fixed Rate User Financing									
7.45%	$111.5	-2.9%	-2.7%	-3.4%	-3.3%	**1.00**	**1.00**	1.03	1.06
6.41%	$98.6	-2.3%	-2.0%	-2.7%	-2.6%	**1.20**	1.22	1.24	1.26
5.03%	$84.0	-1.4%	-1.1%	-1.8%	-1.7%	**1.50**	1.51	1.58	1.61
4.55%	$79.5	-1.0%	-0.8%	-1.5%	-1.3%	1.62	1.62	1.68	1.72
4.17%	$76.1	-0.8%	-0.6%	-1.2%	-1.0%	1.71	1.72	1.80	1.84
3.30%	$69.0	-0.2%	0.0%	-0.6%	-0.4%	1.93	1.94	2.01	2.08
3.07%	$67.2	**0.0%**	0.2%	-0.4%	-0.2%	1.98	1.99	2.08	2.15
2.93%	$66.2	0.1%	0.3%	-0.3%	-0.1%	2.02	2.03	2.14	2.20
1.67%	$57.6	1.0%	1.2%	0.6%	0.8%	2.42	2.40	2.57	2.65
0.83%	$52.6	1.5%	1.7%	1.2%	1.4%	2.70	2.69	2.89	2.97
0.34%	$50.0	1.8%	2.1%	1.6%	1.8%	2.86	2.85	2.94	3.16
0.00%	**$48.2**	2.1%	2.3%	1.8%	2.0%	2.89	2.90	2.96	3.31
-0.78%	$44.4	2.6%	2.8%	2.3%	2.6%	2.94	2.95	3.01	3.39
-1.37%	$41.8	3.0%	3.2%	2.7%	3.0%	2.99	3.00	3.06	3.43
-4.95%	$29.5	5.2%	5.4%	5.2%	5.5%	3.24	3.26	3.31	3.78
-7.64%	$23.2	6.7%	6.9%	6.8%	7.1%	3.43	3.45	3.52	4.07
7.61%	$113.7			-3.5%				**1.00**	
7.72%	$115.2				-3.4%				**1.00**
Assuming Variable Rate User Financing									
5.03%	$84.0				-3.3%				1.01
4.55%	$79.5	-2.7%	-2.5%	-3.1%	-3.1%	**1.00**	**1.00**	1.05	1.08
4.17%	$76.1	-2.5%	-2.4%	-3.0%	-2.9%	1.06	1.06	1.11	1.15
3.30%	$69.0	-2.1%	-2.0%	-2.6%	-2.5%	**1.20**	1.20	1.27	1.32
3.07%	$67.2	-2.0%	-1.9%	-2.5%	-2.3%	1.24	1.24	1.31	1.36
2.93%	$66.2	-2.0%	-1.8%	-2.4%	-2.3%	1.26	1.26	1.34	1.39
1.67%	$57.6	-1.4%	-1.3%	-1.8%	-1.7%	**1.50**	1.50	1.62	1.69
0.83%	$52.6	-1.0%	-0.9%	-1.4%	-1.2%	1.71	1.70	1.84	1.91
0.34%	$50.0	-0.8%	-0.6%	-1.1%	-1.0%	1.82	1.81	1.99	2.05
0.00%	**$48.2**	-0.6%	-0.5%	-1.0%	-0.8%	1.90	1.89	2.07	2.16
-0.78%	$44.4	-0.3%	-0.1%	-0.6%	-0.4%	2.12	2.11	2.31	2.40
-1.37%	$41.8	**0.0%**	0.1%	-0.3%	-0.1%	2.25	2.24	2.35	2.59
-4.95%	$29.5	1.6%	1.7%	1.4%	1.7%	2.42	2.40	2.53	2.87
-7.64%	$23.2	2.6%	2.7%	2.6%	2.9%	2.55	2.53	2.68	3.08
4.87%	$82.4			-3.3%				**1.00**	
5.04%	$84.1				-3.3%				**1.00**

** Of the $78.7 billion of total capital expenditures for highways and bridges in 2006, $48.2 billion (61.3 percent) was used for types of capital improvements modeled in HERS. The amounts shown represent the average annual investment over 20 years that would occur if spending for these types of improvements grows annually by the percentage shown in each row in constant dollar terms.*

Source: Highway Economic Requirements System.

Aggressive Deployments Alternative

Exhibit 10-1 shows that the aggressive operations/ITS deployment scenario would result in lower adjusted average user costs at most of the combined levels of public and private capital spending that were analyzed. If funding levels were maintained somewhere near base year 2006 levels in constant dollars, or if they were increased above that level, then system users would benefit from significant increases in these types of deployments, even if this investment came at the expense of reduced spending on other types of highway improvements. Assuming that a fixed rate user financing mechanism was utilized, adjusted average user costs could be maintained at base year 2006 levels if combined public and private spending rose at a rate somewhere between 1.67 and 2.93 percent, compared to the growth rate of 3.07 percent computed for the baseline. Assuming variable rate user financing, the baseline analyses projected that adjusted average user costs could be maintained even if highway capital spending fell by 1.37 annually in constant dollar terms; under the aggressive deployments scenario this measure could be maintained at an even lower spending level.

Exhibit 10-1 also shows that, at the lower end of the range of the spending levels analyzed, shifting funding away from the types of system expansion and system rehabilitation actions modeled in HERS toward increased operational deployments would not be advantageous. Assuming fixed rate user financing, if combined public and private investment were to decline by 4.95 percent annually in constant dollar terms over 20 years, adjusted average user costs would increase by approximately 5.2 percent in 2026 relative to 2006 for both the aggressive deployment scenario and the existing deployment trends assumed in the baseline. If combined public and private capital spending were to decline by 7.64 percent annually, adjusted average highway user costs would be higher under the aggressive deployments scenario. This suggests that if available funding were constrained to that extent, then cutting spending on system expansion and system rehabilitation even further to accommodate a significant increase in ITS deployments would not be economically justified. Assuming variable rate user financing, the relative returns associated with aggressive operations deployments would be higher than those in the baseline unless combined public and private capital spending were to decline by 7.64 percent or more per year.

Assuming fixed rate user financing, the baseline analyses presented in Chapter 7 identified the level of investment associated with a minimum benefit-cost ratio of 1.0 to be $111.5 billion in constant 2006 dollars for the types of capital improvements modeled in HERS. Under the aggressive deployment scenario, HERS identifies even more potentially cost beneficial investments, so that the minimum benefit-cost ratio associated with this funding level would be 1.03. An average annual investment level of $113.7 billion would be associated with a benefit-cost ratio of 1.00 under this scenario. This finding suggests that the types of operations strategies and ITS deployments considered as part of this scenario are complementary to widening options in some circumstances; in some cases, expanding a facility while simultaneously deploying advanced operations technology can yield more benefits than could be achieved by either action alone.

For the variable rate user financing version of the baseline HERS analyses, an average annual investment level of $79.5 billion in constant 2006 dollars was associated with a minimum benefit-cost ratio cutoff of 1.00. Under the aggressive deployment scenario, the benefit-cost ratio associated with this level of investment would be 1.05. This suggests that applying congestion pricing in conjunction with the aggressive deployment of operations strategies and technology can increase the effectiveness of widening actions, where such actions are economically justified.

Full Deployments Alternative

Exhibit 10-1 shows that the full deployment alternative would not be as beneficial to system users as the aggressive deployment alternative described above. For every funding level analyzed, average user costs would be lower under the aggressive deployment scenario, which assumes a gradual adoption of new technologies, than the full deployment scenario which assumes the immediate deployment of these same technologies. This suggests that fully front-loading these operations/ITS deployments into the first 5 years analyzed by HERS at the expense of the system expansion and system rehabilitation improvements that would otherwise have been funded would create some system performance problems that would not be fully compensated for over time. The more gradual adoption of these same technologies assumed under the aggressive deployment alternative would appear to be a more effective approach.

It should be noted that the full deployments scenario would produce superior results to the baseline existing deployment trends assumption at higher levels of investment assuming fixed rate user financing. Assuming variable rate user financing, adjusted average user costs would be lower in this alternative than in the baseline, unless funding were to decline significantly in constant dollar terms below base year 2006 levels.

Exhibit 10-1 also shows that the minimum benefit-cost ratios associated with the full deployment alternative were higher than those for the baseline or the other alternatives that were analyzed. This appears to be a side effect of the front-loading of deployments under this scenario, because deferring a significant amount of system expansion and pavement rehabilitation actions in the first 5 years would result in additional system deterioration in these areas which would in turn cause the benefit-cost ratios of capital improvements aimed at addressing these deficiencies in later years to be higher.

Pavement Technology

Significant advances have been made in recent years in the development of long-life asphalt and concrete pavements. As these advanced materials and improved construction techniques are adopted more broadly, the average service life of pavements is expected to continue to increase. While some of these materials have higher initial costs than those widely used today, further research is ongoing to bring down these costs. In addition, the widespread adoption of improved construction management, scheduling, and procurement techniques could improve the efficiency of the construction process, thus reducing the overall costs associated with implementing a pavement improvement project.

Within the HERS modeling framework, extending pavement lives can be expected to have the following major effects: (1) pavement improvements would generate a longer stream of lifetime benefits, potentially increasing their benefit-cost ratios; (2) resurfacing or reconstruction actions taken in conjunction with widening improvements would generate a longer stream of lifetime benefits; (3) pavement improvements would be needed less frequently, potentially freeing up resources to be used for capacity expansion within a fixed budget level; and (4) the negative effects of deferring a pavement action would be smaller because pavement deterioration between the 5-year periods analyzed would be less severe.

The information presented in *Exhibit 10-2* represents the potential impacts of improved pavement technology under a hypothetical scenario that assumes that, starting immediately, the pavement lives associated with all new pavement reconstruction and reconstruction actions would extend one-third longer than is assumed in the baseline HERS analyses. Assuming fixed rate user financing, the baseline analyses presented in Chapter 7 identified the level of investment associated with a minimum benefit-cost ratio of 1.0 to be $111.5 billion in constant 2006 dollars. Longer pavement lives would tend to increase the benefits associated with each pavement improvement that is implemented, so the minimum benefit-cost ratio associated with this funding level would be 1.05; an average annual investment level of $115.0 billion would be associated with a benefit-cost ratio of 1.00 under this scenario.

For the variable rate user financing version of the baseline analyses, an average annual investment level of $79.5 billion in constant 2006 dollars was associated with a minimum benefit-cost ratio cutoff of 1.00. Assuming longer pavement lives, HERS projects an average annual investment level of $80.1 billion could be utilized in a cost-beneficial manner.

Exhibit 10-2

Impact of Alternative Pavement Life Assumptions on Selected Indicators (for Different Possible Funding Levels and Financing Mechanisms)

Annual Percent Change Relative to 2006	Average Annual Spending Modeled in HERS (Billions of 2006 Dollars)*	Baseline: Percent Change, 2026 Compared With 2006: Adjusted Average User Costs	Baseline: Average Delay Per VMT	Baseline: Average IRI	Baseline: Minimum Benefit-Cost Ratio	Alternative: Pavement Lives Extended by 1/3: Percent Change, 2026 Compared With 2006: Adjusted Average User Costs	Alternative: Average Delay Per VMT	Alternative: Average IRI	Alternative: Minimum Benefit-Cost Ratio Cutoff
Assuming Fixed Rate User Financing									
7.45%	$111.5	-2.9%	-10.2%	-23.1%	**1.00**	-3.1%	-10.9%	-25.5%	1.05
6.41%	$98.6	-2.3%	-6.9%	-18.1%	**1.20**	-2.4%	-7.5%	-20.8%	1.25
5.03%	$84.0	-1.4%	-2.7%	-11.2%	**1.50**	-1.5%	-3.1%	-13.6%	1.56
4.55%	$79.5	-1.0%	-1.1%	-8.6%	1.62	-1.2%	-1.5%	-11.1%	1.68
4.17%	$76.1	-0.8%	**0.0%**	-6.6%	1.71	-0.9%	-0.3%	-9.1%	1.77
3.30%	$69.0	-0.2%	2.9%	-2.3%	1.93	-0.3%	2.3%	-4.3%	2.00
3.07%	$67.2	**0.0%**	3.6%	-1.0%	1.98	-0.2%	2.9%	-3.0%	2.06
2.93%	$66.2	0.1%	3.9%	**0.0%**	2.02	-0.1%	3.4%	-2.3%	2.10
1.67%	$57.6	1.0%	7.0%	7.9%	2.42	0.8%	6.5%	5.9%	2.49
0.83%	$52.6	1.5%	9.1%	12.4%	2.70	1.4%	8.8%	10.2%	2.76
0.34%	$50.0	1.8%	10.3%	15.1%	2.86	1.7%	10.2%	12.9%	2.93
0.00%	$48.2	2.1%	11.1%	17.1%	2.89	1.9%	11.1%	14.8%	2.95
-0.78%	$44.4	2.6%	13.5%	20.8%	2.94	2.4%	13.4%	18.6%	3.01
-1.37%	$41.8	3.0%	15.1%	23.8%	2.99	2.8%	15.1%	21.5%	3.04
-4.95%	$29.5	5.2%	22.6%	42.0%	3.24	5.1%	22.5%	40.1%	3.30
-7.64%	$23.2	*	27.5%	53.1%	3.43	6.5%	27.0%	51.6%	3.50
7.71%	$115.0					-3.3%	-11.8%	-26.7%	**1.00**
Assuming Variable Rate User Financing									
4.55%	$79.5	-2.7%	-12.3%	-19.3%	**1.00**				
4.17%	$76.1	-2.5%	-11.6%	-17.6%	1.06	-2.7%	-11.7%	-20.4%	1.07
3.30%	$69.0	-2.1%	-10.3%	-14.0%	**1.20**	-2.3%	-10.3%	-16.8%	1.21
3.07%	$67.2	-2.0%	-9.9%	-13.0%	1.24	-2.2%	-9.9%	-15.9%	1.25
2.93%	$66.2	-2.0%	-9.8%	-12.5%	1.26	-2.1%	-9.7%	-15.4%	1.27
1.67%	$57.6	-1.4%	-7.7%	-6.7%	**1.50**	-1.5%	-7.7%	-9.4%	1.53
0.83%	$52.6	-1.0%	-6.5%	-2.6%	1.71	-1.1%	-6.5%	-5.2%	1.74
0.34%	$50.0	-0.8%	-5.8%	**0.0%**	1.82	-0.9%	-5.8%	-2.6%	1.86
0.00%	$48.2	-0.6%	-5.3%	1.8%	1.90	-0.7%	-5.3%	-0.8%	1.94
-0.78%	$44.4	-0.3%	-4.4%	5.7%	2.12	-0.4%	-4.4%	3.1%	2.15
-1.37%	$41.8	**0.0%**	-3.7%	8.4%	2.25	-0.1%	-3.6%	5.9%	2.30
-4.95%	$29.5	1.6%	**0.0%**	25.2%	2.42	1.4%	**0.0%**	23.0%	2.48
-7.64%	$23.2	2.6%	1.4%	37.1%	2.55	2.5%	1.3%	35.2%	2.62
4.62%	$80.1					-2.9%	-12.4%	-22.4%	**1.00**

* *Of the $78.7 billion of total capital expenditures for highways and bridges in 2006, $48.2 billion (61.3 percent) was used for types of capital improvements modeled in HERS. The amounts shown represent the average annual investment over 20 years that would occur if spending for these types of improvements grows annually by the percentage shown in each row in constant dollar terms.*

Source: Highway Economic Requirements System.

