Chapter 7

Potential Capital Investment Impacts

Potential Highway Capital Investment Impacts

The analyses presented in this section use a common set of assumptions to derive relationships between alternative levels of future highway capital investment and various measures of future highway and bridge conditions and performance. A subsequent section within this chapter provides comparable information for different types of potential future transit investments.

The analyses in this section focus on the types of investment within the scopes of the Highway Economic Requirements System (HERS) and the National Bridge Investment Analysis System (NBIAS), and form the building blocks for the capital investment scenarios presented in Chapter 8. The accuracy of the projections in this chapter depends on the validity of the technical assumptions underlying the analysis, some of which are varied in the sensitivity analysis in Chapter 10. Of particular importance are the sensitivity analyses concerning the trend rate at which vehicle miles traveled (VMT) would grow in the absence of any change in average user cost of travel (in constant dollars). In this report's HERS analyses, the baseline assumption is that total VMT would grow over the analysis period at the rate implied by the projections in the Highway Performance Monitoring System (HPMS). If the projected VMT growth rate were lower, the level of performance that would be associated with any particular level of future highway capital investment would tend to be better than that depicted in the exhibits in this chapter.

The analyses presented in this section do not make any explicit assumptions regarding how future investment in highways might be funded. Chapter 9 includes an analysis of the impacts that alternative funding arrangements might have on travel demand and the level of investment needed to achieve certain levels of system performance.

Highway Economic Requirements System

Simulations conducted with the HERS model provide the basis for this report's analysis of investment in highway resurfacing and reconstruction as well as for highway and bridge capacity expansion. HERS

Q&A

How closely does the HERS model simulate the actual project selection processes of State and local highway agencies?

The process of project selection in HERS differs from reality in several respects. HERS assumes that the allocation of total national spending on highway investment will be "economically efficient," meaning that the projects selected will be the set that maximizes total benefits to society. The model takes no account of the division of funding authority among States and localities. It could, for example, program a large increase in highway investment in a State that lacks the needed budgetary resources. The model also ignores the influence on project selection decisions of evaluation criteria other than economic efficiency, such as perceptions of fairness and political considerations. To the extent that these other factors shape the project selection decisions, HERS may underestimate the level of investment needed to achieve a given performance or conditions target, such as maintaining average speed.

In addition, HERS lacks access to the full array of information that governments would need to determine what is economically efficient. It relies on the HPMS database, which provides only a limited amount of information on each sampled highway section. For example, while the HPMS includes information regarding feasibility of adding lanes to each highway section, it does not currently include information on impediments to widening or feasibility of alternative approaches to added capacity in a given location (construction of parallel routes, double-decking, tunneling, investments in other transportation modes, etc.). This issue is discussed further in Appendix A.

employs incremental benefit-cost analysis to evaluate highway improvements based on data from the Highway Performance Monitoring System. The HPMS includes State-supplied information on current roadway characteristics, conditions, and performance and anticipated future travel growth for a nationwide sample of more than 120,000 highway sections. HERS analyzes individual sample sections only as a step toward providing results at the national level; the model does not provide definitive improvement recommendations for individual sections.

Simulations with the HERS model start by evaluating the current state of the highway system using data from the HPMS sample. These data provide information on pavements, roadway geometry, traffic volume and composition (percent trucks), and other characteristics of the sampled highway sections. For sections with one or more deficiencies identified, the model then considers potential improvements, including resurfacing, reconstruction, alignment improvements, and widening or adding travel lanes. HERS selects the improvement (or combination of improvements) with the greatest net benefits, where benefits are defined as reductions in direct highway user costs, agency costs for road maintenance, and societal costs from vehicle emissions of greenhouse gases and other pollutants. (The model uses estimates of emission costs that include damage to property and human health and, in the case of greenhouse gases, certain other potential impacts such as loss of outdoor recreation amenities.) The model allocates investment funding only to the sections where at least one of the potential improvements are projected to produce benefits exceeding construction costs. Appendix A contains a more detailed description of the project selection and implementation process used by HERS.

Operations Strategies

Starting with the 2004 C&P Report, the HERS model has considered the impacts of certain types of highway operational improvements, in which intelligent transportation systems (ITS) feature prominently. The types of strategies currently evaluated by HERS include:

- Freeway management (ramp metering, electronic roadway monitoring, variable message signs, integrated corridor management, variable speed limits, queue warning systems, lane controls)
- Incident management (incident detection, verification, and response)
- Arterial management (upgraded signal control, electronic monitoring, variable message signs)
- Traveler information (511 systems and advanced in-vehicle navigation systems with real-time traveler information)

Appendix A describes these strategies in more detail and their treatment in the HERS model. It is important to note that HERS does not subject these types of investments to benefit-cost analysis and does not directly analyze tradeoffs between them and the pavement improvements and widening options also considered by the model. Instead, operations strategies are modeled via a separate preprocessor that estimates their impact on the performance of highway sections where they are deployed. The analyses presented in this chapter assume a package of investments representing the continuation of existing deployment trends, while a supplemental analysis presented in Chapter 9 considers the impacts of a more aggressive deployment pattern.

Travel Demand Elasticity

One of the key features of the economic analysis in HERS is the modeling of the influence of the cost of travel on the demand for travel. HERS represents this relationship as a travel demand elasticity that relates demand, measured by VMT, to average user cost per VMT. The model applies this elasticity to the forecasts of future travel (VMT) found in the HPMS sample data. For each highway segment, HERS assumes that the traffic forecast pertains to a future in which average conditions and performance are maintained, and highway user costs therefore remain at the current level. Any change that HERS projects in user cost relative to current level will, through the mechanism of the travel demand elasticity, affect the model's projection for future travel growth. For any highway investment scenario that predicts average user cost to decrease, the projected growth rate will be higher than the baseline rate derived from HPMS. For scenarios in which highway user cost increases, the projected VMT growth rate will tend to be lower than the baseline rate. Chapter 10 includes a discussion of how varying the assumptions about the travel demand elasticity affects the projected VMT growth rates associated with different levels of highway capital investment.

National Bridge Investment Analysis System

The scenario estimates relating to bridge repair and replacement shown in this report are derived primarily from NBIAS. This model incorporates analytical methods from the Pontis bridge management system first developed by the FHWA in 1989, and now owned and licensed by the American Association of State Highway and Transportation Officials. NBIAS also incorporates additional economic criteria into its analytical procedures. NBIAS can process detailed structural data on individual bridge elements or, if such information is not available, the model can synthesize such data from the general condition ratings reported for all bridges in the National Bridge Inventory (NBI); the NBIAS simulations conducted for this report have used only the NBI database.

The NBIAS model uses a probabilistic approach to model bridge deterioration for each synthesized bridge element. It relies on a set of transition probabilities to project the likelihood that an element will deteriorate from one condition state to another over a given period of time. The model then determines an optimal set of repair and rehabilitation actions to take for each bridge element, based on the condition of the element. NBIAS can also apply preservation policies at the individual bridge level and directly compare the costs and benefits of performing rehabilitation or repair work relative to completely replacing the bridge.

To estimate functional improvement needs, NBIAS applies a set of improvement standards and costs to each bridge in the NBI. The model then identifies potential improvements—such as widening existing bridge lanes, raising bridges to increase vertical clearances, and strengthening bridges to increase load-carrying capacity—and evaluates their potential benefits and costs. The NBIAS model is discussed in more detail in Appendix B.

Types of Capital Spending Projected by HERS and NBIAS

The types of investments evaluated by HERS and NBIAS can be related to the system of highway functional classification introduced in Chapter 2 and to the broad categories of capital improvements introduced in Chapter 6 (system rehabilitation, system expansion, and system enhancement). NBIAS relies on the NBI database, which covers bridges on all highway functional classes, and evaluates improvements that generally fall within the system rehabilitation category.

HERS evaluates pavement improvements—resurfacing or reconstruction—and highway widening; the types of improvements included in these categories roughly correspond to system rehabilitation and system expansion as described in Chapter 6. In estimating the per-mile costs of widening improvements, HERS recognizes a typical number of bridges and other structures that would need to be modified. Thus, the estimates from HERS are considered to represent system expansion costs for both highways and bridges. Coverage of the HERS analysis is limited, however, to the nine highway functional classes for which the HPMS sample provides data. Excluded are the functional classes comprising the roads generally not eligible for Federal aid: rural minor collectors, rural local roads, and urban local roads.

The term "non-modeled spending" refers in this report to spending on highway and bridge capital improvements not evaluated in HERS or NBIAS; while these types of spending are absent from the analyses presented in this chapter, the capital investment scenarios presented in Chapter 8 are adjusted to account for

How closely do the types of capital improvements modeled in HERS and NBIAS correspond to the specific capital improvement type categories presented in Chapter 6? Q&A

Exhibit 6-9 in Chapter 6 provides a crosswalk between a series of specific capital improvement types for which data are routinely collected from the States, and three major summary categories: system rehabilitation, system expansion, and system enhancement.

The "reconstruction without added capacity," "restoration and rehabilitation," and "resurfacing" capital improvement types included within the system rehabilitation category in Chapter 6 correspond well to the types of capital improvements modeled in HERS. "Reconstruction with added capacity" is split between the system rehabilitation and system expansion categories in Chapter 6 and must also be split between these categories in the HERS output.

Among the improvement types classified in the system expansion category in Chapter 6, "major widening" lines up best with types of improvements modeled in HERS, because such improvements are generally motivated by a desire to address congestion on a facility. The "relocation" improvement type is also a relatively good fit, although some relocation improvements are motivated more by safety concerns than congestion concerns and might not be captured in the HERS analysis.

While HERS does not directly model the construction of new roads and bridges, many such investments are motivated by a desire to alleviate congestion on existing facilities in a corridor, and thus would be captured indirectly by the HERS analysis in the form of additional normal-cost or high-cost lanes. As described in Appendix A, the costs per mile assumed in HERS for high-cost lanes are based on typical costs of tunneling, double-decking, or building parallel routes, depending on the functional class and area population size for the section being analyzed. To the extent that investments in the "new construction" and "new bridge" improvement types identified in Chapter 6 are motivated by desires to encourage economic development or accomplish other goals aside from the reduction of congestion on the existing highway network, such investments would not be captured in the HERS analysis.

The "bridge replacement," "major bridge rehabilitation," and "minor bridge work" categories included as part of the system rehabilitation category in Chapter 6 generally correspond to the types of capital improvements for bridges modeled in NBIAS. However, the expenditure data may include work on bridge approaches and ancillary improvements that would not be captured in the modeling.

The "safety," "traffic management/engineering," and "environmental and other" capital improvement types identified as part of the system enhancement category in Chapter 6 are treated as if they are not captured in the HERS or NBIAS analyses. However, some safety deficiencies may be addressed as part of broader pavement and capacity improvements modeled in HERS. Also, the HERS Operations preprocessor described in Appendix A includes capital investments in operations equipment and technology that would fall under the definition of the "traffic management/engineering" improvement type in Chapter 6.

them. Non-modeled spending includes capital improvements on highway classes omitted from the HPMS sample and, hence, the HERS model. Development of future investment scenarios for the highway system as a whole thus requires separate estimation outside the HERS modeling process.