Relative to the baseline analyses, for all levels of investment that were analyzed, the hypothetical scenario assuming longer pavement lives would result in larger reductions in the average International Roughness Index (IRI) by 2026. The level of investment required to maintain average IRI at 2006 levels would be lower for both the fixed rate user financing and variable rate user financing versions of the scenario. For the fixed rate version of the scenario, average delay per VMT was lower for all levels of investment that were analyzed. While improvements in pavement technology would not significantly reduce congestion, extending the service life of pavements would tend to reduce the frequency of pavement improvements, freeing resources to be directed to capacity expansion.

It is important to note that extending pavement lives would have additional positive impacts beyond the 20-year analysis period addressed in this report. While the benefit-cost procedures in HERS take into account benefits for the full expected life of a project, the application of a 7 percent annual discount rate as part of the analysis significantly reduces the degree to which long-term benefits influence the benefit-cost ratios computed for each potential project. The theoretical basis for the application of a discount rate is discussed later in this section, along with a sensitivity analysis of the impacts of assuming higher or lower discount rates.

Alternative Estimates of Travel Demand

States provide forecasts of future vehicle miles traveled (VMT) for each individual Highway Performance Monitoring System (HPMS) sample highway section. As discussed in Chapter 9, 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 occur at this level only if pavement and capacity improvements made on the segment over the 20-year analysis period are sufficient to maintain highway user costs at 2006 levels. If HERS predicts that highway user costs will deviate from baseline 2006 levels on a given highway segment, the model's travel demand elasticity features will modify the baseline VMT growth projections from HPMS.

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

Q&A

What are some of the technical limitations associated with the analysis of alternative travel growth rates included in this section?

One of the strengths of the State-provided VMT forecasts used in the baseline analysis is their geographic specificity. As separate forecasts are provided for the more than 100,000 HPMS sample sections, this provides States with the opportunity to take into account specific local factors that might influence travel growth on a particular highway section, and to reflect the assumptions they are making in their own long range planning regarding future travel patterns for particular routes or corridors. This allows for more refined analyses of projected future investment/performance relationships for particular system components than could be conducted based on regional or statewide travel estimates.

The analyses of alternative travel growth rates presented in this section use the HPMS forecasts as a starting point, but modify them up or down uniformly on a national basis. In reality, if VMT were to grow faster or slower than what has been projected by the States, these differences would not be uniform, and could be heavily concentrated in particular corridors, regions, or States; this could significantly impact the level of investment that might be required to achieve particular systemwide performance targets.

As the HERS analysis is conducted at the highway section level, it is important that the input data it uses take into account the specific characteristics of that section. As, the analyses of alternative VMT growth rates presented in this section deviate from this approach by applying nationwide adjustments, they should be considered less reliable.

demand elasticity procedures in HERS do not accurately predict how highway users will respond to changes in costs.

This section includes an analysis of three alternative constant levels of service VMT forecasts: one based on historic VMT growth rates, one based on projected population growth, and one assuming no future VMT growth on any highway section. This section also examines the effects of increasing the travel demand elasticity values applied in HERS, which would assume a greater sensitivity of drivers to changes in user costs than is currently reflected in the baseline scenarios.

Historic Travel Growth

As indicated in Chapter 9, the State-supplied VMT growth projections in HPMS for 2006 to 2026 average 1.84 percent per year, well below the 2.52 percent average annual VMT growth rate observed from 1986 to 2006. As noted in Chapter 4, however, the level of service on highways in the United States in terms of traveler delay and overall congestion 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 reflect a declining level of service, rather than the constant level of service assumed by HERS.

The "Historic Rates" values identified in *Exhibit 10-3* reflect the effects of modifying the HPMS forecasts to assume that the average annual VMT growth rate of 2.52 percent over the last 20 years represents the growth that would occur if a constant level of service were sustained for the next 20 years. Higher VMT would increase both overall congestion levels and the rate of pavement deterioration, which would result in higher adjusted average highway user costs for any given level of capital investment. Assuming fixed rate user financing, HERS projects that the annual constant dollar spending increase required to maintain adjusted average user costs lies in a range between 6.41 percent and 7.45 percent for the historic VMT alternative; this is significantly higher than the 3.07 percent annual growth rate associated with meeting this target in the baseline analyses. Assuming variable rate user financing, HERS projects that maintaining adjusted average user costs at 2006 levels would require an increase in combined public and private spending of between 1.67 percent and 2.93 percent annually. In contrast, the baseline analyses assuming variable rate user financing had projected that this target could be achieved even if spending fell by 1.37 percent per year in constant dollar terms.

The minimum benefit-cost ratios associated with the historic travel alternative are significantly higher than those identified for comparable investment levels in the baseline analyses for both the fixed rate and variable rate user financing options; the presence of more system users on all facilities would increase the potential total user benefits of improving each individual facility. While the baseline analyses identified an average annual constant dollar amount of $111.5 billion of potentially cost beneficial investments assuming fixed rate user financing, this amount would increase to $148.9 billion for the higher VMT growth rates. For the analyses reflecting variable rate user financing, the average annual combined public and private spending level associated with a 1.00 minimum benefit-cost ratio would be $99.9 billion in constant 2006 dollars assuming higher VMT growth, well above the $79.5 billion figure identified in the baseline analyses.

Population Growth

Annual VMT growth as reported by the States in HPMS has trended downward in recent years; annual growth rates were below 1 percent in 2005 and 2006, and are expected to be even lower in 2007 and 2008. While some of this decline can be attributed to higher fuel prices, which would not be relevant to a constant price VMT forecast, or to broader macroeconomic trends that are temporary in nature, some of this decline may be the result of fundamental changes in the underlying demand for highway transportation. To the extent that the factors that have led VMT growth per capita to rise for many years have permanently abated,

Exhibit 10-3

Impact of Alternative Constant Price Travel Growth Forecasts on Selected Indicators (for Different Possible Funding Levels and Financing Mechanisms)

Annual Percent Change Relative to 2006	Average Annual Spending Modeled in HERS (Billions of 2006 Dollars)*	Percent Change in Adjusted Average User Cost, 2026 Compared With 2006:				Minimum Benefit-Cost Ratio Cutoff:			
		Constant Price VMT Growth Assumption				Constant Price VMT Growth Assumption			
		Baseline	Alternative			Baseline	Alternative		
		State-Projected	Historic Rates	Population-Driven	No Growth	State-Projected	Historic Rates	Population-Driven	No Growth
Assuming Fixed Rate User Financing									
7.45%	$111.5	-2.9%	-0.6%			**1.00**	1.50		
6.41%	$98.6	-2.3%	0.3%			**1.20**	1.78		
5.03%	$84.0	-1.4%	1.5%			**1.50**	2.20		
4.55%	$79.5	-1.0%	1.9%			1.62	2.33		
4.17%	$76.1	-0.8%	2.2%	-3.5%		1.71	2.45	1.02	
3.30%	$69.0	-0.2%	2.9%	-3.1%		1.93	2.76	1.18	
3.07%	$67.2	**0.0%**	3.1%	-3.0%		1.98	2.85	1.23	
2.93%	$66.2	0.1%	3.2%	-2.9%		2.02	2.92	1.26	
1.67%	$57.6	1.0%	4.3%	-2.3%		2.42	3.26	1.51	
0.83%	$52.6	1.5%	5.0%	-1.9%		2.70	3.31	1.70	
0.34%	$50.0	1.8%	5.4%	-1.6%	-3.4%	2.86	3.34	1.83	1.03
0.00%	**$48.2**	2.1%	5.6%	-1.4%	-3.4%	2.89	3.36	1.91	1.08
-0.78%	$44.4	2.6%	6.2%	-1.0%	-3.1%	2.94	3.43	2.11	1.20
-1.37%	$41.8	3.0%	6.7%	-0.7%	-2.9%	2.99	3.48	2.30	1.31
-4.95%	$29.5	5.2%	9.2%	1.0%	-1.6%	3.24	3.77	2.78	2.04
-7.64%	$23.2	6.7%	10.8%	2.2%	-0.8%	3.43	3.99	2.97	2.42
9.84%	$148.9		-2.5%				**1.00**		
4.28%	$77.1			-3.5%				**1.00**	
0.55%	$51.1				-3.5%				**1.00**
Assuming Variable Rate User Financing									
6.41%	$98.6		-1.9%				1.02		
5.03%	$84.0		-1.2%				1.26		
4.55%	$79.5	-2.7%	-1.0%			**1.00**	1.34		
4.17%	$76.1	-2.5%	-0.8%			1.06	1.41		
3.30%	$69.0	-2.1%	-0.3%			**1.20**	1.60		
3.07%	$67.2	-2.0%	-0.2%			1.24	1.66		
2.93%	$66.2	-2.0%	-0.1%			1.26	1.69		
1.67%	$57.6	-1.4%	0.5%	-3.4%		**1.50**	1.99	1.02	
0.83%	$52.6	-1.0%	1.0%	-3.1%		1.71	2.23	1.16	
0.34%	$50.0	-0.8%	1.3%	-2.9%		1.82	2.36	1.25	
0.00%	**$48.2**	-0.6%	1.4%	-2.8%		1.90	2.45	1.32	
-0.78%	$44.4	-0.3%	1.8%	-2.5%		2.12	2.49	1.46	
-1.37%	$41.8	**0.0%**	2.1%	-2.3%		2.25	2.52	1.58	
-4.95%	$29.5	1.6%	3.8%	-1.0%	-2.8%	2.42	2.69	2.13	1.60
-7.64%	$23.2	2.6%	5.0%	-0.1%	-2.1%	2.55	2.83	2.26	1.94
6.52%	$99.9		-2.0%				**1.00**		
1.82%	$58.6			-3.5%				**1.00**	
-1.73%	$40.3				-3.6%				**1.00**

* *Of the $78.7 billion of total capital expenditures for highways and bridges in 2006, $48.2 billion (61.3 percent) was used for types of capital improvements modeled in HERS. The amounts shown represent the average annual investment over 20 years that would occur if spending for these types of improvements grows annually by the percentage shown in each row in constant dollar terms.*

Source: Highway Economic Requirements System.

projected population growth could serve as a proxy for constant price VMT growth. The Census Bureau's population forecasts for 2026 relative to 2006 equate to an average annual growth rate of 0.95 percent.

The "Population-Driven" values identified in *Exhibit 10-3* reflect the effects of modifying the HPMS forecasts to assume that that VMT per capita will remain unchanged in the future, and that projected population growth years represents the growth that would occur if a constant level of service were sustained for the next 20 years. Reducing the VMT growth rate would tend to reduce congestion levels and the rate of pavement deterioration relative to what was projected in the baseline analyses, which assumed a constant price VMT growth of 1.84 percent per year. Assuming population-driven VMT growth, HERS projects that adjusted average user costs in 2026 could be reduced below base year levels if combined public and private highway capital investment were sustained at base year 2006 levels, regardless of whether or not variable rate user charges were imposed.

The minimum benefit-cost ratios associated with the population-driven travel alternative are significantly lower than those identified for comparable investment levels in the baseline analyses for both the fixed rate and variable rate user financing options. The presence of fewer system users on all facilities would decrease the potential total user benefits of improving each individual facility. While the baseline analyses identified an average annual constant dollar amount of $111.5 billion of potentially cost beneficial investments assuming fixed rate user financing, this amount would decrease to $77.1 billion assuming lower VMT growth. For the analyses reflecting variable rate user financing, the average annual combined public and private spending level associated with a 1.00 minimum benefit-cost ratio would be $58.6 billion in constant 2006 dollars assuming lower travel growth, well below the $79.5 billion figure identified in the baseline analyses.

No Growth

In order to isolate future investment needs associated with accommodating current system users rather than costs associated with accommodating future travel growth, it is useful to compare the baseline analyses to a no growth option. The "No-Growth" values identified in *Exhibit 10-3* reflect the effects of modifying the HPMS VMT forecasts for each sample highway section so that they are equal to current travel volumes. This approach effectively assumes that the only changes in VMT that would occur in the future would be driven by drivers' responses to changes in user costs, rather than by population growth, economic growth, or other factors.

Assuming a constant price VMT growth forecast of zero, the minimum benefit-cost ratios associated with each alternative investment level would be lower than those for the baseline analyses for both the fixed rate and variable rate user financing options because the presence of fewer system users on all facilities would decrease the potential total user benefits of improving each individual facility. While the baseline analyses identified an average annual constant dollar amount of $111.5 billion in potentially cost beneficial investments assuming fixed rate user financing, this amount would decrease to $51.1 billion if no exogenous increase in travel demand is assumed. For the analyses reflecting variable rate user financing, the average annual combined public and private spending level associated with a 1.00 minimum benefit-cost ratio would be $40.3 billion in constant 2006 dollars for the no-growth alternative, well below the $79.5 billion figure identified in the baseline analyses. These findings suggest that a significant percentage of future investment needs are attributable to the costs of accommodating either new system users or additional travel by existing system users on a transportation network that is already over-stressed.

HERS recommends devoting a larger share of total capital investment to system rehabilitation for the no-growth alternative than for the baseline. However, the system expansion investments that are made would reduce congestion, rather than simply slowing its growth, since any new lanes added would not fill up quickly with new traffic. Adjusted average user costs would be expected to decline even if highway capital investment levels were significantly reduced below 2006 levels in constant dollar terms.

Elasticity Values

HERS applies both short-run and long-run travel demand elasticity procedures in its analysis, using assumed input values for these parameters. 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 (-0.4 for short-run elasticity and -0.8 for long-run elasticity) are lower than the comparable parameter values that were used in the 2004 C&P Report (-0.6 for short-run elasticity and -1.2 for long-run elasticity). Appendix A includes a description of the HERS elasticity procedures. Higher elasticity values would cause the changes in VMT associated with increases or decreases in highway user costs to be larger in magnitude. It should be noted that the HERS procedures apply these elasticity values to all costs that would be perceived by highway users, which would include user taxes and the effects of future changes in fuel economy. Both of these are excluded from the adjusted highway user costs statistics presented in this Chapter as a proxy for overall system conditions and performance.

Assuming fixed rate user financing, *Exhibit 10-4* shows that projected 2026 VMT would be higher for most levels of investment based on higher elasticity values assumed in the 2004 C&P Report than for the baseline analyses. This occurs because the reductions in user costs associated with increased investment would translate into higher levels of future travel growth. However, if spending were to decline by approximately 4.95 percent or more per year, or to increase by approximately 5.03 percent or more annually, the higher elasticities would result in lower projected VMT. At lower levels of investment, increased user costs would suppress some travel that would otherwise have occurred. The relatively lower projected VMT at higher levels of investment is an artifact of the way the analyses were constructed; as discussed in Chapter 7, the fixed rate user charges are set at a level sufficient to cover not only the types of investment modeled in HERS, but also proportional increases to the types of investment modeled in NBIAS and non-modeled improvement types. Consequently, at the highest levels of investment analyzed, the increase in fixed rate user charges required to support the investment would exceed the user costs savings derived from them.

Assuming variable rate user financing, *Exhibit 10-4* shows that projected 2026 VMT would be lower for all levels of investment based on higher elasticity values assumed in the 2004 C&P Report than for the baseline analyses. These analyses assume the widespread adoption of congestion pricing; the higher elasticity values would translate into lower levels of future travel growth in response to these user charges. For all levels of investment, adjusted average user costs and average delay per VMT would be lower than in the baseline analyses. Similarly, the higher elasticity values would reduce the level of investment required to maintain these performance indicators at base year levels.

The minimum benefit-cost ratios associated with the higher elasticity alternative are lower than those identified for comparable investment levels in the baseline analyses for both the fixed rate and variable rate user financing options. With fewer travelers to accommodate, the relative benefits associated with many potential capital improvements would be lower. While the baseline analyses identified an average annual constant dollar amount of $111.5 billion of potentially cost beneficial investments assuming fixed rate user financing, this amount would decrease to $100.2 billion based on higher elasticity values. For the analyses reflecting variable rate user financing, the average annual combined public and private spending level associated with a 1.00 minimum benefit-cost ratio would be $70.5 billion in constant 2006 dollars assuming higher elasticity values, compared to $79.5 billion in the baseline analyses.

Exhibit 10-4

Impact of Alternative Travel Demand Elasticity Values on Selected Indicators (for Different Possible Funding Levels and Financing Mechanisms)

Annual Percent Change Relative to 2006	Average Annual Spending Modeled in HERS (Billions of 2006 Dollars)*	Baseline: Percent Change, 2026 Compared With 2006: Adjusted Average User Costs	Baseline: Percent Change, 2026 Compared With 2006: Average Delay Per VMT	Baseline: Projected VMT in 2026 (Trillions)	Baseline: Minimum Benefit-Cost Ratio Cutoff	Alternative: Elasticity from 2004 C&P Report: Percent Change, 2026 Compared With 2006: Adjusted Average User Costs	Alternative: Percent Change, 2026 Compared With 2006: Average Delay Per VMT	Alternative: Projected VMT in 2026 (Trillions)	Alternative: Minimum Benefit-Cost Ratio Cutoff
Assuming Fixed Rate User Financing									
7.45%	$111.5	-2.9%	-10.2%	4.338	**1.00**				
6.41%	$98.6	-2.3%	-6.9%	4.349	**1.20**	-2.6%	-7.6%	4.342	1.02
5.03%	$84.0	-1.4%	-2.7%	4.358	**1.50**	-1.7%	-3.6%	4.358	1.28
4.55%	$79.5	-1.0%	-1.1%	4.359	1.62	-1.4%	-2.3%	4.360	1.38
4.17%	$76.1	-0.8%	**0.0%**	4.360	1.71	-1.2%	-1.1%	4.362	1.45
3.30%	$69.0	-0.2%	2.9%	4.360	1.93	-0.7%	1.0%	4.365	1.66
3.07%	$67.2	**0.0%**	3.6%	4.360	1.98	-0.5%	1.5%	4.366	1.73
2.93%	$66.2	0.1%	3.9%	4.360	2.02	-0.4%	1.9%	4.366	1.77
1.67%	$57.6	1.0%	7.0%	4.358	2.42	0.3%	5.1%	4.365	2.10
0.83%	$52.6	1.5%	9.1%	4.356	2.70	0.8%	7.2%	4.362	2.32
0.34%	$50.0	1.8%	10.3%	4.354	2.86	1.1%	8.3%	4.360	2.49
0.00%	**$48.2**	2.1%	11.1%	4.352	2.89	1.3%	9.0%	4.358	2.58
-0.78%	$44.4	2.6%	13.5%	4.349	2.94	1.8%	10.7%	4.353	2.62
-1.37%	$41.8	3.0%	15.1%	4.346	2.99	2.1%	12.0%	4.350	2.65
-4.95%	$29.5	5.2%	22.6%	4.322	3.24	4.1%	18.2%	4.321	2.87
-7.64%	$23.2	6.7%	27.5%	4.304	3.43	5.3%	21.7%	4.299	3.03
6.55%	$100.2					-2.6%	-8.1%	4.340	**1.00**
Assuming Variable Rate User Financing									
4.55%	$79.5	-2.7%	-12.3%	4.260	**1.00**				
4.17%	$76.1	-2.5%	-11.6%	4.260	1.06				
3.30%	$69.0	-2.1%	-10.3%	4.258	**1.20**	-2.5%	-12.9%	4.237	1.03
3.07%	$67.2	-2.0%	-9.9%	4.257	1.24	-2.4%	-12.6%	4.237	1.07
2.93%	$66.2	-2.0%	-9.8%	4.257	1.26	-2.4%	-12.4%	4.236	1.10
1.67%	$57.6	-1.4%	-7.7%	4.251	**1.50**	-1.9%	-10.8%	4.232	1.31
0.83%	$52.6	-1.0%	-6.5%	4.246	1.71	-1.5%	-9.8%	4.228	1.49
0.34%	$50.0	-0.8%	-5.8%	4.243	1.82	-1.3%	-9.2%	4.224	1.59
0.00%	**$48.2**	-0.6%	-5.3%	4.240	1.90	-1.2%	-8.9%	4.222	1.67
-0.78%	$44.4	-0.3%	-4.4%	4.235	2.12	-0.9%	-8.0%	4.216	1.83
-1.37%	$41.8	**0.0%**	-3.7%	4.231	2.25	-0.6%	-7.5%	4.212	1.96
-4.95%	$29.5	1.6%	**0.0%**	4.205	2.42	0.7%	-4.9%	4.185	2.17
-7.64%	$23.2	2.6%	1.4%	4.187	2.55	1.6%	-3.8%	4.165	2.30
3.50%	$70.5					-2.6%	-13.1%	4.237	**1.00**

* *Of the $78.7 billion of total capital expenditures for highways and bridges in 2006, $48.2 billion (61.3 percent) was used for types of capital improvements modeled in HERS. The amounts shown represent the average annual investment over 20 years that would occur if spending for these types of improvements grows annually by the percentage shown in each row in constant dollar terms.*

Source: Highway Economic Requirements System.

Alternative Economic Analysis Assumptions

The economic assumptions underlying a benefit-cost analysis can have significant impacts on its overall findings. The economic parameter values applied in HERS and NBIAS are generally based on observed conditions in 2006, and are assumed to remain constant unless otherwise specified. However, recent sharp changes in the values for some key parameters increases the uncertainty associated with these assumptions. Conducting sensitivity analyses on these types of parameters is a method for gauging the significance of the baseline assumptions by assessing their relative impact on the overall findings. This section includes an analysis of the potential impacts of significantly raising the values for three key input parameters: the fuel prices assumed in the HERS model, the highway construction costs assumed in the HERS model, and the bridge repair and rehabilitation costs assumed in the NBIAS model.

The benefit-cost analysis procedures employed in the HERS and NBIAS models also require a discount factor to be applied in order to compare the future benefit streams produced by a highway improvement with the initial cost of that improvement. For the baseline investment analyses presented in this report, a 7-percent discount rate is used in accordance with the guidelines for Federal infrastructure investment analyses under OMB Circular A-94. This section includes an analysis of the potential impacts on the HERS and NBIAS analysis of assuming two alternative discount rates: 4 percent and 10 percent.

Fuel Prices

The baseline assumption regarding fuel prices in HERS is generally consistent with the Energy Information Administration's (EIA's) reference case forecast of future fuel prices from its *Annual Energy Outlook 2008* publication. EIA identified 2006 prices of $2.63 per gallon for gasoline and $2.71 per gallon for diesel fuel; the reference case forecast through 2030 projects that costs will rise above this level in the short term, but will fall back below these levels in constant dollar terms in the long run. EIA's publication also includes a high price forecast, which projects an increase in prices by 2030 to $3.52 per gallon for gasoline and $3.80 per gallon for diesel, stated in constant 2006 dollars. The high price forecast also reflects changes to projected vehicle fuel efficiency in response to these price increases.

Exhibit 10-5 demonstrates the impact on the HERS analyses of substituting in the fuel price and vehicle fleet assumption from EIA's high price case in lieu of those from EIA's reference case. Through the operation of the HERS travel demand elasticity procedures, higher fuel prices would result in lower projections for 2026 VMT for all funding levels, regardless of the financing mechanism employed to support that level of investment. As a result of lower overall travel volumes, average delay per VMT in 2026 is projected to be lower for each level of investment analyzed assuming the high price case, relative to the comparable baseline analyses. Average IRI in 2026 is also projected to be lower under the high price case; a portion of this decline is attributable to reduced wear and tear on pavements resulting from lower VMT, but the majority is attributable to changes in HERS investment patterns. Under the high price case alternative, HERS recommends devoting a larger share of total investment to pavement rehabilitation, as the relative benefits of system expansion improvements would be lower in light of the reduced overall traffic volumes relative to the baseline.

Assuming fixed rate user financing and higher fuel prices, HERS projects that the annual constant dollar spending increase required to maintain average delay per VMT would be lower than the 4.17-percent growth figure computed for the baseline. *Exhibit 10-5* also shows that the annual spending increase associated with maintaining average IRI would be lower than the 2.93-percent growth rate computed for the baseline. Assuming variable rate user financing, HERS projects that average delay could be maintained at 2006 levels even if combined public and private highway capital investment were to decline by 7.64 percent annually under the high fuel price alternative; the comparable rate to meet this target under the base case is an annual

Exhibit 10-5

Impact of Alternative Fuel Price Assumptions on Selected Indicators (for Different Possible Funding Levels and Financing Mechanisms)

Annual Percent Change Relative to 2006	Average Annual Spending Modeled in HERS (Billions of 2006 Dollars)*	Baseline: EIA Reference Case — Percent Change, 2026 Compared With 2006: Average Delay Per VMT	Average IRI	Projected VMT in 2026 (Trillions)	Minimum Benefit-Cost Ratio Cutoff	Alternative: EIA High Price Case — Percent Change, 2026 Compared With 2006: Average Delay Per VMT	Average IRI	Projected VMT in 2026 (Trillions)	Minimum Benefit-Cost Ratio Cutoff
Assuming Fixed Rate User Financing									
7.45%	$111.5	-10.2%	-23.1%	4.34	**1.00**				
6.41%	$98.6	-6.9%	-18.1%	4.35	**1.20**	-8.4%	-19.1%	4.27	1.13
5.03%	$84.0	-2.7%	-11.2%	4.36	**1.50**	-4.4%	-11.9%	4.28	1.42
4.55%	$79.5	-1.1%	-8.6%	4.36	1.62	-3.0%	-9.7%	4.28	1.53
4.17%	$76.1	**0.0%**	-6.6%	4.36	1.71	-1.7%	-7.7%	4.28	1.61
3.30%	$69.0	2.9%	-2.3%	4.36	1.93	0.9%	-3.4%	4.28	1.83
3.07%	$67.2	3.6%	-1.0%	4.36	1.98	1.7%	-2.1%	4.28	1.89
2.93%	$66.2	3.9%	**0.0%**	4.36	2.02	2.1%	-1.5%	4.28	1.93
1.67%	$57.6	7.0%	7.9%	4.36	2.42	5.2%	6.3%	4.28	2.31
0.83%	$52.6	9.1%	12.4%	4.36	2.70	7.2%	11.2%	4.28	2.60
0.34%	$50.0	10.3%	15.1%	4.35	2.86	8.5%	13.7%	4.28	2.77
0.00%	**$48.2**	11.1%	17.1%	4.35	2.89	9.2%	15.6%	4.28	2.86
-0.78%	$44.4	13.5%	20.8%	4.35	2.94	11.4%	19.6%	4.27	2.91
-1.37%	$41.8	15.1%	23.8%	4.35	2.99	12.9%	22.6%	4.27	2.95
-4.95%	$29.5	22.6%	42.0%	4.32	3.24	20.4%	40.8%	4.25	3.21
-7.64%	$23.2	27.5%	53.1%	4.30	3.43	24.9%	52.0%	4.23	3.39
7.06%	$106.5					-10.3%	-22.1%	4.26	**1.00**
Assuming Variable Rate User Financing									
4.55%	$79.5	-12.3%	-19.3%	4.26	**1.00**				
4.17%	$76.1	-11.6%	-17.6%	4.26	1.06				
3.30%	$69.0	-10.3%	-14.0%	4.26	**1.20**	-11.2%	-14.7%	4.18	1.13
3.07%	$67.2	-9.9%	-13.0%	4.26	1.24	-10.8%	-13.7%	4.18	1.17
2.93%	$66.2	-9.8%	-12.5%	4.26	1.26	-10.6%	-13.2%	4.18	1.19
1.67%	$57.6	-7.7%	-6.7%	4.25	**1.50**	-8.6%	-7.5%	4.17	1.42
0.83%	$52.6	-6.5%	-2.6%	4.25	1.71	-7.4%	-3.4%	4.17	1.62
0.34%	$50.0	-5.8%	**0.0%**	4.24	1.82	-6.8%	-1.1%	4.17	1.74
0.00%	**$48.2**	-5.3%	1.8%	4.24	1.90	-6.3%	0.6%	4.17	1.82
-0.78%	$44.4	-4.4%	5.7%	4.23	2.12	-5.3%	4.8%	4.16	2.03
-1.37%	$41.8	-3.7%	8.4%	4.23	2.25	-4.6%	7.5%	4.16	2.17
-4.95%	$29.5	**0.0%**	25.2%	4.20	2.42	-1.3%	24.4%	4.13	2.39
-7.64%	$23.2	1.4%	37.1%	4.19	2.55	0.0%	36.4%	4.12	2.52
4.14%	$75.8					-12.5%	-18.1%	4.18	**1.00**

* *Of the $78.7 billion of total capital expenditures for highways and bridges in 2006, $48.2 billion (61.3 percent) was used for types of capital improvements modeled in HERS. The amounts shown represent the average annual investment over 20 years that would occur if spending for these types of improvements grows annually by the percentage shown in each row in constant dollar terms.*

Source: Highway Economic Requirements System.

decline of 4.95 percent. The annual spending increase associated with maintaining average IRI would be lower than the 0.34 percent growth rate computed for the baseline, assuming variable rate user financing.