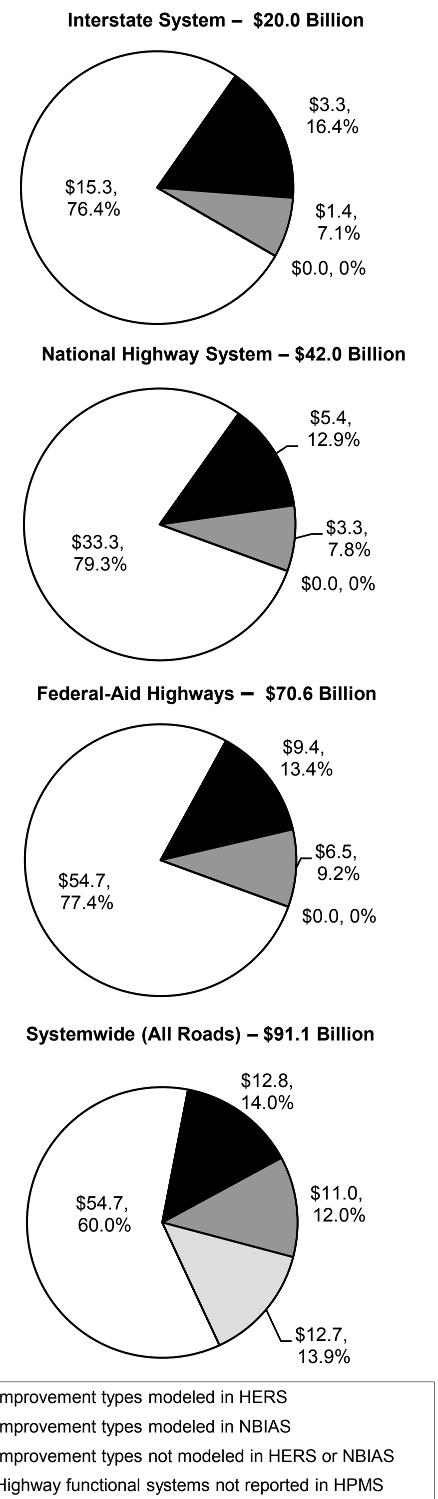
Non-modeled spending also includes types of capital expenditures classified in Chapter 6 as system enhancements, which neither HERS nor NBIAS currently evaluate. Although HERS incorporates assumptions about future operations investments, whose capital components would be classified as system enhancements, the model does not directly evaluate the need for these deployments. In addition, the HERS model does not identify specific safety-oriented investment opportunities, but instead considers the ancillary safety impacts of capital investments that are directed primarily toward system rehabilitation or capacity expansion. This limitation of the model owes to the HPMS database containing no information on the location of crashes or of safety devices such as guardrails or rumble strips.

Exhibit 7-1 shows that systemwide in 2008, highway capital spending amounted to $91.1 billion, of which 60.0 percent ($54.7 billion) went for types of improvements modeled in HERS and 14.0 percent ($12.8 billion) went for types of improvement modeled in NBIAS. The other 26.0 percent that went for non-modeled highway capital spending included system enhancement expenditures (12.1 percent) and capital improvements to classes of highways not reported in HPMS (13.9 percent).

Since the HPMS sample data are available for Federal-aid highways, the percentage of capital improvements classified as non-modeled spending is lower for Federal-aid highways than is the case systemwide. Of the $70.6 billion spent by all levels of government on capital improvements to Federal-aid highways in 2008, 77.4 percent fell within the scope of HERS, 13.4 percent fell within the scope of NBIAS, and 9.2 percent was for spending captured by neither model. The percent distribution is similar for the National Highway System (NHS) and for the Interstate Highway System.

Exhibit 7-1

Portion of 2008 Capital Expenditures Equivalent to Investment Types Modeled in HERS and NBIAS (Billions of Dollars)



Sources: Highway Statistics 2008, Table SF-12A, and unpublished FHWA data.

Alternative Levels of Future Capital Investment Analyzed

The HERS and NBIAS analyses presented in this chapter each assumes that capital investment within the scope of the model will grow over the 20 years at a constant annual percentage rate, which could be positive, negative, or zero. The starting point for each analysis is the level of investment in 2008, and since future levels are measured in constant 2008 dollars, the percent rates of growth are real (inflation-adjusted). This "ramped" approach to analyzing alternative investment levels was introduced in the 2008 C&P Report. Previous editions had either assumed a fixed amount would be spent in each year or set funding levels based on benefit-cost ratios, which tended to front-load the investment within the 20-year analysis period. Chapter 9 includes an analysis of the impacts on conditions and performance of these alternative investment timing patterns, as well as an example of how the ramping approach impacts year-by-year funding levels for some of the highway investment scenarios presented in Chapter 8.

The objective of the analyses presented in this chapter is to provide a quantitative picture of potential highway and bridge system outcomes under alternative assumptions about the rate of ramped investment growth. The particular investment levels identified were selected from among the results of a much larger number of model simulations. **Each investment level shown corresponds to a particular target outcome, such as funding all potential capital improvements with a benefit-cost ratio above a certain threshold or attaining a certain performance standard for highways or bridges.** While each of the particular rates of change selected has some specific analytical significance, the analyses presented in this chapter do not constitute complete investment scenarios, but rather form the building blocks for such scenarios, which are presented in Chapter 8.

Impacts of Federal-Aid Highway Investments Modeled by HERS

Exhibit 7-1 shows that of total capital spending of $91.1 billion on all roads in 2008, $54.7 billion was utilized on Federal-aid highways for the types of improvements modeled in HERS. This section projects the potential impacts on system performance of raising or lowering this amount within the scope of HERS at various annual rates over 20 years. The rates considered are "real," meaning that they measure spending in constant 2008 dollars. *Exhibit 7-2* shows the eight alternative funding growth rates for Federal-aid highways that were selected for further analysis in this chapter, along with the associated funding levels and marginal benefit-cost ratios. In this and previous C&P reports, the analysis follows the HERS convention of a 20-year analysis period divided into four 5-year subperiods.

The marginal benefit cost-ratio in a funding period is the lowest benefit-cost ratio among all the improvements implemented in that period. In *Exhibit 7-2*, this ratio is generally higher for earlier than for later subperiods, resulting in the minimum BCR over the entire analysis period, shown in the last column, equaling the marginal BCR in the last subperiod. This pattern reflects the tendency in the HERS model for the most worthwhile improvements to be implemented first. The exception to this pattern occurs when funding is assumed to decline at an annual real rate of negative 1.00 percent; in this case, the relative scarcity of funding toward the end of the analysis period limits what can be implemented to relatively high return projects.

Exhibit 7-3 describes the significance of the particular eight funding levels (out of the hundreds of levels analyzed) selected for presentation in this chapter. In the first three rows, average annual spending over the 20-year analysis period is targeted to the attainment of a specific minimum BCR value over that period. As explained in the introduction to Part II of this report, HERS ranks potential projects in order of BCR and implements them until the funding constraint is reached. The highest level of spending shown in *Exhibit 7-3*, which corresponds to annual rate of growth in real spending of 5.90 percent, is the estimate of what would be sufficient to finance all potential capital improvements up to a BCR cutoff of 1.00. As shown in *Exhibit 7-2*, meeting this target would require an estimated $2.1 trillion over the analysis period (an average annual of $105 billion over the 20 years); applying the more restrictive minimum BCR targets of 1.20 and 1.50 would require, respectively, 11 percent and 24 percent less than this amount ($1.9 trillion and $1.6 trillion over the analysis period).

The rates of funding growth shown in the next three rows of *Exhibit 7-3* are geared toward achieving a specific level of performance for a particular indicator for 2028. For example, the 1.31 percent growth rate in funding corresponds to maintaining average highway speed on Federal-aid highways at the 2008 level. (The connections between funding growth rates and performance indicators are identifiable from the exhibits presented later in this section). The other two rates of funding growth in *Exhibit 7-3* are based on historical patterns. The zero growth rate would set average annual spending over 2009–2028 at the actual level of spending in 2008. In the last row of *Exhibit 7-3*, the funding growth rate of negative 1.0 percent is the minimum average annual rate of growth in real highway investment over any 20-year period since 1921 (reflecting the period from 1925 to 1945).

Further evident in *Exhibit 7-3* is the inverse relationship described in the introduction to Part II between the minimum BCR and the level of investment. *Exhibit 7-4* graphs this inverse relationship as well as that between the average BCR and the level of investment. At any given level of average annual investment, the average BCR always exceeds the marginal BCR. For example, at the lowest level of investment considered, $986 billion over 20 years, the average BCR of 5.16 exceeds the minimum BCR of 2.72.

Exhibit 7-2

Benefit-Cost Ratio Cutoff Points Associated With Different Possible Funding Levels for Federal-Aid Highways

Annual Percent Change in HERS Capital Spending	Spending Modeled in HERS (Billions of 2008 Dollars)						Marginal BCR [2]				Minimum BCR
	Cumulative					Average					
	5-Year 2009 to 2013	5-Year 2014 to 2018	5-Year 2019 to 2023	5-Year 2024 to 2028	20-Year 2009 to 2028	Annual Spending[1] 2009 to 2028	5-Year 2009 to 2013	5-Year 2014 to 2018	5-Year 2019 to 2023	5-Year 2024 to 2028	20-Year 2009 to 2028
5.90%	$326	$434	$578	$770	$2,108	$105.4	2.32	1.84	1.34	**1.00**	1.00
4.86%	$316	$401	$508	$644	$1,868	$93.4	2.38	1.99	1.52	**1.20**	1.20
3.51%	$304	$361	$429	$509	$1,602	$80.1	2.45	2.18	1.76	**1.50**	1.50
2.88%	$298	$343	$396	$456	$1,493	$74.7	2.48	2.27	1.89	**1.64**	1.64
1.31%	$284	$303	$324	$346	$1,257	$62.9	2.58	2.52	2.22	**2.02**	2.02
0.56%	$278	$286	$294	$302	$1,160	$58.0	2.62	2.65	2.40	**2.24**	2.24
0.00%	$273	$273	$273	$273	$1,094	**$54.7**	2.66	2.76	2.52	**2.42**	2.42
-1.00%	$265	$252	$240	$228	$986	$49.3	**2.72**	2.93	2.79	2.74	2.72

[1] The amounts shown represent the average annual investment over 20 years that would occur if annual investment grows in constant dollar terms by the percentage shown in each row of the first column.

[2] The marginal BCR represents the lowest benefit-cost ratio for any project implemented during the period identified at the level of funding shown. The minimum BCRs, indicated by bold font and also shown in the last column, are the smallest of the marginal BCRs across the funding periods.

Source: Highway Economic Requirements System.

Exhibit 7-3

Description of Eight Alternative HERS-Modeled Investment Levels Selected for Further Analysis

HERS-Modeled Capital Investment		Minimum BCR Cutoff [2]	Funding Level Description
Annual Percent Change in Spending	Average Annual Spending [1] (Billions of 2008 Dollars)		
5.90%	$105.4	1.00	Minimum BCR=1.0
4.86%	$93.4	1.20	Minimum BCR=1.2
3.51%	$80.1	1.50	Minimum BCR=1.5
2.88%	$74.7	1.64	Average Delay per VMT in 2028 Matches 2008 Level
1.31%	$62.9	2.02	Average Speed per VMT in 2028 Matches 2008 Level
0.56%	$58.0	2.24	Average IRI in 2028 Matches 2008 Level
0.00%	**$54.7**	2.42	Investment Sustained in Constant Dollar Terms at 2008 Level
-1.00%	$49.3	2.74	1 Percent Real Decline in Investment per Year [3]

[1] The amounts shown represent the average annual investment over 20 years that would occur if annual investment grows in constant dollar terms by the percentage shown in each row of the first column.

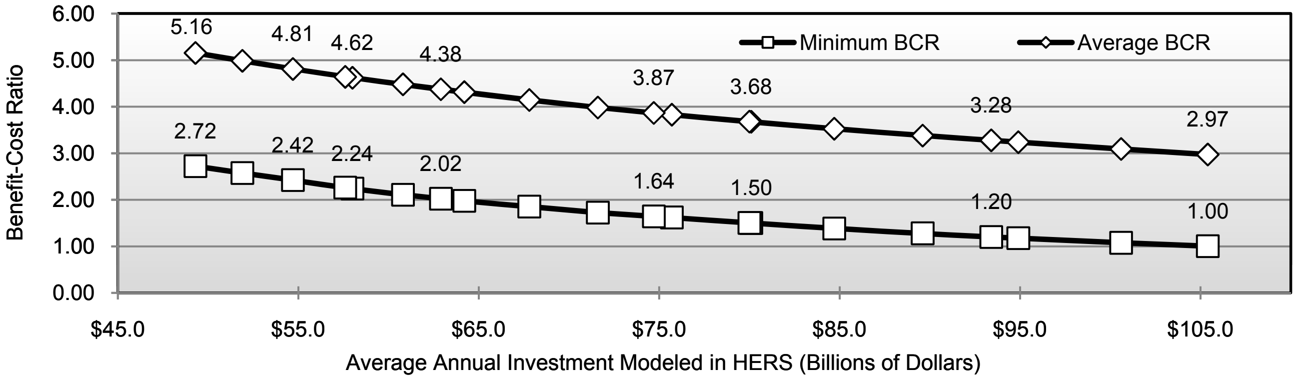
[2] The minimum BCR represents the lowest benefit-cost ratio for any project implemented by HERS during the 20-year analysis period at the level of funding shown.