The minimum benefit-cost ratios associated with EIA's high price case are lower than those identified for comparable investment levels in the baseline analyses for both the fixed rate and variable rate user financing options. With fewer travelers to accommodate, the relative benefits associated with many potential capital improvements would be lower. While the baseline analyses identified an average annual constant dollar amount of $111.5 billion of potentially cost beneficial investments under a fixed rate user financing mechanism, this amount would decline to $106.5 billion assuming higher fuel prices. For the analyses reflecting variable rate user financing, the average annual combined public and private spending level associated with a 1.00 minimum benefit-cost ratio would be $75.8 billion in constant 2006 dollars assuming higher fuel prices, compared to $79.5 billion in the baseline analyses.

Note that *Exhibit 10-5* does not include information of adjusted average user costs; this omission was intentional, as the high price case changes in fuel cost and efficiency would logically affect the base year value for this statistic, so any percentage changes from the base year would not be directly comparable between the baseline and this alternative.

Improvement Costs

The unit improvement costs used in HERS and NBIAS to calculate total investment costs, while periodically resurveyed and adjusted for inflation, are subject to uncertainty. Particularly in light of the recent sharp increases in highway construction costs discussed in Chapters 6 and 9, it is prudent to consider the impact that higher-than-expected capital improvement costs would have on the results of the baseline HERS and NBIAS analyses.

The last several editions of the C&P report have included sensitivity analyses identifying the effect of increasing all constant dollar capital improvement costs by 25 percent in constant dollar terms. This edition includes analyses of this nature, which are presented separately for HERS and NBIAS.

Alternative HERS Improvement Costs

If construction costs for all potential highway capital projects were 25 percent higher, this would limit the total number of projects that could be completed within a fixed budget level, and thus the impacts of that level of investment would be smaller. *Exhibit 10-6* demonstrates this effect, as the projected percent changes between 2006 and 2026 in adjusted average user costs, average delay per VMT, and average IRI are projected to be smaller in magnitude for this alternative relative to the base case for each level of investment analyzed.

Assuming fixed rate user financing and higher construction costs, HERS projects that the annual constant dollar spending increase required to maintain adjusted average user costs lie in a range between 4.55 percent and 5.03 percent, which is significantly higher than the 3.07-percent annual growth rate associated with meeting this target in the baseline analyses. Assuming variable rate user financing, HERS projects that maintaining adjusted average user costs at 2006 levels would require an increase in combined public and private spending of between 0.34 percent and 0.83 percent annually. In contrast, the baseline analyses assuming variable rate user financing had projected that this target could be achieved even if spending fell by 1.37 percent per year in constant dollar terms.

The minimum benefit-cost ratios associated with a 25-percent increase in highway construction costs are higher than those identified for comparable investment levels in the baseline analyses for both the fixed

Exhibit 10-6

Impact of Alternative Construction Cost Assumptions on Selected Indicators (for Different Possible Funding Levels and Financing Mechanisms)

Annual Percent Change Relative to 2006	Average Annual Spending Modeled in HERS (Billions of 2006 Dollars)*	Baseline: Percent Change, 2026 Compared With 2006: Adjusted Average User Costs	Baseline: Average Delay Per VMT	Baseline: Average IRI	Baseline: Minimum Benefit-Cost Ratio Cutoff	Alternative: Increase Costs by 25 Percent: Percent Change, 2026 Compared With 2006: Adjusted Average User Costs	Alternative: Average Delay Per VMT	Alternative: Average IRI	Alternative: Minimum Benefit-Cost Ratio Cutoff
Assuming Fixed Rate User Financing									
7.45%	$111.5	-2.9%	-10.2%	-23.1%	**1.00**	-1.8%	-5.5%	-14.4%	1.09
6.41%	$98.6	-2.3%	-6.9%	-18.1%	**1.20**	-1.1%	-2.1%	-8.6%	1.29
5.03%	$84.0	-1.4%	-2.7%	-11.2%	**1.50**	-0.1%	2.5%	-1.2%	1.57
4.55%	$79.5	-1.0%	-1.1%	-8.6%	1.62	0.2%	3.9%	1.9%	1.69
4.17%	$76.1	-0.8%	**0.0%**	-6.6%	1.71	0.5%	4.7%	4.4%	1.79
3.30%	$69.0	-0.2%	2.9%	-2.3%	1.93	1.2%	6.8%	10.7%	2.02
3.07%	$67.2	**0.0%**	3.6%	-1.0%	1.98	1.3%	7.3%	12.0%	2.08
2.93%	$66.2	0.1%	3.9%	**0.0%**	2.02	1.4%	7.7%	12.8%	2.12
1.67%	$57.6	1.0%	7.0%	7.9%	2.42	2.3%	11.5%	19.5%	2.50
0.83%	$52.6	1.5%	9.1%	12.4%	2.70	2.9%	13.9%	24.1%	2.67
0.34%	$50.0	1.8%	10.3%	15.1%	2.86	3.2%	15.3%	26.6%	2.70
0.00%	**$48.2**	2.1%	11.1%	17.1%	2.89	3.5%	16.2%	28.5%	2.72
-0.78%	$44.4	2.6%	13.5%	20.8%	2.94	4.0%	18.0%	33.1%	2.75
-1.37%	$41.8	3.0%	15.1%	23.8%	2.99	4.4%	19.2%	36.3%	2.80
-4.95%	$29.5	5.2%	22.6%	42.0%	3.24	6.5%	26.3%	52.7%	3.01
-7.64%	$23.2	6.7%	27.5%	53.1%	3.43	7.9%	30.6%	63.3%	3.18
7.94%	$118.3					-2.2%	-7.1%	-17.0%	**1.00**
Assuming Variable Rate User Financing									
4.55%	$79.5	-2.7%	-12.3%	-19.3%	**1.00**	-1.8%	-9.8%	-10.8%	1.06
4.17%	$76.1	-2.5%	-11.6%	-17.6%	1.06	-1.6%	-9.1%	-8.8%	1.12
3.30%	$69.0	-2.1%	-10.3%	-14.0%	**1.20**	-1.2%	-7.8%	-4.4%	1.27
3.07%	$67.2	-2.0%	-9.9%	-13.0%	1.24	-1.1%	-7.5%	-3.2%	1.32
2.93%	$66.2	-2.0%	-9.8%	-12.5%	1.26	-1.1%	-7.2%	-2.5%	1.36
1.67%	$57.6	-1.4%	-7.7%	-6.7%	**1.50**	-0.4%	-5.3%	4.2%	1.60
0.83%	$52.6	-1.0%	-6.5%	-2.6%	1.71	-0.1%	-4.2%	8.1%	1.79
0.34%	$50.0	-0.8%	-5.8%	**0.0%**	1.82	0.2%	-3.6%	10.8%	1.90
0.00%	**$48.2**	-0.6%	-5.3%	1.8%	1.90	0.3%	-3.2%	12.6%	1.97
-0.78%	$44.4	-0.3%	-4.4%	5.7%	2.12	0.7%	-2.3%	16.5%	2.06
-1.37%	$41.8	**0.0%**	-3.7%	8.4%	2.25	1.0%	-1.6%	19.4%	2.09
-4.95%	$29.5	1.6%	**0.0%**	25.2%	2.42	2.5%	0.8%	36.9%	2.22
-7.64%	$23.2	2.6%	1.4%	37.1%	2.55	3.5%	2.1%	48.2%	2.36
4.94%	$83.1					-2.0%	-10.5%	-12.7%	**1.00**

* *Of the $78.7 billion of total capital expenditures for highways and bridges in 2006, $48.2 billion (61.3 percent) was used for types of capital improvements modeled in HERS. The amounts shown represent the average annual investment over 20 years that would occur if spending for these types of improvements grows annually by the percentage shown in each row in constant dollar terms.*

Source: Highway Economic Requirements System.

rate and variable rate user financing options. While the benefit-cost ratios for each individual project would be reduced under this alternative, the number of projects that could be implemented would also be reduced, resulting in a higher benefit-cost ratio cutoff point for each level of investment. While the baseline analyses identified an average annual constant dollar amount of $111.5 billion of potentially cost beneficial investments assuming fixed rate user financing, this amount would increase by 6.1 percent to $118.3 billion assuming higher construction costs. For the analyses reflecting variable rate user financing, the average annual combined public and private spending level associated with a 1.00 minimum benefit-cost ratio would be $83.1 billion in constant 2006 dollars assuming higher construction costs, 4.5 percent higher than the $79.5 billion figure identified in the baseline analyses. It should be noted that these percentage increases are smaller than the 25-percent increase in construction costs, as this alternative would cause some capital improvement projects with a benefit-cost ratio below 1.25 that were included in the baseline analyses to be excluded because their revised benefit-cost ratios assuming higher construction costs would fall below 1.00.

Alternative NBIAS Improvement Costs

As discussed in Chapter 7, the NBIAS model considers bridge deficiencies at the level of individual bridge elements based on engineering criteria, and computes a value for the cost of a set of corrective actions that would address all such deficiencies. The portion of this engineering-based backlog that would pass a benefit-cost test is identified as an economic bridge investment backlog. If construction costs for all potential bridge repair and rehabilitation actions were 25 percent higher, this would limit the total number of bridge projects that could be completed within a fixed budget level to address that backlog.

The baseline NBIAS analyses presented in Chapter 7 projected that an annual constant dollar growth rate of 5.15 percent in combined public and private spending on the types of bridge capital improvements modeled in NBIAS would be sufficient to eliminate the economic bridge investment backlog by 2026; this rate of growth would translate into an average annual investment level of $17.9 billion stated in constant 2006 dollars. As shown in *Exhibit 10-7*, this level of investment would not be adequate to eliminate the bridge investment backlog if bridge repair and rehabilitation costs were to rise by 25 percent in constant dollar terms, and would leave a backlog of $21.2 billion in 2026. NBIAS predicts that eliminating the economic bridge backlog under this alternative assuming higher construction costs would require an average annual

Exhibit 10-7

Impact of Alternative Repair and Rehabilitation Cost Assumptions on Projected Bridge Investment Backlog in 2026 (for Different Possible Funding Levels)

Annual Percent Change Relative to 2006	Average Annual Spending Modeled in NBIAS (Billions of 2006 Dollars)[1]	2026 Bridge Economic Investment Backlog for for System Rehabilitation (Billions of 2006 Dollars)[2]	
		Baseline	Alternative: Increase Costs by 25%
5.15%	$17.9	**$0.0**	$21.2
5.03%	$17.6	$3.5	$24.0
4.55%	$16.7	$18.4	$35.4
4.17%	$16.0	$28.5	$43.9
3.30%	$14.5	$49.7	$62.3
3.07%	$14.1	$55.0	$65.2
2.93%	$13.9	$57.8	$69.9
1.67%	$12.1	$83.4	$94.8
0.83%	$11.1	**$98.9**	$109.4
0.34%	$10.5	$107.0	$117.5
0.00%	**$10.1**	$112.6	$123.0
-0.78%	$9.3	$125.9	$135.0
-1.37%	$8.8	$134.9	$144.1
-4.95%	$6.2	$180.9	$186.4
-7.64%	$4.9	$206.0	$190.2
6.04%	$19.8		**$0.0**
2006 Baseline Value:		**$98.9**	

[1] Of the $78.7 billion of total capital expenditures for highways and bridges in 2006, $10.1 billion (12.9 percent) was used for types of capital improvements modeled in NBIAS. The amounts shown represent the average annual investment over 20 years that would occur if spending for these types of improvements grows annually by the constant dollar growth rate specified.

[2] The amounts shown do not reflect system expansion needs; the bridge component of such needs are addressed as part of the HERS model analysis.

Source: National Bridge Investment Analysis System.

investment level of $19.8 billion, which would equate to an annual growth rate of 6.04 percent over the base year 2006 spending level.

It should be noted that this sensitivity analysis applies only to the repair and rehabilitation costs assumed in NBIAS; the cost of bridge replacements was not modified, as the model is not currently equipped to vary that parameter in an automated fashion. Had all construction costs in NBIAS been included as part of this sensitivity analysis, the impact on the economic backlog would have been larger.

Discount Rate

The discount rate is a mechanism used in benefit-cost analysis to address the time value of resources, otherwise referred to as the time value of money or the opportunity cost (or value) of resources. It reflects the fact that there is a cost associated with diverting resources needed for a highway or bridge capital improvement from other productive uses in the public or private sector. The appropriate discount rate to use in any particular situation could vary depending on the potential alternative uses of the resources involved. OMB Circular A-94, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*, directs that a real 7 percent discount rate should be used for constant dollar analyses such as those presented in this report, indicating that this rate "approximates the marginal pretax rate of return on an average investment in the private sector in recent years." The OMB Circular A-94 guidance suggests that sensitivity analyses be conducted using alternative discount rates; rates of 4 percent and 10 percent have been selected for such analyses in this report.

The benefit-cost analysis procedures employed in the HERS and NBIAS models each apply the discount rate in order to compare the future benefit streams produced by a highway improvement with the initial cost of that improvement. This information feeds into the benefit-cost ratios that are used to prioritize potential investments. **The discount rate should not be confused with the rate of inflation; each involves a completely different set of economic concepts.**

Alternative HERS Discount Rates

Exhibit 10-8 compares the impacts of assuming real discount rates in HERS of 4 percent or 10 percent compared to the baseline assumption of 7 percent. Applying a smaller discount rate of 4 percent would increase the lifetime benefits computed for a project, and would thus raise its benefit-cost ratio. *Exhibit 10-8* shows that the minimum benefit-cost ratio cutoff associated with each investment level analyzed is higher for the 4 percent discount rate alternative than for the 7 percent baseline. The application of a lower discount ratio would tend to favor longer-lived capital improvements, and thus has an impact on the mix of investments recommended by HERS for each level of investment. Consequently, there are small variations between the projected changes in adjusted average user costs and average delay per VMT for the baseline analyses and the 4 percent discount rate alternative.