[3] This investment level was selected to acknowledge that highway capital spending does not always grow in real terms. Between 1925 and 1945, real spending fell at an average annual rate of approximately 1.0 percent. This was the lowest rate experienced over any 20-year period since highway finance data collection began in 1921.

Source: Highway Economic Requirements System.

Exhibit 7-4

Minimum and Average Benefit-Cost Ratios for Different Possible Funding Levels for Federal-Aid Highways



Note: The eight minimum BCR points that are labeled correspond to the eight investment levels presented in Exhibit 7-3. As HERS ranks potential improvements by their estimated BCRs and assumes that the improvements with the highest BCRs will be implemented first (up until the point where the available budget specified is exhausted), the minimum and average BCRs will both naturally tend to decline as the level of investment analyzed rises.

Source: Highway Economic Requirements System.

Shaping the results for average user cost and measures of highway performance examined below is the operation of the elasticity feature in HERS. On congested sections of highway, the initial congestion relief afforded by an increase in capacity will reduce the costs of travel to highway users, of which the largest component is the cost of travel time. The reduction in user cost, in turn, will stimulate demand for travel on the affected sections as travelers adjust in various ways—for example, changing route or mode of travel, or even the total amount of travel undertaken—and this increased demand undoes a portion of the initial congestion relief. More broadly, any initial reduction in user cost of travel, whether brought about by an increase in the physical capacity of a highway or, say, a decline in gasoline prices, will induce much the same sort of casual chain. (Conversely, any initial increase in user costs will start a causal chain with effects in the opposite direction). By capturing these demand offsets to initial impacts on highway user costs, the operation of the elasticity feature in HERS (described earlier in this chapter) allows estimation of the net impacts. The elasticity feature operates likewise with respect to improvements in pavement quality by allowing for induced traffic that adds to pavement wear.

Q&A

Can the average BCRs presented in *Exhibit 7-4* be used to accurately estimate total net benefits associated with different levels of investment?

No. It is important to recognize that the base case system conditions at the time each set of investments is made will influence the benefit-cost ratios calculated. The BCRs for the alternative investment levels are most directly comparable for the first 5-year analysis period, since each analysis uses current conditions as a starting point. However, for subsequent periods, the base case depends on the improvements made in the previous period(s). For those analyses in which investment levels are rising over time, the base case conditions will be better than in those analyses where investment levels are falling, which will influence the calculated benefit-cost ratios. Simply multiplying the average BCR over 20 years by total investment over 20 years does not take into account these different base conditions within the analysis period.

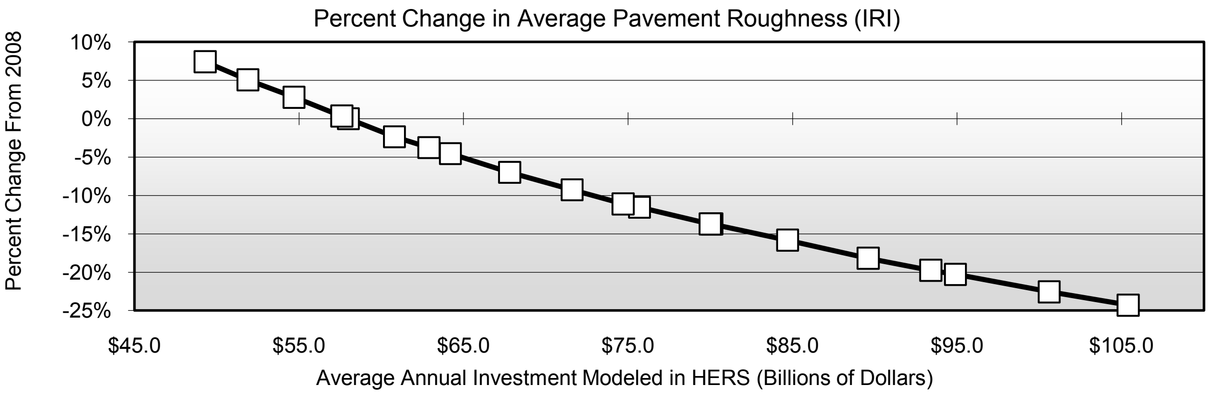
It is also important to note that the BCRs capture only the benefits associated with the investments that are made and do not reflect the additional costs experienced by users and agencies on highway sections that are not improved. A better indication of the benefits associated with each investment level is provided by the findings for highway user costs presented later in this chapter.

Impact of Future Investment on Highway Pavement Ride Quality

The primary measure in HERS of highway physical condition, pavement ride quality, is based on the International Roughness Index (IRI) defined in Chapter 3. The HERS analyses presented in this report focus on VMT-weighted IRI values; the average IRI values shown thus reflect the pavement ride quality experienced on a typical mile of travel. *Exhibit 7-5* shows how the HERS projections for the average IRI on Federal-aid highways vary with the total amount of HERS-modeled investment. Of particular relevance is the amount invested in system rehabilitation, which is more consequential for pavement roughness than investment in system expansion.

Exhibit 7-5

Projected 2028 Pavement Ride Quality Indicators on Federal-Aid Highways Compared With 2008, for Different Possible Funding Levels



HERS-Modeled Capital Investment			Projected Impact of HERS-Modeled Capital Investment on Federal-Aid Highways [3]				
Annual Percent Change in Spending	Average Annual Spending (Billions of 2008 Dollars)		Percent of 2028 VMT on Roads With...[4]		Average IRI (VMT-Weighted)		Minimum BCR Cutoff [5]
	Total Spending[1]	System Rehabilitation[2]	IRI<95	IRI<170	Projected 2028 Level	Change Relative to Baseline	
5.90%	$105.4	$50.7	74.1%	91.7%	86.6	-24.3%	1.00
4.86%	$93.4	$46.0	71.0%	90.1%	91.8	-19.8%	1.20
3.51%	$80.1	$40.2	66.6%	88.0%	98.7	-13.7%	1.50
2.88%	$74.7	$38.1	64.6%	87.1%	101.7	-11.1%	1.64
1.31%	$62.9	$32.7	59.4%	84.6%	110.1	-3.8%	2.02
0.56%	$58.0	$30.5	56.9%	83.3%	114.4	**0.0%**	2.24
0.00%	$54.7	$29.0	55.0%	82.4%	117.6	2.8%	2.42
-1.00%	$49.3	$26.5	52.1%	81.0%	122.9	7.4%	2.72
2008 Baseline Values:			**46.9%**	**85.2%**	**114.4**		

[1] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column.

[2] The portion of HERS-modeled spending directed toward system rehabilitation varies by funding level and is not directly linked to actual spending for this purpose in the baseline year.

[3] The HERS model relies on information from the HPMS sample section database, which is limited to those portions of the road network that are generally eligible for Federal funding (i.e., "Federal-aid highways") and excludes roads classified as rural minor collectors, rural local, and urban local.

[4] As discussed in Chapter 3, IRI values of 95 and 170 inches per mile, respectively, are the thresholds associated with "good" and "acceptable" pavement ride quality on the NHS.

[5] The minimum BCR cutoff represents the lowest BCR for any project implemented by HERS at the level of funding shown.

Source: Highway Economic Requirements System.

Sustaining spending in constant dollars at the $54.7 billion invested in the 2008 base year is projected to cause average pavement roughness to increase between that year and 2028 by an estimated 2.8 percent. A larger deterioration, 7.4 percent, is projected for the case where investment would decrease by 1.0 percent annually. To maintain average pavement roughness at the 2008 level would require the amount invested in highways to increase at an estimated 0.56 percent annual rate in constant dollar terms. At sufficiently higher spending levels, improvements in pavement quality become significant. At the highest rate of funding growth considered, the average pavement roughness is projected to decline 24.3 percent over the 20 years analyzed.

Exhibit 7-5 also shows the HERS projections for the percentage of travel occurring on pavements with ride quality that would be rated good or acceptable based on the IRI thresholds set in Chapter 3. For the case where real highway spending per year remains constant from 2008 to 2028, HERS projects the percentage of VMT occurring on pavements with good ride quality (IRI≤95) would increase from 46.9 percent to 55.0 percent. At the same time, the model projects the percentage of VMT occurring on pavement with acceptable ride quality (IRI≤170) to decrease by 2.8 points, from 85.2 percent to 82.4 percent. It should be noted that even if highway investment is assumed to increase at a rate sufficient to implement all cost-beneficial investment, HERS projects that only 91.7 percent of travel in 2028 would occur on pavement with acceptable ride quality. As noted in Chapter 3, the IRI threshold of 170 used to identify acceptable ride quality was originally set to measure performance on the NHS and may not fully reflect an acceptable standard for non-NHS routes, which tend to have lower travel volumes and speeds.

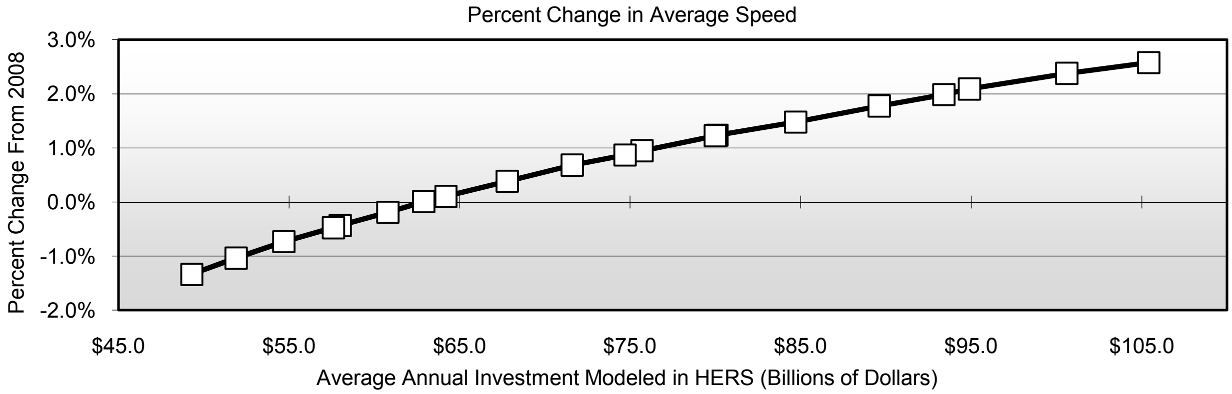
Impact of Future Investment on Highway Operational Performance

Among the HERS indicators of a highway section's operational performance is the peak ratio of volume to service flow (V/SF). A ratio above 0.80 has traditionally been associated with congested conditions, and above 0.95 with severe congestion. *Exhibit 7-6* shows for alternative levels of investment the projected percentages of Federal-aid highway travel in 2028 that will occur on sections where peak V/SF ratios exceed these thresholds. Also presented is the portion of each investment level that HERS programs for capacity expansion (such as the widening of existing highways or building new routes in existing corridors), as such spending affects the amount of delay more directly than does investment in system rehabilitation.

Exhibit 7-6 indicates that if real annual investment in highways continued at the 2008 level through 2028, the percentage of VMT occurring on congested roads would increase over that period from 22.1 percent to 36.1 percent, and on severely congested roads from 11.8 percent to 19.9 percent. Although increasing the rate of investment in highways would stem part of this deterioration, even the highest level of investment that could be economically justified would not prevent deterioration from occurring. Funding all improvements with a BCR above 1.0 would entail an annual investment in capacity expansion averaging $54.7 billion over the 20-year analysis period. Consistent with the consensus in economics that eliminating all congestion is not cost-beneficial, the amount of congestion projected for the end of the period, 2028, is nevertheless substantial, with 29.7 percent of VMT occurring on congested sections. Yet consistent with a strategy of concentrating investment on mitigating the worst congestion, HERS also projects that funding all improvements with a BCR greater than 1.0 would increase average speed on Federal-aid highways by 2.6 percent, from 43.2 miles per hour (mph) in 2008 to 44.3 mph in 2028. In comparison, with zero growth in annual spending assumed, average speed is projected to decrease over the same period by 0.4 mph; annual real growth in investment of 1.31 percent is estimated to be required to maintain average speed at the 2008 level.