Applying a discount rate of 10 percent would decrease the lifetime benefits computed for a project, particularly for potential improvements with relatively long lives. This would alter the mix of investment recommended by HERS, which would cause small changes in performance indicators such as adjusted average user costs or average delay per VMT. *Exhibit 10-8* shows that the minimum benefit-cost ratio cutoff associated with each investment level analyzed is lower for the 10 percent discount rate alternative than for the 7 percent baseline.

The baseline analyses identified an average annual level of $111.5 billion of potentially cost-beneficial investments for the types of capital improvements modeled in HERS assuming fixed rate user financing based on a 7 percent real discount rate; the comparable amount assuming a 4 percent discount rate would be $127.5 billion, while applying a 10 percent discount rate would trim this amount to $95.4 billion. Assuming variable rate user financing, HERS identifies $79.5 billion of potential investments with a benefit-

Exhibit 10-8

Impact of Alternative Discount Rates on Selected Indicators (for Different Possible Funding Levels and Financing Mechanisms)

Annual Percent Change Relative to 2006	Average Annual Spending Modeled in HERS (Billions of 2006 Dollars)*	Percent Change in Adjusted Average User Cost, 2026 Compared With 2006: Discount Rate			Percent Change in Average Delay Per VMT, 2026 Compared With 2006: Discount Rate			Minimum Benefit-Cost Ratio Cutoff: Discount Rate		
		Baseline	Alternative		Baseline	Alternative		Baseline	Alternative	
		7.0 Percent	4.0 Percent	10.0 Percent	7.0 Percent	4.0 Percent	10.0 Percent	7.0 Percent	4.0 Percent	10.0 Percent
Assuming Fixed Rate User Financing										
7.45%	$111.5	-2.9%	-2.9%		-10.2%	-10.3%		**1.00**	1.29	
6.41%	$98.6	-2.3%	-2.2%		-6.9%	-6.8%		**1.20**	1.55	
5.03%	$84.0	-1.4%	-1.3%	-1.4%	-2.7%	-2.5%	-2.5%	**1.50**	1.94	1.19
4.55%	$79.5	-1.0%	-1.0%	-1.1%	-1.1%	-1.0%	-1.3%	1.62	2.06	1.31
4.17%	$76.1	-0.8%	-0.7%	-0.8%	**0.0%**	0.2%	0.1%	1.71	2.18	1.38
3.30%	$69.0	-0.2%	-0.1%	-0.2%	2.9%	2.6%	2.8%	1.93	2.48	1.55
3.07%	$67.2	**0.0%**	0.1%	-0.1%	3.6%	3.4%	3.5%	1.98	2.55	1.59
2.93%	$66.2	0.1%	0.2%	0.0%	3.9%	3.8%	4.0%	2.02	2.59	1.61
1.67%	$57.6	1.0%	1.1%	0.9%	7.0%	6.9%	7.6%	2.42	3.09	1.91
0.83%	$52.6	1.5%	1.6%	1.4%	9.1%	9.0%	9.5%	2.70	3.49	2.16
0.34%	$50.0	1.8%	2.0%	1.8%	10.3%	10.3%	10.6%	2.86	3.70	2.29
0.00%	**$48.2**	2.1%	2.2%	2.0%	11.1%	11.2%	11.7%	2.89	3.73	2.34
-0.78%	$44.4	2.6%	2.7%	2.5%	13.5%	13.1%	13.6%	2.94	3.80	2.37
-1.37%	$41.8	3.0%	3.1%	2.9%	15.1%	14.4%	15.2%	2.99	3.86	2.40
-4.95%	$29.5	5.2%	5.3%	5.1%	22.6%	21.8%	23.6%	3.24	4.20	2.59
-7.64%	$23.2	6.7%	6.7%	6.6%	27.5%	27.0%	28.4%	3.43	4.48	2.74
8.58%	$127.7		-3.6%			-13.8%			**1.00**	
6.13%	$95.4			-2.1%			-5.9%			**1.00**
Assuming Variable Rate User Financing										
5.03%	$84.0		-2.8%			-13.0%			1.18	
4.55%	$79.5	-2.7%	-2.6%		-12.3%	-12.3%		**1.00**	1.28	
4.17%	$76.1	-2.5%	-2.5%		-11.6%	-11.7%		1.06	1.37	
3.30%	$69.0	-2.1%	-2.1%		-10.3%	-10.4%		**1.20**	1.54	
3.07%	$67.2	-2.0%	-2.0%		-9.9%	-10.0%		1.24	1.59	
2.93%	$66.2	-2.0%	-1.9%	-2.0%	-9.8%	-9.7%	-9.7%	1.26	1.63	1.01
1.67%	$57.6	-1.4%	-1.3%	-1.4%	-7.7%	-7.7%	-7.7%	**1.50**	1.95	1.20
0.83%	$52.6	-1.0%	-0.9%	-1.0%	-6.5%	-6.6%	-6.5%	1.71	2.21	1.36
0.34%	$50.0	-0.8%	-0.7%	-0.8%	-5.8%	-5.8%	-5.8%	1.82	2.37	1.45
0.00%	**$48.2**	-0.6%	-0.5%	-0.7%	-5.3%	-5.4%	-5.4%	1.90	2.48	1.52
-0.78%	$44.4	-0.3%	-0.2%	-0.3%	-4.4%	-4.3%	-4.4%	2.12	2.76	1.67
-1.37%	$41.8	**0.0%**	0.1%	-0.1%	-3.7%	-3.6%	-3.7%	2.25	2.87	1.79
-4.95%	$29.5	1.6%	1.7%	1.5%	**0.0%**	-0.2%	0.1%	2.42	3.08	1.95
-7.64%	$23.2	2.6%	2.7%	2.5%	1.4%	1.1%	1.5%	2.55	3.27	2.05
5.94%	$93.3		-3.2%			-14.6%			**1.00**	
3.00%	$66.7			-2.0%			-9.8%			**1.00**

* *Of the $78.7 billion of total capital expenditures for highways and bridges in 2006, $48.2 billion (61.3 percent) was used for types of capital improvements modeled in HERS. The amounts shown represent the average annual investment over 20 years that would occur if spending for these types of improvements grows annually by the percentage shown in each row in constant dollar terms.*

Source: Highway Economic Requirements System.

How do the discount rates as applied in HERS correspond to internal rates of return?

Q&A

The real rate of return associated with an improvement with a benefit-cost ratio of 1.0 would generally be equal to the real discount rate assumed in the analysis.

The baseline analyses presented in Chapter 7 applied a real discount rate of 7 percent. The analyses, assuming fixed rate user financing, identified an average annual level of potentially cost beneficial investment of $111.5 billion for the types of capital improvements modeled in HERS; the comparable amount for a minimum benefit-cost ratio of 1.0, assuming variable rate user financing, was $79.5 billion. Consequently, the marginal rate of return at these levels is estimated to be 7 percent.

By varying the discount rate, and determining the dollar amount associated with a minimum benefit-cost ratio of 1.0, it is possible to estimate the rate of return associated with other investment levels.

Exhibit 7-14 identified the levels of HERS-modeled investment associated with minimum benefit-cost ratios of 1.2 or 1.5 to be $98.6 billion and $84.0 billion, respectively, assuming fixed rate user financing. The estimated real rates of return associated with these levels of investment are 9.5 percent and 12.6 percent, respectively. These findings are consistent with those presented in Exhibit 10-8, which found that assuming a 10 percent discount rate would yield an estimated $95.4 billion of investment considered by HERS to have a benefit-cost ratio of 1.0 or higher.

For the analyses assuming variable rate user financing, Exhibit 7-14 identified the levels of HERS-modeled investment associated with minimum benefit cost ratios of 1.2 or 1.5 to be $69.0 billion and $57.6 billion, respectively. The estimated real rates of return associated with these levels of investment are 9.4 percent and 12.7 percent, respectively. This is consistent with Exhibit 10-8, which indicates that assuming a 10 percent discount rate would yield an estimated $66.7 billion of investment considered by HERS to be cost-beneficial.

It should be noted that the investment levels identified above as associated with minimum benefit-cost ratios of 1.0, 1.2, and 1.5, represent the HERS-modeled component of the MinBCR=1.0, MinBCR=1.2, and MinBCR=1.5 scenarios presented in Chapter 8. Consequently, the implied rates of return cited above would be linked to the HERS components of those scenarios.

cost ratio of 1.00 or higher; the comparable amounts assuming a 4 percent or 10 percent discount rate are $93.3 billion or $66.7 billion, respectively. All of these amounts are stated in constant 2006 dollars.

Alternative NBIAS Discount Rates

Given the relatively long lives of many of the bridge improvements evaluated in NBIAS, the discount rate applied can have a significant impact on the estimated economic bridge investment backlog. Applying a lower discount rate would tend to increase the portion of the engineering-based backlog computed by NBIAS that would pass a benefit-cost test, while applying a higher discount rate would reduce the number of potential bridge improvements determined to be cost beneficial. *Exhibit 10-9* compares the impacts of assuming real discount rates in NBIAS of 4 percent or 10 percent compared to the baseline assumption of 7 percent. Assuming a 4 percent discount rate, the size of the initial economic bridge investment backlog would be $119.4 billion, well above the $98.9 billion estimated in the baseline analysis. Assuming a 10 percent discount rate, the size of the initial economic bridge investment backlog would be $81.7 billion.

The baseline NBIAS analyses presented in Chapter 7 projected that an annual constant dollar growth rate of 5.15 percent in combined public and private spending on the types of bridge capital improvements modeled in NBIAS would be sufficient to eliminate the economic bridge investment backlog by 2026; this rate of growth would translate into an average annual investment level of $17.9 billion, stated in constant 2006 dollars. As shown in *Exhibit 10-9*, this level of investment would not be adequate to eliminate the larger economic bridge investment backlog estimated assuming a 4 percent discount rate; this level of investment would leave a backlog of $33.5 billion in 2026. NBIAS projects that eliminating the economic bridge backlog assuming a 4 percent discount rate would require an average annual investment level of $20.4 billion, which would equate to an annual growth rate of 6.26 percent over the base year 2006 spending level in constant dollar terms. Assuming a 10 percent discount rate would reduce the level of investment associated with eliminating the economic bridge backlog to $15.2 billion, which would equate to an annual growth rate of 3.71 percent over base year spending in constant dollar terms.

Exhibit 10-9

Impact of Alternative Discount Rates on Projected Bridge Investment Backlog in 2026 (for Different Possible Funding Levels)

Annual Percent Change Relative to 2006	Average Annual Spending Modeled in NBIAS (Billions of 2006 Dollars) [1]	2026 Bridge Economic Investment Backlog for System Rehabilitation (Billions of 2006 Dollars) [2]		
		Discount Rate		
		Baseline	Alternatives	
		7 Percent	4 Percent	10 Percent
5.15%	$17.9	**$0.0**	$33.5	
5.03%	$17.6	$3.5	$36.6	
4.55%	$16.7	$18.4	$49.9	
4.17%	$16.0	$28.5	$59.5	
3.30%	$14.5	$49.7	$79.2	$12.3
3.07%	$14.1	$55.0	$84.1	$19.4
2.93%	$13.9	$57.8	$87.2	$23.3
1.67%	$12.1	$83.4	$113.4	$49.7
0.83%	$11.1	**$98.9**	$129.4	$64.7
0.34%	$10.5	$107.0	$138.3	$73.5
0.00%	**$10.1**	$112.6	$143.8	$79.5
-0.78%	$9.3	$125.9	$156.5	$91.5
-1.37%	$8.8	$134.9	$165.5	$101.1
-4.95%	$6.2	$180.9	$210.9	$148.8
-7.64%	$4.9	$206.0	$235.0	$175.4
6.26%	$20.4		**$0.0**	
3.71%	$15.2			**$0.0**
	2006 Baseline Value:	**$98.9**	**$119.4**	**$81.7**

[1] Of the $78.7 billion of total capital expenditures for highways and bridges in 2006, $10.1 billion (12.9 percent) was used for types of capital improvements modeled in NBIAS. The amounts shown represent the average annual investment over 20 years that would occur if spending for these types of improvements grows annually by the constant dollar growth rate specified.

[2] The amounts shown do not reflect system expansion needs; the bridge component of such needs are addressed as part of the HERS model analysis.

Source: National Bridge Investment Analysis System.

Alternative Valuation of Non-Monetary Benefits

The appropriate valuation of non-monetary benefits such as the prevention of a fatality or the reduction of travel time is a subject of significant debate within the academic community, and no single dollar figures have been uniformly accepted. To ensure consistency among the analyses developed by the Department of Transportation, guidance has been developed requiring the use of standard procedures for the valuation of a statistical life and travel time. The guidance pertaining to the treatment of the economic value of a statistical life was revised in February 2008, and requires a standard value of $5.8 million be applied, which represents a significant increase over the previous standard value of $3.0 million used in the 2006 C&P Report. The guidance further requires that supplementary analyses be conducted based on assumptions of $3.2 million and $8.4 million for the value associated with each life saved. Separate analyses reflecting the impacts that changing this assumption would have on the HERS and NBIAS findings, respectively, are presented below.

The Department of Transportation's standard methodology regarding the valuation of travel time has not been revised recently, so the approach used to develop value of time savings estimates in HERS for the analyses presented in this edition of the C&P report are consistent with the approach utilized in the 2006 edition. This section includes analyses describing the impact of increasing or lowering the baseline estimates of the value of travel time by 25 percent.

Research has indicated that unpredictable delay associated with traffic incidents may be perceived by highway users as more onerous (and thus more "costly" on a per hour basis) than 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. This section includes analyses comparing the effects of setting this parameter at 1.0, 2.0, and 3.0.

Note that the tables presented in this section do not include information of adjusted average user costs; this omission was intentional because each of these alternative valuations of non-monetary benefits would logically affect the base year value for this statistic, so any percentage changes from the base year would not be directly comparable between the baseline and these alternatives.

Value of a Statistical Life

The effect of changes to the value of a statistic life would generally be more noticeable in evaluating targeted safety-oriented capital improvements that are primarily directed at saving lives than in evaluating the ancillary safety impacts of capital improvements oriented toward system expansion or system rehabilitation, such as those modeled in HERS and NBIAS. The Afterword in Part IV of this report contains discussion of future research options for improving the analytical capabilities of HERS and NBIAS in this area.