Exhibit 7-6

Projected 2028 Highway Operational Performance Indicators on Federal-Aid Highways Compared With 2008, for Different Possible Funding Levels



HERS-Modeled Capital Investment			Projected Impact of HERS-Modeled Capital Investment on Federal-Aid Highways[3]				
Annual Percent Change in Spending	Average Annual Spending (Billions of 2008 Dollars)		Percent of 2028 VMT on Roads With...[4]		Average Speed		Minimum BCR Cutoff[5]
	Total Spending[1]	System Expansion[2]	V/SF > 0.80	V/SF > 0.95	Projected 2028 Level (mph)	Change Relative to Baseline	
5.90%	$105.4	$54.7	29.7%	12.9%	44.3	2.6%	1.00
4.86%	$93.4	$47.4	31.3%	14.3%	44.0	2.0%	1.20
3.51%	$80.1	$39.9	32.9%	16.1%	43.7	1.2%	1.50
2.88%	$74.7	$36.6	33.6%	16.9%	43.5	0.9%	1.64
1.31%	$62.9	$30.1	35.0%	18.5%	43.2	**0.0%**	2.02
0.56%	$58.0	$27.5	35.6%	19.3%	43.0	-0.4%	2.24
0.00%	$54.7	$25.7	36.1%	19.9%	42.8	-0.7%	2.42
-1.00%	$49.3	$22.8	36.8%	20.8%	42.6	-1.3%	2.72
2008 Baseline Values:			**22.1%**	**11.8%**	**43.2**		

[1] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column.

[2] The portion of HERS-modeled spending directed toward system expansion varies by funding level and is not directly linked to actual spending for this purpose in the baseline year.

[3] The HERS model relies on information from the HPMS sample section database, which is limited to those portions of the road network that are generally eligible for Federal funding (i.e., "Federal-aid highways") and excludes roads classified as rural minor collectors, rural local, and urban local.

[4] As discussed in Chapter 4, V/SF ratios of 0.80 and 0.95, respectively, are thresholds commonly associated with congested conditions and severely congested conditions.

[5] The minimum BCR cutoff represents the lowest BCR for any project implemented by HERS at the level of funding shown.

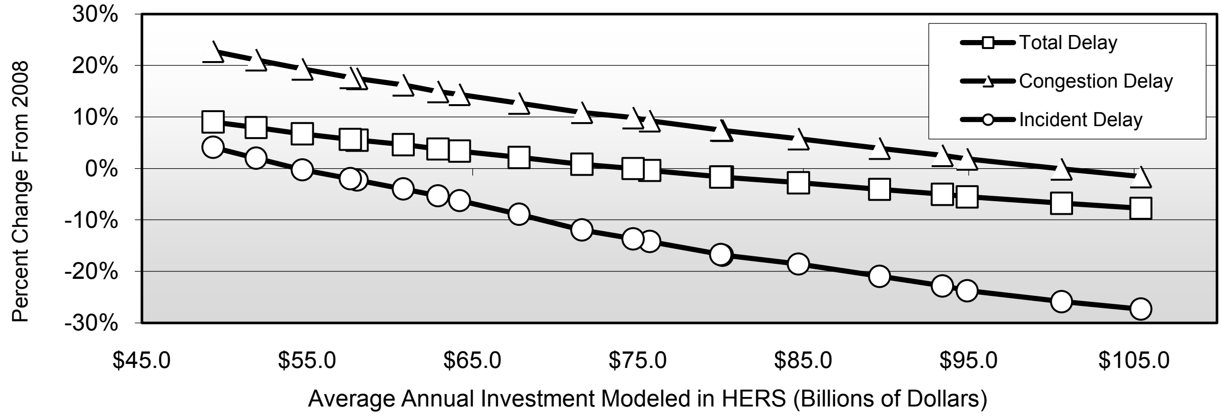
Source: Highway Economic Requirements System.

Congestion Delay and Incident Delay

As noted above, the HERS model assumes the continuation of existing trends in the deployment of certain system management and operations strategies. Among these strategies are several, such as freeway incident management programs, that can be expected to mitigate delay associated with isolated incidents more than the delay associated with recurring congestion ("congestion delay"). In line with this, the HERS projections reported in *Exhibit 7-7* show the amount of incident delay decreasing relative to congestion delay over the 2008–2028 period. For the case where investment within the scope of HERS is sustained in real terms at its 2008 level, the model projects incident delay on Federal-aid highways to be slightly lower in 2028 than in

Exhibit 7-7

Projected Changes in 2028 Highway Travel Delay on Federal-Aid Highways Compared With 2008, for Different Possible Funding Levels



HERS-Modeled Capital Investment			Projected Impact of HERS-Modeled Capital Investment on Federal-Aid Highways[3]				
Annual Percent Change in Spending	Average Annual Spending (Billions of 2008 Dollars)		Annual Hours of Delay per Vehicle[4]	Percent Change Relative to Baseline			Minimum BCR Cutoff[5]
	Total Spending[1]	System Expansion[2]		Total Delay per VMT	Congestion Delay per VMT	Incident Delay per VMT	
5.90%	$105.4	$54.7	46.5	-7.7%	-1.6%	-27.3%	1.00
4.86%	$93.4	$47.4	47.9	-5.0%	2.5%	-22.8%	1.20
3.51%	$80.1	$39.9	49.5	-1.7%	7.4%	-16.8%	1.50
2.88%	$74.7	$36.6	50.4	**0.0%**	9.9%	-13.7%	1.64
1.31%	$62.9	$30.1	52.3	3.8%	14.9%	-5.3%	2.02
0.56%	$58.0	$27.5	53.2	5.5%	17.5%	-2.3%	2.24
0.00%	$54.7	$25.7	53.8	6.7%	19.3%	-0.3%	2.42
-1.00%	$49.3	$22.8	54.9	9.0%	22.8%	4.1%	2.72
	2008 Baseline Values:		**50.4**				

[1] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column.

[2] The portion of HERS-modeled spending directed toward system expansion varies by funding level and is not directly linked to actual spending for this purpose in the baseline year.

[3] The HERS model relies on information from the HPMS sample section database, which is limited to those portions of the road network that are generally eligible for Federal funding (i.e., "Federal-aid highways") and excludes roads classified as rural minor collectors, rural local, and urban local.

[4] The values shown were computed by multiplying HERS estimates of average delay per VMT by 11,619, the average VMT per registered vehicle in the 2008 base year. HERS does not forecast changes in VMT per vehicle over time. The HERS delay figures include delay attributable to stop signs and signals, as well as delay resulting from congestion and incidents.

[5] The minimum BCR cutoff represents the lowest BCR for any project implemented by HERS at the level of funding shown.

Sources: Highway Economic Requirements System; Highway Statistics 2008, Table VM-1.

2008 (down 0.3 percent), and congestion delay to be 19.3 percent higher. The highest level of investment considered would fund all cost-beneficial improvements at an average annual expenditure of $50.7 billion greater than what was actually spent in 2008 ($105.4 billion vs. $54.7 billion) and is projected to reduce both types of delay. Again, however, the outlook from these projections is much better for incident delay, down 27.3 percent, than for congestion delay, for which a 1.6 percent decrease is predicted.

For the case where real highway spending continues at the 2008 level, HERS projects that from 2008 to 2028 overall delay per VMT will increase 6.7 percent, which equates to 3.4 hours per vehicle per year. In the projections assuming that real spending declines by 1.00 percent annually, the corresponding increases in overall delay are still larger, at 9.0 percent and 4.5 annual hours per vehicle. Alternatively, when spending increases at an annual rate of 5.90 percent, enough to fund all cost-beneficial improvements, HERS projects a 7.7 percent reduction in delay from 2008 to 2028, which equates to 3.9 fewer hours per year relative to the 2008 baseline.

Impact of Future Investment on Highway User Costs

The HERS model defines benefits as reductions in highway user costs, agency costs, and societal costs of vehicle emissions. In measuring the highway user costs, the model includes the costs of travel time, vehicle operation, and crashes, but excludes from vehicle operating costs taxes imposed on highway users (such as motor fuel taxes and vehicle registration fees). As discussed in the introduction to this report's Part II, the exclusion of these taxes conforms with the principle in benefit-cost analysis of measuring the costs of transportation inputs at their opportunity cost to society. The exclusion also makes the measure of user costs more of an indicator of highway conditions and performance, of which the amount paid in highway-user taxes provides no indication.

Impact on User Cost Components

Crash costs form the smallest of the three categories of highway user costs, with an estimated 12 percent share in the 2008 base year, compared with 49 percent for travel time costs. Although highway trips always consume traveler time and resources for vehicle operation, only a small fraction involve crashes. In addition, most crashes are non-catastrophic: particularly on urban highways, many involve only damage to property without anyone being injured.

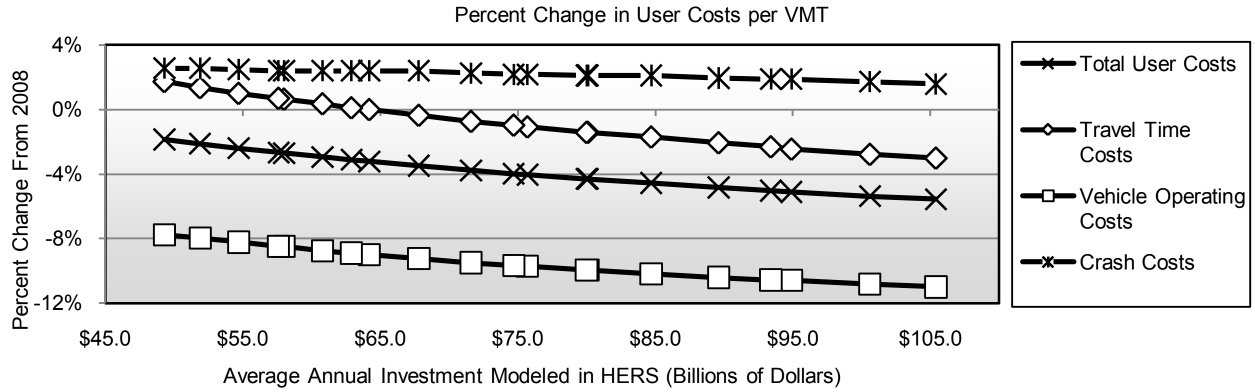
Crashes also emerge from the HERS projections as the component of user costs least sensitive to the assumptions on the rate at which highway investment increases over the 2009–2028 analysis period. As shown in *Exhibit 7-8*, for Federal-aid highways, altering this rate from the lowest rate considered (-1.00 percent) to the highest (+5.90 percent) reduces the crash costs per VMT projected for 2028, but only by 1.0 percentage points. The highway investment totals are limited, however, to the types of improvements that the HERS model evaluates, which are geared toward system rehabilitation and expansion. Since the HPMS lacks detailed information on the current location and characteristics of safety-related features (e.g., guardrail, rumble strips, roundabouts, yellow change intervals at signals), safety-focused investments are not evaluated. However, the findings do not imply that investing more in highways, including spending more on safety projects, makes little difference to highway safety.

For the other components of user cost, the same comparison between spending levels shows much larger differences in the projection for 2028. Moving from the lowest to highest levels adds $56.1 billion ($105.4 billion vs. $49.3 billion) to the annual average spending and results in a travel time cost per VMT in 2028 that is 4.7 percentage points lower (+1.7 percent vs. -3.0 percent). For vehicle operating costs, the estimated impact on the value projected for 2028 is a reduction of 3.2 percentage points.

At all levels of investment considered in *Exhibit 7-8*, the projections are for vehicle operating cost per mile to decline from 2008 to 2028. Even at the lowest rate of spending growth, which would reduce spending by 1.0 percent each year, the projection is for a 7.8 percent decline. The reason for this sizable decrease is that the analysis assumes substantial increases in average vehicle fuel economy over the future. Forecasts of fuel economy were taken from the Energy Information Administration's publication, *Annual Energy Outlook 2010* (Early Release). EIA's forecasts incorporate the effect of recent changes in Corporate Average Fuel Economy (CAFE) standards and the establishment in 2010 of Federal standards for vehicle emissions of greenhouse gases under the provisions of the Clean Air Act.

Exhibit 7-8

Projected Changes in 2028 Highway User Costs on Federal-Aid Highways Compared With 2008 Levels, for Different Possible Funding Levels



HERS-Modeled Capital Investment		Projected Impact of HERS-Modeled Capital Investment on Federal-Aid Highways[2]					
			Percent Change Relative to Baseline Average per VMT				
Annual Percent Change in Spending	Average Annual Spending[1] (Billions of 2008 Dollars)	Average Total User Costs per VMT	Total User Costs	Travel Time Costs	Vehicle Operating Costs	Crash Costs[3]	Minimum BCR Cutoff[4]
5.90%	$105.4	$1.067	-5.6%	-3.0%	-11.0%	1.6%	1.00
4.86%	$93.4	$1.073	-5.0%	-2.3%	-10.6%	1.9%	1.20
3.51%	$80.1	$1.081	-4.3%	-1.4%	-10.0%	2.1%	1.50
2.88%	$74.7	$1.085	-4.0%	-1.0%	-9.7%	2.2%	1.64
1.31%	$62.9	$1.095	-3.1%	0.1%	-8.9%	2.4%	2.02
0.56%	$58.0	$1.100	-2.7%	0.6%	-8.5%	2.4%	2.24
0.00%	$54.7	$1.103	-2.4%	1.0%	-8.2%	2.5%	2.42
-1.00%	$49.3	$1.109	-1.8%	1.7%	-7.8%	2.6%	2.72
2008 Baseline Values:		**$1.130**					

[1] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column.

[2] The HERS model relies on information from the HPMS sample section database, which is limited to those portions of the road network that are generally eligible for Federal funding (i.e., "Federal-aid highways") and excludes roads classified as rural minor collectors, rural local, and urban local.

[3] The HPMS does not contain the type of detail that would be needed to conduct an analysis of targeted safety enhancements. The crash costs estimated by the HERS model represent ancillary impacts associated with pavement and capacity improvements and are heavily influenced by traffic volume and speed.

[4] The minimum BCR cutoff represents the lowest BCR for any project implemented by HERS at the level of funding shown.

Source: Highway Economic Requirements System.

Impact on Overall User Cost

For all highway user costs combined, HERS projects that at any of the investment levels considered, the per mile cost of travel will be lower in 2028 than 2008. Even at the lowest level of investment considered, an average of $49.3 billion per year, the projection is for user costs per VMT to decrease from $1.130 (i.e., 113.0 cents) to $1.109 because of the expected improvements in fuel economy. At higher levels of investment, the projections for 2028 are for still sharper reductions in user costs relative to 2008. At the highest level shown in *Exhibit 7-8*, an average of $105.4 billion per year, average user costs per VMT in 2028 are projected to be $1.067. Thus, according to these projections, investing at the maximum rather

What changes in CAFE standards have recently been adopted, and what impacts are these changes expected to have?

Q&A

The Energy Independence and Security Act of 2007 (Public Law 110-140) included several provisions to increase the fuel efficiency of the American motor vehicle fleet, including a requirement to raise CAFE standards. On March 30, 2009, the U.S. Department of Transportation (DOT) established higher CAFE standards for passenger vehicles and light trucks produced during model year 2011; on May 7, 2010, DOT and the U.S. Environmental Protection Agency jointly adopted fuel efficiency standards for cars and light trucks to be produced during model years 2012 through 2016. For passenger cars, these new standards will increase required fuel economy from the current 27.5 miles per gallon to 37.8 miles per gallon by 2016. For light trucks, the proposal would increase fuel economy from 23.5 miles per gallon in 2010 to 28.8 miles per gallon in 2016. The impacts of these standards on the fuel economy of the overall vehicle fleet will continue to be felt for many years beyond 2016, as new vehicles meeting the higher fuel economy requirements gradually replace older, less fuel-efficient vehicles.

In announcing the new standards, the DOT estimated that they would save nearly 61 billion gallons of fuel and reduce carbon dioxide emissions by 655 million metric tons over the lifetimes of cars and light trucks produced in 2012 through 2016. The Department also estimated that the plan would save the Nation's drivers nearly $180 billion in fuel costs over the lifetimes of the vehicles covered by its most recent CAFE rule.

The 2009 and 2010 CAFE rules build on two previous changes that increased the mileage requirements for light trucks beginning with model year 2005.

than the minimum level considered, which would entail slightly more than a doubling of expenditure, would result in user costs per mile at the end of the period being reduced by 4.2 cents, or 3.6 percent. For the case where real investment in Federal-aid highways is sustained at the 2008 level, HERS projects highway user costs in 2028 to average $1.10 per mile, which translates to savings of 0.6 percent relative to the projection assuming future investment at the lowest level in *Exhibit 7-8*.

Although the results indicate that additional investment reduces user costs by only a small percentage, *Exhibit 7-9* shows that on Federal-aid highways the total dollar savings are large relative to the increment in investment. To allow measurement of these savings without conflating the impact of highway investment on VMT (operating through the demand elasticity), *Exhibit 7-9* computes the average VMT projected for 2028 across all levels of future investment. The estimated savings shown in the last column are calculated for each level of investment by multiplying this average VMT, 3.687 trillion, by the projected 2008–2028 reduction in average user cost per VMT. The resulting estimate of savings in user costs ranges from $231.9 billion at the maximum level of investment considered to $77.1 billion at the minimum level of investment. The difference between these figures, $154.8 billion, is the estimated savings in highway user costs in a single year, 2028, attributable to additional investment averaging $56.1 billion per year over the preceding 20 years. Alternatively, comparing the maximum level of investment with zero growth in investment, the corresponding estimates are savings of $132.0 billion in 2028 versus an additional investment of $50.7 billion per year.

Adjustment for Fuel Economy Improvements

The 2006 C&P report and several prior editions had used average user costs per VMT as a proxy for the overall conditions and performance of the highway system. Since factors that affect average user costs other than pavement condition and traffic congestion, such as vehicle technology, were held constant in the analysis, decreases in average user costs could be directly associated with improvements in overall system conditions and performance.

Exhibit 7-9

Analysis of User Cost Savings in 2028 Relative to 2008 at Average VMT Projected for 2028, Federal-Aid Highways

HERS-Modeled Capital Investment		Projected 2028 VMT on Federal-Aid Highways (Trillions of VMT)[2]	Average Total User Costs per VMT (2008 Dollars)		Estimated 2028 User Cost Savings at Average VMT Projection for 2028 (Billions of 2008 Dollars)[3]	Minimum BCR Cutoff [4]
Annual Percent Change in Spending	Average Annual Spending[1] (Billions of 2008 Dollars)		2028	Change Relative to Baseline		
5.90%	$105.4	3.724	$1.067	-$0.063	-$231.9	1.00
4.86%	$93.4	3.714	$1.073	-$0.057	-$209.4	1.20
3.51%	$80.1	3.700	$1.081	-$0.049	-$179.6	1.50
2.88%	$74.7	3.694	$1.085	-$0.045	-$165.9	1.64
1.31%	$62.9	3.677	$1.095	-$0.035	-$129.8	2.02
0.56%	$58.0	3.670	$1.100	-$0.031	-$112.5	2.24
0.00%	$54.7	3.664	$1.103	-$0.027	-$99.9	2.42
-1.00%	$49.3	3.655	$1.109	-$0.021	-$77.1	2.72
Projected 2028 Average:		**3.687**				
2008 Baseline Values:		**2.520**	**$1.130**			

[1] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column.

[2] The HERS model relies on information from the HPMS sample section database, which is limited to those portions of the road network that are generally eligible for Federal funding (i.e., "Federal-aid highways") and excludes roads classified as rural minor collectors, rural local, and urban local.

[3] The implied user cost savings for 2028 were computed by multiplying projected 2028 VMT by the reduction in average user costs per VMT relative to the 2008 baseline. Part of these savings are attributable to improvements in fuel economy resulting from changes to CAFE standards, rather than to the capital investment modeled in HERS.

[4] The minimum BCR cutoff represents the lowest BCR for any project implemented by HERS at the level of funding shown.

Source: Highway Economic Requirements System.

This direct relationship between average user costs and system conditions and performance was broken in the 2008 C&P report, as the analysis of future user costs was modified to take into account EIA forecasts of future fuel efficiency of the vehicle fleet. Adding this refinement to the analysis created a situation in which average user costs would decline over time, even if the physical conditions and operational performance of the highway system remained unchanged. In order to counteract this effect, the 2008 C&P report introduced a new metric, "adjusted user costs." This statistic was computed by recalculating user costs in the 2006 base year as though the fuel economy improvements projected through the end of the analysis period had already occurred. By netting out the impacts of the fuel economy changes, the adjusted user cost metric represents a better proxy for overall system conditions and performance, and was utilized as the metric for a key scenario in the 2008 C&P report.

In the present report, the HERS estimate of average user costs in 2008 has already been noted to be $1.130 (i.e., 113.0 cents) per VMT. The corresponding figure for adjusted user costs, modified as if the improvements in future fuel economy projected by EIA (roughly 28.2 percent for cars and 13.7 percent for trucks) had already occurred in 2008, is $1.096 per VMT or 3.1 percent lower. *Exhibit 7-10* indicates that meeting a target of maintaining user costs through 2028 at the adjusted 2008 level of $1.096 per VMT would require investment in system preservation and expansion on Federal-aid highways to increase at an average annual rate of 1.20 percent. This rate of spending growth is quite close to the 1.31 percent

Exhibit 7-10

Alternative Scenario Targets for Federal-Aid Highways: Maintaining Adjusted User Costs Versus Maintaining Average Speed

HERS-Modeled Capital Investment		Average Total User Costs per VMT in 2028 (2008 Dollars)	Average Speed in 2028 (mph)	Percent Change in Average User Costs per VMT		Percent Change in Average Speed Relative to Baseline	Minimum BCR Cutoff [3]
Annual Percent Change in Spending	Average Annual Spending [1] (Billions of 2008 Dollars)			Relative to Baseline	Relative to Adjusted Baseline		
5.90%	$105.4	$1.067	44.3	-5.6%	-2.6%	2.6%	1.00
4.86%	$93.4	$1.073	44.0	-5.0%	-2.0%	2.0%	1.20
3.51%	$80.1	$1.081	43.7	-4.3%	-1.3%	1.2%	1.50
2.88%	$74.7	$1.085	43.5	-4.0%	-1.0%	0.9%	1.64
1.31%	$62.9	$1.095	43.2	-3.1%	-0.1%	**0.0%**	2.02
1.20%	$62.1	$1.096	43.1	-3.1%	**0.0%**	-0.1%	2.06
0.56%	$58.0	$1.100	43.0	-2.7%	0.7%	-0.4%	2.24
0.00%	$54.7	$1.103	42.8	-2.4%	0.7%	-0.7%	2.42
-1.00%	$49.3	$1.109	42.6	-1.8%	1.2%	-1.3%	2.72
2008 Baseline Values:		**$1.130**	**43.2**				
2008 Adjusted Baseline: [2]		**$1.096**					

[1] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column.

[2] The adjusted baseline value estimates what 2008 user costs might have been had the fuel economy improvements assumed in HERS for the year 2028 occurred in the 2008 base year. This statistic is meant to offset the effects of changes in CAFE standards to more directly show the impact of highway investment on user costs.

[3] The minimum BCR cutoff represents the lowest BCR for any project implemented by HERS at the level of funding shown.

Source: Highway Economic Requirements System.

per annum estimated to be required for the alternative performance target of maintaining average network speed at the 2008 level. Since the average annual investment levels associated with maintaining these two metrics is relatively similar ($62.9 billion for average speed versus $62.1 billion for adjusted user costs), and the concept of average speed is easier to explain, this edition focuses more on the results for average speed in developing the scenarios presented in Chapter 8.

Future editions of this report may revert to using adjusted user costs more prominently or switch to highlighting some other metric, especially if the costs associated with maintaining average speed in future analyses begin to deviate significantly from those associated with maintaining adjusted user costs. It should be noted that average speed also corresponds to one of the transit performance measures used in the Transit Economic Requirements Model, which is discussed later in this chapter.