Alternative HERS Values of a Statistical Life

Exhibit 10-10 shows the impacts of assuming statistical values of life of $3.2 million or $8.4 million in HERS compared to the baseline assumption of $5.8 million. Applying a lower statistical value of life would tend to reduce the estimated safety benefits of highway capital improvements, and thus would reduce their benefit-cost ratios; applying a higher value of life would tend to increase their benefit-cost ratios. The baseline analyses identified an average annual level of $111.5 billion of potentially cost beneficial investments stated in constant 2006 dollars for the types of capital improvements modeled in HERS assuming fixed rate user financing; the comparable amount assuming an $3.2 million value of life would be $109.8 billion, while applying a value of $8.4 million would boost this amount to $112.1 billion. Assuming variable rate user financing, HERS identifies $79.5 billion of potential investments with a benefit-cost ratio of 1.00 or higher in the baseline analyses; the comparable amounts assuming a $3.2 million or $8.4 million value of life are $78.0 billion or $80.4 billion, respectively.

Changing the statistical value of life would have a small effect on the mix of investments recommended by HERS for each level of investment; a higher value of life would favor projects with higher potential safety benefits or lower potential safety risks. In general, regardless of the financing mechanism assumed, the investment levels associated with either maintaining average delay per VMT or maintaining average IRI would be slightly higher assuming a $8.4 million value of life than the baseline. The converse is true for the $3.2 million value of life alternative, as the costs associated with either maintaining average delay per VMT or maintaining average IRI would be slightly lower.

Alternative NBIAS Values of a Statistical Life

As shown in *Exhibit 10-11,* assuming a statistical value of life of $8.4 million, the estimated size of the initial economic bridge investment backlog would be $103.3 billion, which is 4.4 percent higher than the $98.9 billion estimated in the baseline analysis assuming a $5.8 million value of life. Assuming a statistical value of life of $3.2 million, the size of the initial economic bridge investment backlog would be $94.2 billion stated in constant 2006 dollars.

Exhibit 10-10

Impact of Alternative Value of a Statistical Life Assumptions on Selected Indicators (for Different Possible Funding Levels and Financing Mechanisms)

Annual Percent Change Relative to 2006	Average Annual Spending Modeled in HERS (Billions of 2006 Dollars)*	Percent Change in Average Delay Per VMT, 2026 Compared With 2006: Value of a Statistical Life			Percent Change in Average IRI, 2026 Compared With 2006: Value of a Statistical Life			Minimum Benefit-Cost Ratio Cutoff: Value of a Statistical Life		
		Baseline	Alternative		Baseline	Alternative		Baseline	Alternative	
		$5.8 Million	$3.2 Million	$8.4 Million	$5.8 Million	$3.2 Million	$8.4 Million	$5.8 Million	$3.2 Million	$8.4 Million
Assuming Fixed Rate User Financing										
7.45%	$111.5	-10.2%		-10.1%	-23.1%		-22.8%	**1.00**		1.01
6.41%	$98.6	-6.9%	-7.0%	-6.7%	-18.1%	-18.6%	-17.6%	**1.20**	1.18	1.23
5.03%	$84.0	-2.7%	-2.8%	-2.7%	-11.2%	-11.5%	-10.5%	**1.50**	1.48	1.53
4.55%	$79.5	-1.1%	-1.3%	-1.0%	-8.6%	-9.0%	-8.0%	1.62	1.59	1.64
4.17%	$76.1	**0.0%**	0.0%	0.2%	-6.6%	-7.0%	-6.1%	1.71	1.68	1.73
3.30%	$69.0	2.9%	2.8%	3.0%	-2.3%	-2.6%	-1.8%	1.93	1.90	1.96
3.07%	$67.2	3.6%	3.5%	3.7%	-1.0%	-1.4%	-0.6%	1.98	1.96	2.01
2.93%	$66.2	3.9%	3.9%	4.0%	**0.0%**	-0.5%	0.4%	2.02	2.00	2.04
1.67%	$57.6	7.0%	6.8%	7.1%	7.9%	7.6%	8.4%	2.42	2.40	2.42
0.83%	$52.6	9.1%	9.0%	9.2%	12.4%	12.2%	13.0%	2.70	2.66	2.71
0.34%	$50.0	10.3%	10.4%	10.4%	15.1%	14.6%	15.5%	2.86	2.84	2.87
0.00%	**$48.2**	11.1%	11.2%	11.2%	17.1%	16.6%	17.6%	2.89	2.86	2.93
-0.78%	$44.4	13.5%	13.4%	13.7%	20.8%	20.2%	21.3%	2.94	2.92	2.97
-1.37%	$41.8	15.1%	14.9%	15.2%	23.8%	23.3%	24.4%	2.99	2.96	3.01
-4.95%	$29.5	22.6%	22.5%	22.8%	42.0%	41.5%	42.5%	3.24	3.21	3.27
-7.64%	$23.2	27.5%	27.4%	27.7%	53.1%	52.5%	53.5%	3.43	3.38	3.45
7.32%	$109.8		-10.0%			-22.8%			**1.00**	
7.49%	$112.1			-10.1%			-23.0%			**1.00**
Assuming Variable Rate User Financing										
4.55%	$79.5	-12.3%		-12.0%	-19.3%		-18.9%	**1.00**		1.02
4.17%	$76.1	-11.6%	-11.9%	-11.4%	-17.6%	-18.2%	-17.1%	1.06	1.03	1.08
3.30%	$69.0	-10.3%	-10.6%	-10.0%	-14.0%	-14.5%	-13.4%	**1.20**	1.17	1.23
3.07%	$67.2	-9.9%	-10.2%	-9.7%	-13.0%	-13.5%	-12.5%	1.24	1.21	1.27
2.93%	$66.2	-9.8%	-10.0%	-9.5%	-12.5%	-12.9%	-11.8%	1.26	1.24	1.29
1.67%	$57.6	-7.7%	-7.9%	-7.5%	-6.7%	-7.0%	-6.2%	**1.50**	1.48	1.53
0.83%	$52.6	-6.5%	-6.7%	-6.7%	-2.6%	-2.9%	-2.9%	1.71	1.68	1.68
0.34%	$50.0	-5.8%	-6.0%	-5.6%	**0.0%**	-0.4%	0.4%	1.82	1.80	1.85
0.00%	**$48.2**	-5.3%	-5.5%	-5.2%	1.8%	1.3%	2.2%	1.90	1.88	1.94
-0.78%	$44.4	-4.4%	-4.6%	-4.2%	5.7%	5.1%	5.9%	2.12	2.10	2.15
-1.37%	$41.8	-3.7%	-3.9%	-3.4%	8.4%	8.0%	8.8%	2.25	2.22	2.27
-4.95%	$29.5	**0.0%**	-0.1%	0.2%	25.2%	24.7%	25.6%	2.42	2.39	2.46
-7.64%	$23.2	1.4%	1.1%	1.6%	37.1%	36.6%	37.6%	2.55	2.52	2.58
4.39%	$78.0		-12.2%			-19.1%			**1.00**	
4.65%	$80.4			-12.2%			-19.3%			**1.00**

* *Of the $78.7 billion of total capital expenditures for highways and bridges in 2006, $48.2 billion (61.3 percent) was used for types of capital improvements modeled in HERS. The amounts shown represent the average annual investment over 20 years that would occur if spending for these types of improvements grows annually by the percentage shown in each row in constant dollar terms.*

Source: Highway Economic Requirements System.

The baseline NBIAS analyses presented in Chapter 7 projected that an annual constant dollar growth rate of 5.15 percent in combined public and private spending on the types of bridge capital improvements modeled in NBIAS would be sufficient to eliminate the economic bridge investment backlog by 2026; this rate of growth would translate into an average annual investment level of $17.9 billion, stated in constant 2006 dollars. As shown in *Exhibit 10-11*, this level of investment would not be adequate to eliminate the larger economic bridge investment backlog estimated assuming an $8.4 million statistical value of life; this level of investment would leave a backlog of $21.6 billion in 2026. NBIAS projects that eliminating the economic bridge backlog assuming an $8.4 million value of life would require an average annual investment level of $19.2 billion, which would equate to an annual growth rate of 5.75 percent over the base year 2006 spending level in constant dollar terms.

Assuming a $3.2 million statistical value of life would reduce the estimated level of investment associated with eliminating the economic bridge backlog to $16.4 billion. This would equate to an annual growth rate of 4.39 percent over base year spending in constant dollar terms.

Exhibit 10-11

Impact of Alternative Value of a Statistical Life Assumptions on Projected Bridge Investment Backlog in 2026 (for Different Possible Funding Levels)

Annual Percent Change Relative to 2006	Average Annual Spending Modeled in NBIAS (Billions of 2006 Dollars) [1]	2026 Bridge Economic Investment Backlog for System Rehabilitation (Billions of 2006 Dollars) [2]		
		Value of a Statistical Life		
		Baseline	Alternatives	
		$5.8 Million	$3.2 Million	$8.4 Million
5.15%	$17.9	**$0.0**		$20.2
5.03%	$17.6	$3.5		$23.3
4.55%	$16.7	$18.4		$36.2
4.17%	$16.0	$28.5	$6.5	$45.9
3.30%	$14.5	$49.7	$29.7	$66.1
3.07%	$14.1	$55.0	$35.5	$71.3
2.93%	$13.9	$57.8	$38.7	$74.4
1.67%	$12.1	$83.4	$65.4	$98.3
0.83%	$11.1	$98.9	$82.1	$113.9
0.34%	$10.5	$107.0	$90.8	$122.5
0.00%	$10.1	$112.6	$97.2	$128.2
-0.78%	$9.3	$125.9	$109.7	$140.2
-1.37%	$8.8	$134.9	$119.6	$149.0
-4.95%	$6.2	$180.9	$168.9	$192.0
-7.64%	$4.9	$206.0	$195.9	$216.0
4.39%	$16.4		**$0.0**	
5.75%	$19.2			**$0.0**
	2006 Baseline Value:	**$98.9**	**$94.2**	**$103.3**

[1] Of the $78.7 billion of total capital expenditures for highways and bridges in 2006, $10.1 billion (12.9 percent) was used for types of capital improvements modeled in NBIAS. The amounts shown represent the average annual investment over 20 years that would occur if spending for these types of improvements grows annually by the constant dollar growth rate specified.

[2] The amounts shown do not reflect system expansion needs; the bridge component of such needs are addressed as part of the HERS model analysis.

Source: National Bridge Investment Analysis System.

Value of Ordinary Travel Time

Exhibit 10-12 shows the impacts of assuming values of time that are 25 percent higher or lower than the baseline assumption. Increasing the value of time causes HERS to attribute more benefits, particularly to widening projects (which reduce travel time costs). The baseline analyses assuming fixed rate user financing identified an average annual level of $111.5 billion of potentially cost beneficial investments stated in constant 2006 dollars for the types of capital improvements modeled in HERS assuming fixed rate user financing; the minimum benefit-cost ratio associated with this level of investment assuming a 25 percent increase in the value of time would be 1.13. Assuming fixed rate user financing and a value of time 25 percent higher than the baseline, HERS identifies $119.5 billion of potential investments with a benefit-cost ratio of 1.00 or higher; the comparable amount assuming a 25 percent decrease in the value of time would be $100.7 billion. Assuming variable rate user financing, HERS identifies $79.5 billion of potential investments with a benefit-cost ratio of 1.00 or higher in the baseline analyses stated in constant 2006 dollars; this would rise to $84.6 billion or fall to $73.1 billion assuming a 25 percent increase or decrease, respectively, in the value of time.

Changing the value of time would affect the mix of investments at any given funding level. A higher value of time would be associated with a higher percentage of investment going toward system expansion, a greater relative impact on improving average delay per VMT, and a smaller relative impact on improving average IRI. Assuming a lower value of time, HERS would direct more investment to system rehabilitation, and thus projected average IRI for 2026 would be lower than in the baseline analysis and projected average delay per VMT would be higher.

Value of Incident Delay Reduction

The investment scenario estimates 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 10-13* shows the impact of changing this premium at a higher level of 3.0 times the value of ordinary travel time, or setting it at a lower level of 1.0, which effectively assumes that no premium exists and that the value of incident delay is equal to that of ordinary time.

Increasing the reliability premium would affect the mix of investments at any given funding level, favoring those that would tend to have the largest impact on reducing incident delay. The 3.0 times reliability premium alternative would direct a higher percentage of investment toward system expansion at all funding levels, producing a greater relative impact on improving average delay per VMT, and a smaller relative impact on improving average IRI. Assuming no reliability premium, HERS would direct more investment to system rehabilitation, and thus projected average IRI for 2026 would be lower than in the baseline analysis and projected average delay per VMT would be higher for all of the combined public and private highway capital spending levels that were analyzed.

The baseline analyses assuming fixed rate user financing identified an average annual level of $111.5 billion of potentially cost beneficial investments stated in constant 2006 dollars for the types of capital improvements modeled in HERS assuming fixed rate user financing; the minimum benefit-cost ratio associated with this level of investment assuming a reliability premium for incident delay of 3.0 times ordinary time would be 1.10. Assuming fixed rate user financing and a reliability premium of 3.0, HERS identifies $117.8 billion of potential investments with a benefit-cost ratio of 1.00 or higher; the comparable amount assuming a reliability premium of 1.0 would be $102.4 billion. Assuming variable rate user financing, HERS identifies $79.5 billion of potential investments with a benefit-cost ratio of 1.00 or higher in the baseline analyses stated in constant 2006 dollars; this would rise to $83.8 billion or fall to $74.1 billion assuming reliability premiums of 3.0 or 1.0, respectively.

Exhibit 10-12

Impact of Alternative Value of Time Assumptions on Selected Indicators (for Different Possible Funding Levels and Financing Mechanisms)

Annual Percent Change Relative to 2006	Average Annual Spending Modeled in HERS (Billions of 2006 Dollars)*	Percent Change in Average Delay Per VMT, 2026 Compared With 2006: Value of Time			Percent Change in Average IRI, 2026 Compared With 2006: Value of Time			Minimum Benefit-Cost Ratio Cutoff: Value of Time		
			Alternative			Alternative			Alternative	
		Baseline	Reduce by 25%	Increase by 25%	Baseline	Reduce by 25%	Increase by 25%	Baseline	Reduce by 25%	Increase by 25%
Assuming Fixed Rate User Financing										
7.45%	$111.5	-10.2%		-11.2%	-23.1%		-21.6%	**1.00**		1.13
6.41%	$98.6	-6.9%	-5.2%	-8.0%	-18.1%	-19.9%	-16.3%	**1.20**	1.03	1.37
5.03%	$84.0	-2.7%	-0.8%	-4.0%	-11.2%	-12.8%	-9.2%	**1.50**	1.31	1.70
4.55%	$79.5	-1.1%	1.0%	-2.5%	-8.6%	-10.4%	-6.4%	1.62	1.40	1.83
4.17%	$76.1	**0.0%**	2.2%	-1.3%	-6.6%	-8.5%	-4.5%	1.71	1.49	1.93
3.30%	$69.0	2.9%	5.3%	1.2%	-2.3%	-4.2%	0.0%	1.93	1.67	2.18
3.07%	$67.2	3.6%	5.9%	1.9%	-1.0%	-2.7%	1.1%	1.98	1.73	2.25
2.93%	$66.2	3.9%	6.2%	2.3%	**0.0%**	-1.8%	1.9%	2.02	1.77	2.29
1.67%	$57.6	7.0%	9.7%	5.5%	7.9%	5.7%	9.5%	2.42	2.08	2.74
0.83%	$52.6	9.1%	12.0%	7.4%	12.4%	10.3%	14.6%	2.70	2.31	3.08
0.34%	$50.0	10.3%	13.4%	8.7%	15.1%	12.9%	17.1%	2.86	2.46	3.25
0.00%	**$48.2**	11.1%	14.5%	9.5%	17.1%	14.4%	19.1%	2.89	2.55	3.26
-0.78%	$44.4	13.5%	16.8%	11.5%	20.8%	18.3%	22.9%	2.94	2.60	3.31
-1.37%	$41.8	15.1%	18.2%	12.9%	23.8%	21.5%	25.8%	2.99	2.64	3.35
-4.95%	$29.5	22.6%	26.1%	20.3%	42.0%	40.1%	43.5%	3.24	2.86	3.66
-7.64%	$23.2	27.5%	31.2%	24.7%	53.1%	51.4%	54.4%	3.43	3.00	3.89
6.59%	$100.7		-5.8%			-20.9%			**1.00**	
8.03%	$119.5			-12.9%			-24.5%			**1.00**
Assuming Variable Rate User Financing										
5.03%	$84.0			-14.3%			-20.2%			1.02
4.55%	$79.5	-12.3%		-13.6%	-19.3%		-18.1%	**1.00**		1.10
4.17%	$76.1	-11.6%		-13.1%	-17.6%		-16.4%	1.06		1.16
3.30%	$69.0	-10.3%	-7.9%	-11.8%	-14.0%	-14.9%	-12.8%	**1.20**	1.08	1.31
3.07%	$67.2	-9.9%	-7.5%	-11.5%	-13.0%	-14.0%	-11.8%	1.24	1.12	1.36
2.93%	$66.2	-9.8%	-7.3%	-11.2%	-12.5%	-13.4%	-11.2%	1.26	1.13	1.39
1.67%	$57.6	-7.7%	-5.2%	-9.5%	-6.7%	-7.9%	-5.2%	**1.50**	1.36	1.66
0.83%	$52.6	-6.5%	-4.0%	-8.4%	-2.6%	-3.8%	-1.1%	1.71	1.54	1.87
0.34%	$50.0	-5.8%	-3.2%	-7.6%	**0.0%**	-1.3%	1.3%	1.82	1.65	2.01
0.00%	**$48.2**	-5.3%	-2.7%	-7.2%	1.8%	0.4%	2.9%	1.90	1.73	2.10
-0.78%	$44.4	-4.4%	-1.6%	-6.2%	5.7%	4.1%	6.8%	2.12	1.90	2.35
-1.37%	$41.8	-3.7%	-0.8%	-5.6%	8.4%	6.8%	9.7%	2.25	2.04	2.43
-4.95%	$29.5	**0.0%**	2.9%	-1.9%	25.2%	23.9%	26.7%	2.42	2.21	2.65
-7.64%	$23.2	1.4%	4.5%	-0.6%	37.1%	36.0%	38.7%	2.55	2.35	2.77
3.82%	$73.1		-8.9%			-17.2%			**1.00**	
5.10%	$84.6			-14.4%			-20.7%			**1.00**

** Of the $78.7 billion of total capital expenditures for highways and bridges in 2006, $48.2 billion (61.3 percent) was used for types of capital improvements modeled in HERS. The amounts shown represent the average annual investment over 20 years that would occur if spending for these types of improvements grows annually by the percentage shown in each row in constant dollar terms.*

Source: Highway Economic Requirements System.

Exhibit 10-13

Impact of Alternative Reliability Premium Assumptions on Selected Indicators (for Different Possible Funding Levels and Financing Mechanisms)

Annual Percent Change Relative to 2006	Average Annual Spending Modeled in HERS (Billions of 2006 Dollars)*	Percent Change in Average Delay Per VMT, 2026 Compared With 2006: Reliability Premium			Percent Change in Average IRI, 2026 Compared With 2006: Reliability Premium			Minimum Benefit-Cost Ratio Cutoff: Reliability Premium		
		Baseline	Alternative		Baseline	Alternative		Baseline	Alternative	
		2.0 Times	1.0 Times	3.0 Times	2.0 Times	1.0 Times	3.0 Times	2.0 Times	1.0 Times	3.0 Times
Assuming Fixed Rate User Financing										
7.45%	$111.5	-10.2%		-11.2%	-23.1%		-21.7%	**1.00**		1.10
6.41%	$98.6	-6.9%	-5.1%	-7.9%	-18.1%	-20.1%	-16.3%	**1.20**	1.06	1.33
5.03%	$84.0	-2.7%	-0.7%	-4.0%	-11.2%	-13.2%	-8.7%	**1.50**	1.35	1.66
4.55%	$79.5	-1.1%	1.1%	-2.5%	-8.6%	-11.0%	-6.1%	1.62	1.44	1.79
4.17%	$76.1	**0.0%**	2.3%	-1.4%	-6.6%	-9.1%	-4.2%	1.71	1.54	1.89
3.30%	$69.0	2.9%	5.6%	1.0%	-2.3%	-4.8%	0.6%	1.93	1.74	2.12
3.07%	$67.2	3.6%	6.3%	1.6%	-1.0%	-3.6%	1.9%	1.98	1.80	2.18
2.93%	$66.2	3.9%	6.8%	2.0%	**0.0%**	-2.9%	2.7%	2.02	1.84	2.23
1.67%	$57.6	7.0%	10.1%	5.0%	7.9%	4.2%	10.6%	2.42	2.19	2.61
0.83%	$52.6	9.1%	12.2%	7.1%	12.4%	9.5%	15.5%	2.70	2.44	2.94
0.34%	$50.0	10.3%	13.9%	8.5%	15.1%	11.7%	17.9%	2.86	2.58	3.13
0.00%	**$48.2**	11.1%	14.7%	9.5%	17.1%	13.7%	19.6%	2.89	2.61	3.21
-0.78%	$44.4	13.5%	16.9%	11.3%	20.8%	17.3%	23.7%	2.94	2.66	3.26
-1.37%	$41.8	15.1%	18.7%	12.5%	23.8%	20.3%	26.9%	2.99	2.69	3.29
-4.95%	$29.5	22.6%	27.8%	19.6%	42.0%	37.9%	45.1%	3.24	2.90	3.57
-7.64%	$23.2	27.5%	32.5%	24.0%	53.1%	49.6%	56.0%	3.43	3.07	3.76
6.73%	$102.4		-6.2%			-21.4%			**1.00**	
7.91%	$117.8			-12.4%			-23.9%			**1.00**
Assuming Variable Rate User Financing										
4.55%	$79.5	-12.3%		-13.8%	-19.3%		-18.0%	**1.00**		1.07
4.17%	$76.1	-11.6%		-13.2%	-17.6%		-16.4%	1.06		1.14
3.30%	$69.0	-10.3%	-7.2%	-12.0%	-14.0%	-15.0%	-12.6%	**1.20**	1.10	1.29
3.07%	$67.2	-9.9%	-6.7%	-11.7%	-13.0%	-14.0%	-11.7%	1.24	1.14	1.33
2.93%	$66.2	-9.8%	-6.5%	-11.4%	-12.5%	-13.5%	-11.0%	1.26	1.16	1.36
1.67%	$57.6	-7.7%	-4.2%	-9.7%	-6.7%	-8.0%	-5.0%	**1.50**	1.39	1.62
0.83%	$52.6	-6.5%	-2.9%	-8.6%	-2.6%	-4.2%	-0.6%	1.71	1.56	1.85
0.34%	$50.0	-5.8%	-2.0%	-8.0%	**0.0%**	-1.9%	1.8%	1.82	1.68	1.96
0.00%	**$48.2**	-5.3%	-1.5%	-7.6%	1.8%	-0.1%	3.3%	1.90	1.76	2.05
-0.78%	$44.4	-4.4%	-0.3%	-6.8%	5.7%	3.8%	7.4%	2.12	1.98	2.24
-1.37%	$41.8	-3.7%	0.6%	-6.1%	8.4%	6.5%	10.4%	2.25	2.09	2.39
-4.95%	$29.5	**0.0%**	4.7%	-2.8%	25.2%	23.4%	26.9%	2.42	2.26	2.58
-7.64%	$23.2	1.4%	6.0%	-1.3%	37.1%	35.9%	38.9%	2.55	2.40	2.72
3.94%	$74.1		-8.3%			-17.7%			**1.00**	
5.01%	$83.8			-14.4%			-20.1%			**1.00**

* *Of the $78.7 billion of total capital expenditures for highways and bridges in 2006, $48.2 billion (61.3 percent) was used for types of capital improvements modeled in HERS. The amounts shown represent the average annual investment over 20 years that would occur if spending for these types of improvements grows annually by the percentage shown in each row in constant dollar terms.*

Source: Highway Economic Requirements System.

Potential Impacts of Aging Structures

The internal logic of the NBIAS model is designed to project the future performance of structures based on the conditions states of various individual bridge elements, rather than the chronological age of the bridge. The underlying bridge management philosophy inherent in this approach is that following a program of timely maintenance, repair, and rehabilitation actions to keep a bridge in good condition can extend the service life of that bridge for an extended or theoretically indefinite period. This approach assumes that the probability of a bridge element deteriorating from one condition state to the next is completely independent of a structure's age. However, this assumption may not be warranted in all cases, particularly in situations in which a bridge has not been aggressively maintained over its full lifetime and/or has been subject to loadings in excess of what was anticipated when the structure was built. In such instances, an older structure may tend to deteriorate more quickly or require more aggressive treatments than a newer facility in otherwise similar condition.

Another issue of concern regarding older bridges is functional adequacy. In many cases, older bridges were built to standards that are not consistent with current requirements, particularly in the area of safety design standards. A bridge may also be functionally inadequate simply as a result of the difference between current utilization rates and the uses envisioned at the time it was constructed. Even if an existing older bridge can successfully be kept in a state of good repair indefinitely, functional considerations may warrant its eventual replacement.

As discussed in Chapters 2 and 11, the pace of construction of new bridges has not been uniform over time; in particular, many of the existing bridges on the Interstate system were constructed in a relatively short time frame. To the extent that a bridge's age (independent of current bridge conditions) has an effect on its deterioration rate and the need for bridge replacement, this could create a situation in which bridge investment needs would be clustered in certain time frames rather than distributed more evenly over time. To the extent that such spikes can be anticipated, such information would be very useful in designing systemwide bridge management strategies.

The baseline NBIAS analyses presented in Chapter 7 had identified a backlog of potentially cost-beneficial bridge investments of $98.9 billion in 2006. This economic backlog excluded $19.1 billion of potential corrective actions to address engineering deficiencies that would not pass a benefit-cost test; the total backlog identified by NBIAS based solely on engineering criteria was $118.0 billion in 2006. While NBIAS does not directly model age-related bridge deterioration effects, it does allow the user to specify mandatory bridge replacement criteria relating to bridge age and other factors. *Exhibit 10-14* shows the relative impacts of requiring all bridges to be reconstructed at either age 75 or 50, subject to the availability of funding within the investment level being analyzed, compared to the baseline analyses which did not impose any form of age constraint. Assuming mandatory replacement ages of 75 years or 50 years would increase the base year 2006 engineering backlog estimated by NBIAS to $125.4 billion or $160.8 billion, respectively.

Assuming a fixed life span for bridges of 50 or 75 years would make it more difficult to reduce the backlog over time as additional bridges reached the specified age threshold. The baseline NBIAS analyses presented in Chapter 7 projected that an annual constant dollar growth rate of 5.15 percent in combined public and private spending on the types of bridge capital improvements modeled in NBIAS would be sufficient to eliminate the economic bridge investment backlog by 2026, leaving an engineering backlog of $19.1 billion. This rate of growth would translate into an average annual investment level of $17.9 billion, stated in constant 2006 dollars. As shown in *Exhibit 10-14*, assuming either a fixed life span of 75 or 50 years, this level of investment would leave an engineering backlog of either $78.9 billion or $335.4 billion, respectively, in 2026. The impact of assuming a fixed 50-year life span is particularly dramatic because a large percentage

Exhibit 10-14

Impact of Alternative Age-Based Bridge Replacement Strategies on Projected Bridge Investment Backlog in 2026 (for Different Possible Funding Levels)

Annual Percent Change Relative to 2006	Average Annual Spending Modeled in NBIAS (Billions of 2006 Dollars)[1]	Baseline 2026 Bridge Economic Investment Backlog for System Rehabilitation (Billions of 2006 Dollars)[2]	2026 Bridge Engineering Investment Backlog for System Rehabilitation (Billions of 2006 Dollars)[2]		
			Mandatory Replacement Age		
			Baseline	Alternatives	
			None	75 Years	50 Years
5.15%	$17.9	**$0.0**	**$19.1**	$78.9	$335.4
5.03%	$17.6	$3.5	$22.6	$81.4	$336.4
4.55%	$16.7	$18.4	$37.5	$92.3	$341.0
4.17%	$16.0	$28.5	$47.6	$100.5	$344.5
3.30%	$14.5	$49.7	$68.8	$117.9	$351.9
3.07%	$14.1	$55.0	$74.1	$121.9	$353.7
2.93%	$13.9	$57.8	$76.9	$124.3	$354.9
1.67%	$12.1	$83.4	$102.5	$145.8	$363.9
0.83%	$11.1	$98.9	$118.0	$159.4	$369.2
0.34%	$10.5	$107.0	$126.1	$165.9	$372.3
0.00%	$10.1	$112.6	$131.7	$170.8	$374.2
-0.78%	$9.3	$125.9	$145.0	$181.9	$378.8
-1.37%	$8.8	$134.9	$154.0	$189.4	$381.8
-4.95%	$6.2	$180.9	$200.0	$228.3	$397.4
-7.64%	$4.9	$206.0	$225.1	$249.9	$406.4
5.95%	$19.6			**$58.6**	
9.27%	$29.2				**$286.8**
2006 Baseline Value:		**$98.9**	**$118.0**	**$125.4**	**$160.8**

[1] Of the $78.7 billion of total capital expenditures for highways and bridges in 2006, $10.1 billion (12.9 percent) was used for types of capital improvements modeled in NBIAS. The amounts shown represent the average annual investment over 20 years that would occur if spending for these types of improvements grows annually by the constant dollar growth rate specified.