Impacts of NHS Investments Modeled by HERS

As described in Chapter 2, the NHS includes the Interstate System as well as other routes most critical to national defense, mobility, and commerce. This section examines the total spending modeled in HERS, identifying the portion of this investment that is directed by the model to the NHS, and the impacts that such investment could have on future NHS conditions and performance.

HERS allocates a portion of future investment to the NHS based on the model's engineering and economic criteria, which give funding priority to high-BCR projects. As in this chapter's preceding sections, this section considers levels of total investment in Federal-aid highways that are each based on a particular target. However, whereas the targets in the preceding sections pertained to Federal-aid highways as a whole, this section adds targets that are NHS-specific.

Exhibit 7-11

Alternative Funding Levels Analyzed for the NHS in HERS

HERS-Modeled Capital Investment			Computed Average Annual Percent Change in HERS NHS Spending Relative to 2008[3]	Minimum BCR Cutoff[4]
Annual Percent Change in Spending	Average Annual Spending (Billions of 2008 Dollars): Total Spending[1]	Average Annual Spending (Billions of 2008 Dollars): Spending on NHS[2]		
5.90%	$105.4	$57.3	4.91%	1.00
4.86%	$93.4	$51.7	4.02%	1.20
3.51%	$80.1	$45.1	2.80%	1.50
2.88%	$74.7	$42.2	2.19%	1.64
1.31%	$62.9	$36.1	0.75%	2.02
0.56%	$58.0	$33.5	0.05%	2.24
0.51%	$57.7	$33.3	**0.00%**	2.26
0.00%	$54.7	$31.8	-0.45%	2.42
-0.25%	$53.3	$31.0	-0.71%	2.49
-0.42%	$52.3	$30.4	-0.87%	2.55
-1.00%	$49.3	$28.8	-1.41%	2.72
-2.57%	$42.1	$24.8	-2.92%	2.83
2008 Baseline Value:		**$33.3**		

[1] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column.

[2] The portion of HERS-modeled spending directed toward the NHS varies by funding level and is not directly linked to actual spending on the NHS in the baseline year.

[3] The amounts shown represent the average annual growth rate in NHS spending that would generate a cumulative 20-year spending level consistent with the average annual HERS-modeled NHS investment levels identified. These values are computed from the results of these HERS analyses rather than having been assumed as part of the inputs to the HERS analyses.

[4] The minimum BCR cutoff represents the lowest BCR for any project implemented by HERS at the level of funding shown.

Source: Highway Economic Requirements System.

Exhibit 7-11 shows these investment levels and portion that HERS allocates to the NHS. In the first three rows, the target is to implement all improvements on Federal-aid highways, including the NHS portion, that have a BCR above a certain minimum. Similarly, most of the other targets represented in *Exhibit 7-11* pertain to measures of performance or spending growth on Federal-aid highways as a whole. However, since the NHS is only a subset of Federal-aid highways, achieving a certain target for Federal-aid highways, such as maintaining average speed at the 2008 level, will generally not result in the same target being met for the NHS.

Exhibit 7-11 also considers four alternative targets for maintaining particular NHS-specific measures at their 2008 levels. Three of these alternative targets would maintain certain measures of NHS performance: average speed, average delay per VMT, and average IRI. The associated levels of total average annual spending (on both the NHS and other Federal-aid highways) are $53.3 billion, $52.3 billion, and $42.1 billion; since these are all less than the $54.7 billion spent in 2008, the corresponding rates of annual percent change over the 2008–2028 period are all negative: -0.25 percent, -0.42 percent, and -2.57 percent, respectively. In the simulations with the NHS-specific targets, HERS allocates to the NHS the amount needed to meet these targets without the same target being achieved for other Federal-aid highways. The fourth alternative target is to sustain average annual spending on the NHS at the 2008 level of $33.3 billion per year. For HERS to allocate this distribution of spending to the NHS based on benefit-cost criteria, the total level of spending on all Federal-aid highways would need to be increasing by 0.51 percent annually, which translates into an average annual investment on Federal-aid highways of $57.7 billion per year.

Alternatively, when the target is to implement all cost-beneficial improvements, HERS programs $57.3 billion for the NHS, or 54.4 percent out of a $105.4 billion total. At lower levels of total investment, the portion of investment that HERS directs to the NHS increases somewhat, up to 58.9 percent at the lowest investment total considered (which averages $42.1 billion per year). At each level, however, the share of investment that HERS programs for the NHS is smaller than the 60.1 percent share that the NHS actually received in the base year ($33.3 billion out of a $54.7 billion total).

Impact of Future Investment on NHS Pavement Ride Quality

As the BCR cutoff for funding highway projects (the "minimum BCR") is reduced, the amount that HERS programs for investment in highways increases. *Exhibit 7-12* shows the variation in the amount programmed for the NHS and the associated change in future pavement ride quality as measured by the IRI. Central to the results is the amount that HERS programs for NHS rehabilitation projects. Although investment in system expansion reduces roughness by adding new, smooth lanes, system rehabilitation investments tend to have a significantly greater impact. At a BCR cutoff of 2.26, HERS programs for the NHS an average of $33.3 billion per year in real capital spending, the same as the 2008 level; of this amount, the model programs an average of $13.7 billion for rehabilitation projects. At these levels, the model projects that in 2028 pavements with an IRI value below 95, which is the criterion in Chapter 3 for rating ride quality as "good," will carry 73.6 percent of VMT on the NHS, up from the 56.4 percent estimated for 2008. The results also indicate that bringing this percentage above 89.6 percent would not be cost-beneficial: the capital and work zone delay costs entailed would outweigh the benefits from reduced vehicle operating and other user costs.

Exhibit 7-12 also indicates that average ride quality on the NHS could be sustained at the 2008 level if capital spending on the NHS were to decrease at the equivalent of 2.92 percent annually (constant dollars). Such a decrease would follow what appears to have been a substantial increase in real spending on the NHS that occurred between 2006 (the base year for the 2008 C&P Report) and 2008 (the base year for this report). (The National Highway Construction Cost Index decreased over that period; using that index to convert nominal to real spending, the estimated increase in real spending was 22 percent).

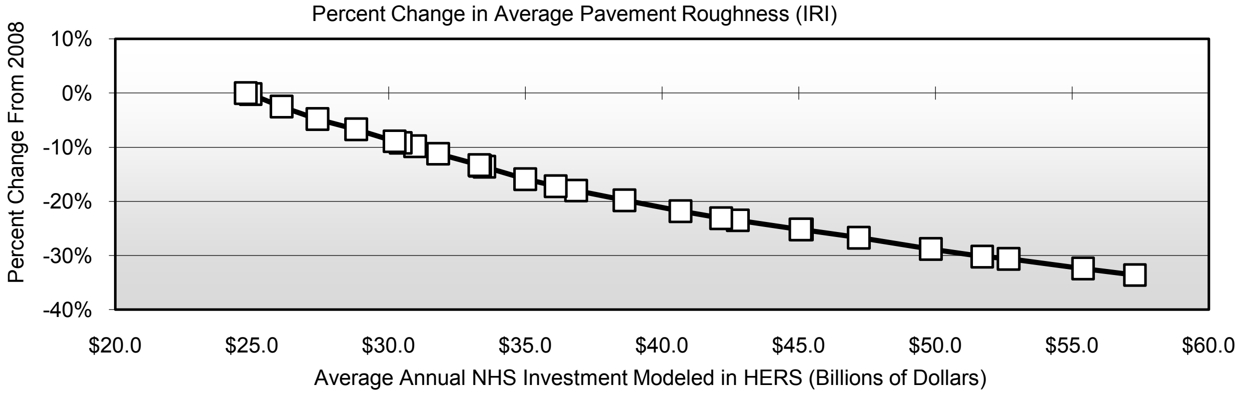
Impact of Future Investment on NHS Travel Times and User Costs

Exhibit 7-13 presents HERS projections for average delay and user costs on the NHS at alternative levels of investment. Also presented is the portion of the NHS investment that HERS programs for system expansion. In the case where HERS programs for NHS investment over 2009–2028 an annual average amount equal to the 2008 level of $33.3 billion (constant dollars), the model allocates $19.6 billion of this amount to system expansion. At these levels, the model projections for the NHS from 2008 to 2028 show average speed decreasing from 52.7 mph to 53.1 mph and average delay per VMT decreasing by 2.9 percent. HERS also predicts that maintaining average speed at the 2008 level could be achieved with constant-dollar investment in the NHS decreasing at an annual equivalent of about 0.87 percent.

Another indication from *Exhibit 7-13* is that implementing all cost-beneficial widening and rehabilitation improvements to the NHS (minimum BCR=1.00) would substantially improve NHS performance. According to the HERS projections, if investment in the NHS increased by 4.91 percent annually in constant dollar terms, average speed on the NHS would increase from 52.7 mph in 2008 to 55.7 mph in 2028, while average delay per VMT would fall 26.3 percent.

Exhibit 7-12

Projected 2028 Pavement Ride Quality Indicators on the NHS Compared With 2008, for Different Possible Funding Levels



	HERS-Modeled NHS Capital Investment			Projected Impact of HERS-Modeled Capital Investment on the NHS			
	Computed Average Annual Percent Change in Spending[1]	Average Annual Spending (Billions of 2008 Dollars)		Percent of 2028 VMT on Roads With...[4]		Average IRI	
Minimum BCR Cutoff		Total Spending[2]	System Rehabilitation[3]	IRI<95	IRI<170	Projected 2028 Level	Change Relative to Baseline
1.00	4.91%	$57.3	$20.9	89.6%	97.4%	66.4	-33.6%
1.20	4.02%	$51.7	$19.4	86.9%	96.8%	69.8	-30.2%
1.50	2.80%	$45.1	$17.4	83.0%	95.8%	74.8	-25.2%
1.64	2.19%	$42.2	$16.6	81.1%	95.5%	76.9	-23.1%
2.02	0.75%	$36.1	$14.6	76.1%	94.3%	82.8	-17.2%
2.24	0.05%	$33.5	$13.8	73.8%	93.7%	86.4	-13.6%
2.26	**0.00%**	$33.3	$13.7	73.6%	93.6%	86.6	-13.4%
2.42	-0.45%	$31.8	$13.2	72.0%	93.2%	88.8	-11.2%
2.49	-0.71%	$31.0	$12.9	71.3%	92.9%	90.2	-9.8%
2.55	-0.87%	$30.4	$12.7	70.8%	92.8%	90.8	-9.2%
2.72	-1.41%	$28.8	$12.2	69.1%	92.4%	93.3	-6.7%
2.83	-2.92%	$24.8	$10.8	64.4%	91.1%	100.0	**0.0%**
			2008 Baseline Values:	**56.4%**	**91.4%**	**100.0**	

[1] The amounts shown represent the average annual growth rate in NHS spending that would generate a cumulative 20-year spending level consistent with the average annual HERS-modeled NHS investment levels identified in the third column.

[2] The amounts shown represent the average annual investment over 20 years by all levels of government combined on the NHS for the HERS analysis with the minimum BCR cutoff identified in each row of the first column. Exhibit 7-11 associates these NHS investment levels with the broader HERS analyses from which they were derived.

[3] The portion of HERS-modeled spending directed toward system rehabilitation varies by funding level and is not directly linked to actual spending for this purpose in the baseline year.