[2] The amounts shown do not reflect system expansion needs; the bridge component of such needs are addressed as part of the HERS model analysis.

Source: National Bridge Investment Analysis System.

of bridges are currently between 30 and 50 years of age; such bridges would not exceed the alternative 75-year threshold until after the end of the 20-year analysis period in 2026.

NBIAS projects that assuming a fixed life span of 75 years, the engineering backlog could be reduced to $58.6 billion by 2026 if combined public and private spending on the types of bridge improvements modeled in NBIAS rose to an average annual investment level of $19.6 billion; this would equate to an annual growth rate of 5.95 percent over the base year 2006 spending level in constant dollar terms. NBIAS estimates that spending above this level would not be cost-beneficial.

Assuming a fixed bridge life span of 50 years, NBIAS identifies a sufficiently large pool of

For the sensitivity analyses assuming fixed life spans, are all bridges replaced immediately when they reach age 50 or 75?

No. The gradual ramping up of spending assumed in these sensitivity analyses would tend to spread out the pace of bridge replacements, so that in any given year, all bridges reaching the age of 50 years or 75 years would not automatically be replaced immediately. In the absence of such funding constraints, NBIAS would spend $108.5 billion immediately assuming a fixed bridge life span of 50 years, and would spend an average of $38.0 billion annually over 20 years.

potentially cost-beneficial improvements to justify a 9.27 percent annual increase in spending over the base year 2006 level, equating to an average annual investment level of $29.2 billion. This level of investment is projected to reduce the engineering backlog in 2026 to $286.8 billion. While this represents a sharp increase over the 2006 backlog of $160.8 billion assuming a 50-year bridge life span, NBIAS projects that additional investment above this level could not be justified on economic grounds.

Transit Sensitivity Analysis

This section examines the sensitivity of projected transit investment estimates 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 the baseline investment estimates for transit presented in Chapter 8 will vary in response to changes in the assumed values of input variables.

Changes in Passenger Miles Traveled

TERM relies heavily on forecasts of PMT 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, as defined by current 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 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 based on the most recent update of rates from a sample of MPO forecasts available for the Nation's largest metropolitan areas. National Transit Database (NTD) data show that PMT increased at an average annual rate of 2.3 percent between 1997 and 2006 and at an average annual rate of 3.1 percent between 2004 and 2006.

Future transit investment levels have been estimated by TERM for three alternative projected PMT scenarios to examine the sensitivity of transit investment needs to variations in PMT *[Exhibit 10-15*]. These three scenarios are compared to the baseline as presented in chapter 8. 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 projected transit investment. This effect is more pronounced under the **Maintain Conditions and Performance** scenario than under the **Improve Conditions and Performance** scenario because PMT growth rates primarily affect asset expansion costs, which comprise a larger portion of the total amount to maintain conditions and performance than the total amount to improve conditions and performance. As *Exhibit 10-15* shows, TERM projects that a 50-percent increase in PMT growth would increase the cost to **Maintain Conditions and Performance** by

Exhibit 10-15

Impact of Alternative PMT Growth Rates on Transit Investment Estimates by Scenario*

Annual PMT Growth Rate	Annual Cost to Maintain Conditions & Performance (Billions of 2006 Dollars)	Percent Change	Annual Cost to Improve Conditions & Performance (Billions of 2006 Dollars)	Percent Change
Baseline (1.5%)	$15.07	-	$21.11	-
Increased 50% (to 2.25%)	$16.72	11.0%	$23.27	10.2%
Decreased 50% (to 0.75%)	$12.86	-14.6%	$19.42	-8.0%
Decreased 100% (to 0%)	$10.27	-31.8%	$11.08	-47.5%

* *Investment estimates 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.

11.0 percent and the cost to **Improve Conditions and Performance** by 10.2 percent. On the other hand, a 50-percent decrease in PMT growth will decrease the cost to **Maintain Conditions and Performance** by 14.6 percent and the cost to **Improve Conditions and Performance** by 8.0 percent. TERM estimates of future investment to maintain conditions and performance would decrease by 31.8 percent if PMT ceases to grow, and by 47.5 percent for the improve conditions and performance scenario.

Changes in Capital Costs

The capital costs used in TERM are based on actual prices paid by agencies for asset purchases as reported to the Federal Transit Administration in the Transit Electronic Award and Management System (TEAM) and in special surveys. Asset prices in the current version of TERM have been converted to 2006 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 TERM's baseline projected transit investment.

As shown in *Exhibit 10-16,* TERM projects that a 25-percent increase in capital costs would increase the cost to **Maintain Conditions and Performance** by 9.9 percent, but the cost to **Improve Conditions and Performance** would decrease by 20.7 percent. With this increase in costs, fewer investments are economically viable under the **Improve Conditions and Performance** scenario than under the **Maintain Conditions and Performance** scenario.

Exhibit 10-16

Impact of a 25 Percent Increase in Capital Costs on Transit Investment Estimates by Scenario*

	Annual Cost to Maintain Conditions & Performance (Billions of 2004 Dollars)	Percent Change	Annual Cost to Improve Conditions & Performance (Billions of 2004 Dollars)	Percent Change
Baseline	$15.07	–	$21.11	–
Increase Costs 25%	$16.56	9.9%	$16.73	-20.7%

** Investment estimates 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.

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 for both the Maintain Performance and the 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 10-17 shows the effect of varying the value of time. The baseline value of time is assumed to be $11.20, as recommended by the Department of Transportation's 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. (Departmental guidance on the value of time has not changed since the 2004 C&P Report, which also used these values.) Future transit investment levels have been estimated by TERM based on three different scenarios to examine the sensitivity of transit investment needs to changes in the value of time. These scenarios are as follows:

(1) Value of time is double (increase by 100 percent)

(2) Value of time is half (decrease by 50 percent)

(3) Value of time is inflated to 2006 dollars.

By increasing the value of time to $22.40 per hour, the cost to **Maintain Conditions and Performance** is projected to increase by 16.0 percent, while the cost to **Improve Conditions and Performance** would increase by 10.8 percent. A decrease by 50 percent in the value of time would decrease the cost to **Maintain Conditions and Performance** by 46.6 percent and the cost to **Improve Conditions and Performance** by 35.4 percent. Inflating the value of time to 2006 dollars had a smaller upward effect, adding between 4.0 and 2.7 percent to the costs for both maintaining and improving conditions and performance, respectively. Overall, 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 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 10-17

Impact of Change in the Value of Time on Transit Investment Estimates by Scenario*

	Annual Cost to Maintain Conditions & Performance		Annual Cost to Improve Conditions & Performance	
Value of Time	**(Billions of 2006 Dollars)**	**Percent Change**	**(Billions of 2006 Dollars)**	**Percent Change**
Baseline	$15.07	–	$21.11	–
Increase 100%	$17.48	16.0%	$23.39	10.8%
Decrease 50%	$8.05	-46.6%	$13.64	-35.4%
Inflate to $2006	$15.67	4.0%	$21.69	2.7%

** Investment estimates 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.

Changes in User Cost Elasticities

User cost elasticity is the percentage change in ridership resulting from a change in user costs. TERM uses cost elasticities to estimate the changes in ridership that will result from changes in fare and travel time costs. These changes are 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 10-18*, a doubling of these elasticities or setting them to zero has almost no effect on projected investment scenarios; the largest projected effect is a decrease of 6.5 percent in the costs to improve conditions and performance when elasticities are estimated at 0 percent.

Exhibit 10-18

Impact of Change in the Value of User Cost Elasticities on Transit Investment Estimates by Scenario*

User Cost Elasticities	Annual Cost to Maintain Conditions & Performance (Billions of 2004 Dollars)	Annual Cost to Maintain Conditions & Performance Percent Change	Annual Cost to Improve Conditions & Performance (Billions of 2004 Dollars)	Annual Cost to Improve Conditions & Performance Percent Change
Baseline	$15.07	–	$21.11	–
Increase 100%	$15.07	0.0%	$21.19	0.4%
Decrease 100%	$15.07	0.0%	$19.73	-6.5%

* *Investment estimates 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.

Comparison

The layout and content of Part II of this edition of the C&P report, including Chapters 7 through 10, has been restructured significantly relative to that of recent editions. Among the four chapters in Part II, this chapter changed the least, and has retained the chapter title that was used in the 2006 C&P Report. However, some new sensitivity analyses have been added to this chapter, others have been rearranged relative to how they were presented in previous editions, and some have been excluded.

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. This chapter explores the effects of altering some of the key assumptions underlying the potential capital investment impacts and selected capital investment scenarios presented in Chapters 7 and 8.

Exhibit 10-19 provides a crosswalk between the information presented in the exhibits located in the highway and transit sections of this chapter and the location of comparable information in the 2006 C&P Report.

Exhibit 10-19

Cross-Reference Between Chapter 10 Exhibits and the Location of Comparable Information in the 2006 C&P Report

Chapter 10 Exhibit	Location of Comparable Information in the 2006 C&P Report
Exhibit 10-1	"Fixed Rate User Charges" values for "Aggessive" and "Full" deployments in the "7.45%" and "3.07%" rows are comparable to information shown in Exhibit 10-1. "Variable Rate User Charges" values for "Baseline" deployments in the "4.55%" and "-1.37%" rows are somewhat comparable to information shown in Exhibit 10-1.
Exhibit 10-2	No direct equivalent.
Exhibit 10-3	"Fixed Rate User Charges" values for "Historic Rates" VMT growth in the "7.45%" and "3.07%" rows are comparable to information shown in Exhibit 10-3.
Exhibit 10-4	"Fixed Rate User Charges" values in the "7.45%" row are comparable to information shown in Exhibit 10-4 for elasticity values.
Exhibit 10-5	No direct equivalent.
Exhibit 10-6	No direct equivalent. Similar information for capital improvement costs for HERS and NBIAS combined are shown in Exhibit 10-4.
Exhibit 10-7	No direct equivalent. Similar information for capital improvement costs for HERS and NBIAS combined are shown in Exhibit 10-4.
Exhibit 10-8	No direct equivalent.
Exhibit 10-9	No direct equivalent.
Exhibit 10-10	No direct equivalent. Information regarding a different set of alternative values of a statistical life are shown in Exhibit 10-4.
Exhibit 10-11	No direct equivalent.
Exhibit 10-12	"Fixed Rate User Charges" values in the "7.45%" row are comparable to information shown in Exhibit 10-4 for the value of ordinary travel time.
Exhibit 10-13	"Fixed Rate User Charges" values in the "7.45%" row are comparable to information shown in Exhibit 10-4 for the value of incident delay reduction.
Exhibit 10-14	No direct equivalent.
Exhibit 10-15	Equivalent exhibit presented in Exhibit 10-5.
Exhibit 10-16	Equivalent exhibit presented in Exhibit 10-6.
Exhibit 10-17	Equivalent exhibit presented in Exhibit 10-9.
Exhibit 10-18	Equivalent exhibit presented in Exhibit 10-10.

Highways and Bridges

The sensitivity analyses presented in the highway section of this chapter reflect the impact of varying key assumptions in the analyses used to develop the projections of potential impacts of highway capital investment presented in Chapter 7. Unlike the 2006 C&P Report, which focused primarily on the impact that alternative assumptions would have on the average annual investment level for one or two capital investment scenarios, this section presents projected performance impacts for a range of alternative funding levels.

Exhibits 10-1 and *10-2* describe the potential impacts of technological advances; the analysis of operations/ITS deployments are comparable to those in the 2006 C&P Report, but the pavement technology is a new addition. *Exhibits 10-3* and *10-4* describe the potential impacts of alternative estimates of travel demand. The impacts of alternative VMT growth forecasts presented in *Exhibit 10-3* represent an extension of comparable analyses in prior reports, while the analysis of alternative travel demand elasticity values are directly comparable to those shown in the 2006 C&P Report.

Exhibits 10-5 through *10-9* show the potential impacts of alternative economic assumptions. The analysis of alternative fuel price assumptions in *Exhibit 10-5* is a new addition; the projected impacts of increasing capital costs in HERS and NBIAS shown in *Exhibits 10-6* and *10-7* are comparable to analyses presented in the 2006 C&P Report. The analyses of the application of alternative discount rates in *Exhibits 10-8* and *10-9* also represent new additions to this chapter.

Exhibits 10-10 through *10-13* describe the impacts of alternative valuation of non-monetary benefits, including the value of a statistical life, the value of ordinary time, and the reliability premium associated with reducing incident delay. Comparable analyses were included in the 2006 C&P Report, although the alternative values of a statistical life that were studied were different from those in this edition. *Exhibit 10-14* reflects a new analysis conducted using NBIAS projecting the impacts of alternative age-based bridge replacement strategies.

Certain sensitivity analyses from the 2006 C&P Report were dropped; these include estimates of the impacts of "No Link Between Revenue and Investment" and "Universal Congestion Pricing," as these alternatives evolved into two of the alternative financing mechanisms presented in Chapter 7, assuming funding from non-user sources and variable rate user charges, respectively. The "Minimum BCR" analysis was moved to Chapter 9 as part of the analysis of alternative timing of investment; the "No Work Zone Delay" and "Geometric VMT Growth" alternatives were dropped from this edition of the report entirely.

Transit

The sensitivity analysis conducted for transit is consistent with the 2006 C&P Report in that it examines the sensitivity of projected transit investment estimates by the Transit Economic Requirements Model (TERM) to variations in the following assumptions: passenger miles traveled (PMT), capital costs, value of time, and user travel cost elasticities. In the 2006 C&P Report, two additional scenarios were assessed that are not included in this edition's discussion: type of performance enhancing investment and replacement condition thresholds. The analyses included in this chapter illustrate how the baseline investment estimates for transit presented in Chapter 8 will vary in response to changes in the assumed values of input variables. For all of the analyses presented in Chapter 10, it is important to note that investment estimates for rural and special service vehicles are included in the totals, but are not subject to the sensitivity analysis.

Exhibit 10-15 presents the impact of alternative PMT growth rates on transit investment estimates by scenario (the **Maintain Conditions and Performance scenario** and the **Improve Conditions and Performance scenario**). The impact of a 25-percent increase in capital costs on transit investment estimates by scenario is presented in *Exhibit 10-16*. *Exhibit 10-17* presents the impact of change in the value of time on transit investment estimates by scenario. The final exhibit in this year's report presents the impact of change in the value of user cost elasticities on transit investment estimates by scenario. These exhibits are all consistent with those presented in the 2006 C&P Report.