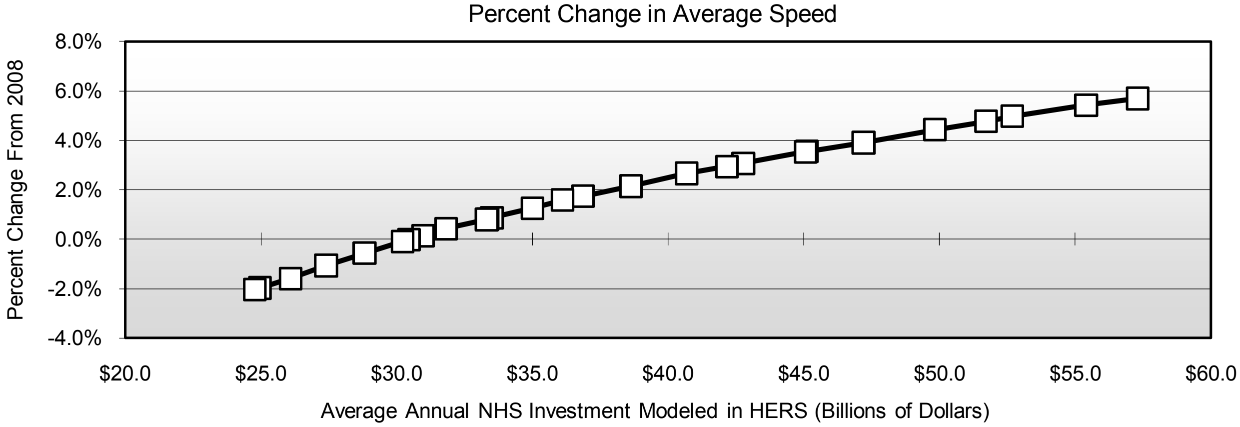
[4] As discussed in Chapter 3, IRI values of 95 and 170 inches per mile, respectively, are the thresholds associated with "good" and "acceptable" pavement ride quality on the NHS.

Source: Highway Economic Requirements System.

At all the BCR cutoffs considered, HERS projects average user cost per VMT on the NHS would decline over the 20-year analysis period. The decline ranges from 2.9 percent at the highest cutoff, which has NHS capital spending decreasing at the equivalent of 2.92 percent annually, to 8.2 percent when all cost-beneficial projects are funded (minimum BCR=1.00). A significant portion of these declines can be attributed to the projected improvements in vehicle fuel technology (see above discussion under "Adjustment for Fuel Economy Improvements").

Exhibit 7-13

Projected Changes in 2028 Speed, Delay, and Highway User Costs on the NHS Compared With 2008, for Different Possible Funding Levels



	HERS-Modeled NHS Capital Investment			Projected Impact of HERS-Modeled Capital Investment on the NHS			
	Computed	Average Annual Spending (Billions of 2008 Dollars)		Percent Change Relative to Baseline per VMT		Average Speed	
Minimum BCR Cutoff	Average Annual Percent Change in Spending[1]	Total Spending[2]	System Expansion[3]	Average User Costs	Average Delay	Projected 2028 Level (mph)	Change Relative to Baseline
1.00	4.91%	$57.3	$36.4	-8.2%	-26.3%	55.7	5.7%
1.20	4.02%	$51.7	$32.3	-7.6%	-21.9%	55.2	4.8%
1.50	2.80%	$45.1	$27.7	-6.8%	-16.1%	54.5	3.6%
1.64	2.19%	$42.2	$25.6	-6.4%	-13.0%	54.2	2.9%
2.02	0.75%	$36.1	$21.5	-5.4%	-6.1%	53.5	1.6%
2.24	0.05%	$33.5	$19.7	-5.0%	-3.1%	53.1	0.9%
2.26	**0.00%**	$33.3	$19.6	-4.9%	-2.9%	53.1	0.8%
2.42	-0.45%	$31.8	$18.7	-4.6%	-1.2%	52.9	0.4%
2.49	-0.71%	$31.0	$18.1	-4.4%	-0.1%	52.7	0.1%
2.55	-0.87%	$30.4	$17.7	-4.3%	0.7%	52.7	**0.0%**
2.72	-1.41%	$28.8	$16.6	-3.9%	3.2%	52.4	-0.6%
2.83	-2.92%	$24.8	$13.9	-2.9%	10.2%	51.6	-2.0%
					2008 Baseline Values:	52.7	

[1] The amounts shown represent the average annual growth rate in NHS spending that would generate a cumulative 20-year spending level consistent with the average annual HERS-modeled NHS investment levels identified in the third column.

[2] The amounts shown represent the average annual investment over 20 years by all levels of government combined on the NHS for the HERS analysis with the minimum BCR cutoff identified in each row of the first column. Exhibit 7-11 associates these NHS investment levels with the broader HERS analyses from which they were derived.

[3] The portion of HERS-modeled spending directed toward system expansion varies by funding level and is not directly linked to actual spending for this purpose in the baseline year. System expansion expenditures have a more direct impact on delay and speed, while both system expansion and system rehabilitation expenditures impact highway user costs.

Source: Highway Economic Requirements System.

Impacts of Interstate System Investments Modeled by HERS

The Interstate System, unlike the broader NHS of which it is a part, has standard design and signing requirements, which makes it the most recognizable subset of the highway network. This section examines the amount of investment that HERS directs to the Interstate System, and the potential impacts of this investment on future Interstate System conditions and performance.

Exhibit 7-14

Alternative Funding Levels Analyzed for the Interstate System in HERS

Annual Percent Change in HERS Capital Spending	Average Annual HERS-Modeled Capital Investment (Billions of 2008 Dollars)		Computed Average Annual Percent Change in HERS Interstate Spending Relative to 2008[3]	Minimum BCR Cutoff
	Total Spending[1]	Spending on Interstates[2]		
5.90%	$105.4	$34.6	7.27%	1.00
4.86%	$93.4	$31.8	6.55%	1.20
3.51%	$80.1	$28.3	5.54%	1.50
2.88%	$74.7	$26.5	4.99%	1.64
1.31%	$62.9	$23.0	3.75%	2.02
0.56%	$58.0	$21.6	3.18%	2.24
0.00%	$54.7	$20.6	2.77%	2.42
-0.65%	$51.1	$19.3	2.17%	2.63
-1.12%	$48.7	$18.5	1.78%	2.73
-2.50%	$42.4	$16.5	0.74%	2.83
-3.47%	$38.5	$15.3	**0.00%**	2.90
-3.57%	$38.2	$15.2	-0.05%	2.90
2008 Baseline Value:		**$15.3**		

[1] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if such spending grows annually in constant dollar terms by the percentage shown in each row of the first column.

[2] The portion of HERS-modeled spending directed toward Interstate highways varies by funding level and is not directly linked to actual spending on the Interstate highways in the baseline year.

[3] The amounts shown represent the average annual growth rate in NHS spending that would generate a cumulative 20-year spending level consistent with the average annual HERS-modeled NHS investment levels identified. These values are computed from the results of these HERS analyses rather than having been assumed as part of the inputs to the HERS analyses.

Source: Highway Economic Requirements System.

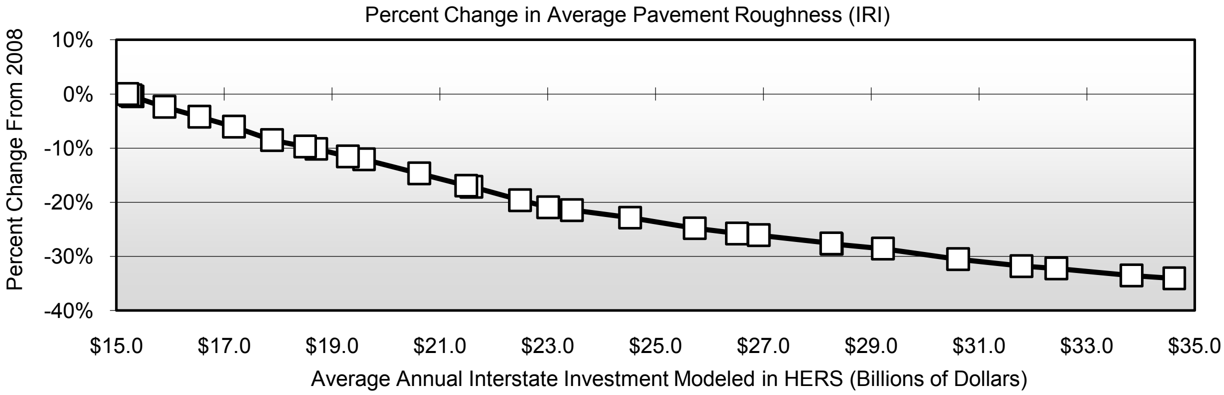
Exhibit 7-14 identifies the alternative funding levels analyzed for the Interstate System in HERS for this analysis. These levels were selected in a manner comparable to that described for the NHS earlier (and summarized in *Exhibit 7-11*), except that in place of the four investment levels targeted to achieving a particular outcome on the NHS, *Exhibit 7-14* considers investment levels geared toward achieving the same targets on the Interstate System. These targets would maintain at the 2008 level either the average annual amount invested in the Interstate System or a measure of the system's performance: average speed, average delay, average pavement roughness, or average annual capital spending in constant dollars. Apart from these four targets pertaining to the Interstate System, all the investment levels in *Exhibit 7-14* pertain to the previously considered targets for Federal-aid highways. The portion of total investment in Federal-aid highways that HERS directs to the Interstate System is determined by the model's optimization rules. When the target is to implement all cost-beneficial improvements, HERS programs $34.6 billion for the Interstate System, or about one-third of the $105.4 billion total on all Federal-aid highways. At lower levels of total investment, the portion that HERS directs to the Interstate System increases somewhat, up to 39.8 percent at the lowest investment total considered (which averages $38.2 billion per year). At each level, however, the share of investment that HERS programs for the Interstate System exceeds the 28.0 percent share that the Interstate System actually received in the base year ($15.3 billion out of a $54.7 billion total). When the target is to sustain average annual investment in the Interstate System at the 2008 level (0.00 percent growth), total funding for Federal-aid highways must decrease at a 3.47 percent annual rate for HERS to allocate out of that total the target amount for the Interstate System. In this case, HERS allocates to the Interstate System an annual average of $15.3 billion out of $38.5 billion for all Federal-aid highways.

Impact of Future Investment on Interstate Pavement Ride Quality

Exhibit 7-15 shows how pavement ride quality (based on the IRI defined in Chapter 3) of the Interstate System could be affected by the total amount invested in types of capital improvements modeled in HERS, particularly Interstate System rehabilitation expenditures. When investment in the Interstate System remains at the $15.3 billion spent in 2008, HERS allocates $6.0 billion of this annual amount to system rehabilitation expenditure (*Exhibit 7-15*). At these levels, the projections for 2028 are for 72.4 percent of

Exhibit 7-15

Projected 2028 Pavement Ride Quality Indicators on the Interstate System Compared With 2008, for Different Possible Funding Levels



Minimum BCR Cutoff	HERS-Modeled Interstate Capital Investment: Computed Average Annual Percent Change in Spending [1]	Average Annual Spending (Billions of 2008 Dollars): Total Spending [2]	System Rehabilitation [3]	Projected Impact of HERS-Modeled Capital Investment on the Interstate System: Percent of 2028 VMT on Roads With...[4] IRI<95	IRI<170	Average IRI: Projected 2028 Level	Change Relative to Baseline
1.00	7.27%	$34.6	$10.9	94.2%	99.3%	61.2	-34.1%
1.20	6.55%	$31.8	$10.4	92.5%	99.1%	63.3	-31.8%
1.50	5.54%	$28.3	$9.6	89.8%	98.3%	67.1	-27.7%
1.64	4.99%	$26.5	$9.2	88.3%	98.0%	68.9	-25.8%
2.02	3.75%	$23.0	$8.3	84.7%	97.2%	73.4	-20.9%
2.24	3.18%	$21.6	$7.9	82.8%	96.7%	76.9	-17.1%
2.42	2.77%	$20.6	$7.6	81.4%	96.1%	79.2	-14.7%
2.63	2.17%	$19.3	$7.2	79.7%	95.6%	82.1	-11.5%
2.73	1.78%	$18.5	$7.0	78.6%	95.4%	83.8	-9.7%
2.83	0.74%	$16.5	$6.5	75.3%	94.6%	88.9	-4.2%
2.90	**0.00%**	$15.3	$6.0	72.4%	93.9%	92.4	-0.4%
2.90	-0.05%	$15.2	$6.0	72.1%	93.8%	92.8	**0.0%**
			2008 Baseline Values:	**63.9%**	**93.4%**	**92.8**	

[1] The amounts shown represent the average annual growth rate in spending on the Interstate Highway System that would generate a cumulative 20-year spending level consistent with the average annual HERS-modeled Interstate investment levels identified in the third column.

[2] The amounts shown represent the average annual investment over 20 years by all levels of government combined on the Interstate Highway System for the HERS analysis with the minimum BCR cutoff identified in each row of the first column. Exhibit 7-14 associates these Interstate investment levels with the broader HERS analyses from which they were derived.

[3] The portion of HERS-modeled spending directed toward system rehabilitation varies by funding level and is not directly linked to actual spending for this purpose in the baseline year.

[4] As discussed in Chapter 3, IRI values of 95 and 170 inches per mile, respectively, are the thresholds associated with "good" and "acceptable" pavement ride quality on the NHS.

Source: Highway Economic Requirements System.

Interstate System travel to occur on pavements with "good" quality (IRI below 95) and 93.9 percent to occur on pavements with "acceptable" quality (IRI below 170). The increase in these percentages above the 2008 values of 63.9 percent and 93.4 percent, respectively, indicates an overall improvement in the Interstate System pavement quality.

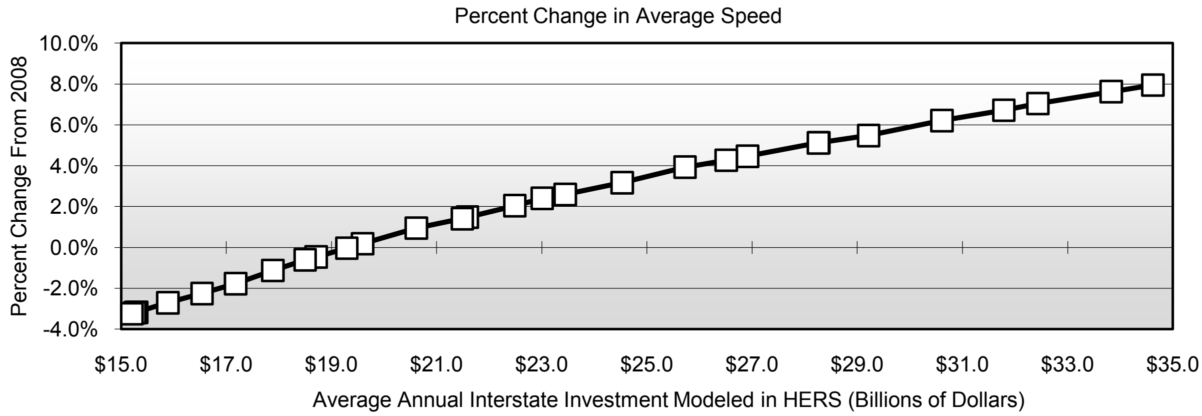
Implementation of all cost-beneficial improvements (minimum BCR=1.00) would improve pavement quality on the Interstate System to the economically justifiable extent. In this case, the average IRI on the Interstate System is projected to fall from 92.8 in 2008 to 61.2 in 2028, an improvement of 34.1 percent.

Impact of Future Investment on Interstate System Travel Times and User Costs

The impact of future investment on Interstate System travel times and user costs depends especially on the amount invested in Interstate System expansion. As shown in *Exhibit 7-16*, when total investment in Interstate System improvements within the scope of HERS is assumed to continue at the 2008 rate (minimum BCR=2.90), HERS allocates $9.3 billion for Interstate System expansion, and average system speed is projected to decrease from 60.1 mph in 2008 to 58.2 mph in 2028. With average speed lower, average delay for travel on the Interstate System increases 13.4 percent. At the limits of the investment levels

Exhibit 7-16

Projected Changes in 2028 Speed, Delay, and Highway User Costs on the Interstate System Compared With 2008, for Different Possible Funding Levels



	HERS-Modeled Interstate Capital Investment			Projected Impact of HERS-Modeled Capital Investment on the Interstate System			
	Computed Average Annual Percent Change in Spending [1]	Average Annual Spending (Billions of 2008 Dollars)		Percent Change Relative to Baseline per VMT		Average Speed	
Minimum BCR Cutoff		Total Spending [2]	System Expansion [3]	Average User Costs	Average Delay	Projected 2028 Level (mph)	Change Relative to Baseline
1.00	7.27%	$34.6	$23.7	-9.4%	-41.5%	64.8	8.0%
1.20	6.55%	$31.8	$21.4	-8.8%	-35.3%	64.1	6.7%
1.50	5.54%	$28.3	$18.7	-8.0%	-27.8%	63.1	5.1%
1.64	4.99%	$26.5	$17.3	-7.5%	-23.3%	62.6	4.3%
2.02	3.75%	$23.0	$14.7	-6.5%	-13.5%	61.5	2.4%
2.24	3.18%	$21.6	$13.7	-5.9%	-9.8%	61.0	1.5%
2.42	2.77%	$20.6	$13.0	-5.6%	-7.5%	60.6	0.9%
2.63	2.17%	$19.3	$12.0	-5.0%	-2.9%	60.0	**0.0%**
2.73	1.78%	$18.5	$11.5	-4.7%	-0.2%	59.7	-0.6%
2.83	0.74%	$16.5	$10.1	-3.7%	8.2%	58.7	-2.3%
2.90	**0.00%**	$15.3	$9.3	-3.1%	13.4%	58.2	-3.2%
2.90	-0.05%	$15.2	$9.2	-3.1%	13.7%	58.1	-3.2%
				2008 Baseline Values:		**60.1**	

[1] The amounts shown represent the average annual growth rate in spending on the Interstate Highway System that would generate a cumulative 20-year spending level consistent with the average annual HERS-modeled Interstate investment levels identified in the third column.

[2] The amounts shown represent the average annual investment over 20 years by all levels of government combined on the Interstate Highway System for the HERS analysis with the minimum BCR cutoff identified in each row of the first column.
Exhibit 7-14 associates these Interstate investment levels with the broader HERS analyses from which they were derived.

[3] The portion of HERS-modeled spending directed toward system expansion varies by funding level and is not directly linked to actual spending for this purpose in the baseline year. System expansion expenditures have a more direct impact on delay and speed, while both system expansion and system rehabilitation expenditures impact highway user costs.

Source: Highway Economic Requirements System.

presented in *Exhibit 7-16*, the changes in travel time and delay are more pronounced. At one extreme where the Interstate System receives the average $34.6 billion per year that HERS estimates is required to fund all cost-beneficial improvements, projections for the Interstate System in 2028 are for speed to average 64.8 mph and for delay per VMT to average 41.5 percent less than in 2008. At the other extreme, *Exhibit 7-16* shows total investment within the scope of HERS decreasing over the 20-year analysis period by 1.00 percent per year, and average delay per VMT on the Interstate System increasing by 13.7 percent.

The projections for average user costs on the Interstate System show declines between 3.1 percent and 9.4 percent over 20 years, depending on the level of investment. Again, the projected improvements in vehicle fuel efficiency contribute significantly to these results.

Impacts of Systemwide Investments Modeled by NBIAS

Early in this chapter, *Exhibit 7-1* showed that of the $91.1 billion invested in highways in 2008, $12.8 billion was used for bridge system rehabilitation (repair and replacement). In using the NBIAS model to project conditions and performance of the Nation's bridges over 20 years, this section considers the alternatives of continuing to invest in bridge rehabilitation at this level and at higher or lower levels. The expenditures modeled pertain only to bridge system rehabilitation; expenditures associated with bridge system expansion are modeled separately as part of the capacity expansion analysis in the HERS model. (The NBIAS-modeled investments presented here should be considered as additive to the HERS-modeled investments presented above; each of the capital investment scenarios presented in Chapter 8 combines one of the HERS analyses with one of the NBIAS analyses, and makes adjustments to account for non-modeled spending).

Impact of Future Investment on Overall Bridge Conditions

The NBIAS model considers bridge deficiencies at the level of individual bridge elements based on engineering criteria and computes an initial value for the cost of a set of corrective actions that would address all such deficiencies. NBIAS tracks this "backlog" of potential bridge improvements over time, recomputing it to account for corrective actions taken and for the ongoing deterioration of bridge elements. A portion of this engineering-based backlog represents potential corrective actions that would not pass a benefit-cost test and thus would not be implemented by the model, even if available funding were unlimited. Such potential actions are not included in the statistics presented in this chapter, which focuses on the backlog of actions for which benefits would exceed the costs, and the total cost of their full implementation. Changes in this "economic" bridge investment backlog can be viewed as a proxy for changes in overall bridge conditions.

Q&A

How does the NBIAS definition of bridge deficiencies compare with the information on structurally deficient bridges reported in Chapter 3?

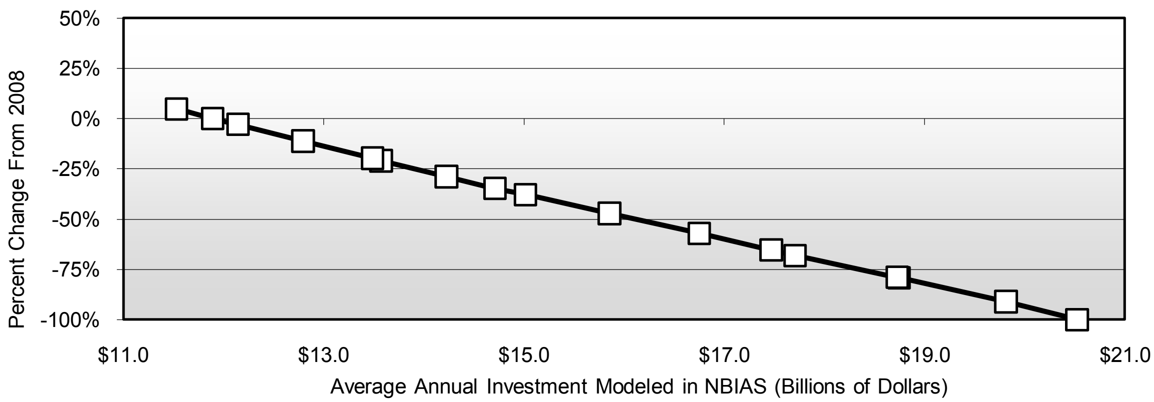
NBIAS considers bridge deficiencies and corrective improvements at the level of individual bridge elements. The economic backlog of bridge deficiencies estimated by NBIAS thus consists of the cost of all improvements to bridge elements that would be justified on both engineering and economic grounds. It includes many improvements on bridges with certain components that may warrant repair, rehabilitation, or replacement, but whose overall condition is not sufficiently deteriorated for them to be classified as structurally deficient.

The corrective actions recommended by NBIAS would include those aimed at addressing structural deficiencies, as well as some functional deficiencies. System expansion needs for both highways and bridges are addressed separately as part of the HERS model analysis.

Exhibit 7-17 describes how the economic backlog of system rehabilitation investments for bridges could be influenced by the total amount invested in the types of capital improvements modeled in NBIAS. NBIAS estimates the size of the backlog in 2008 to be $121.2 billion; the model projects that if combined spending on the types of capital improvements modeled in NBIAS were sustained at the 2008 level of $12.8 billion in constant dollar terms, the economic bridge backlog could be reduced by 11.2 percent to $107.6 billion in 2028. Less funding would be needed to maintain the backlog at its 2008 level; NBIAS projects that an average annual investment level of $11.9 billion would be sufficient to prevent the backlog from rising. To eliminate the backlog by 2028, NBIAS projects that an average annual investment of $20.5 billion (investment increasing by 4.31 percent annually) would be needed. Investment above this level would not be considered cost-beneficial.

Exhibit 7-17

Projected Changes in 2028 Economic Bridge Investment Backlog for All Bridges Compared With 2008, for Different Possible Funding Levels



NBIAS-Modeled Capital Investment		Projected Impact of NBIAS-Modeled Capital Investment on All Bridges				
		Economic Bridge Investment Backlog for System Rehabilitation in 2028 (Billions of 2008 Dollars)[2]				
Annual Percent Change in Spending	Average Annual Spending[1] (Billions of 2008 Dollars)	Replacement	Improvement[3]	Rehabilitation and Repair	Total	Change Relative to Baseline
4.31%	$20.5	$0.0	$0.0	$0.0	$0.0	**-100.0%**
3.51%	$18.7	$13.1	$1.0	$11.2	$25.3	-79.1%
2.88%	$17.5	$24.6	$1.9	$15.5	$42.0	-65.3%
1.31%	$14.7	$55.9	$3.1	$20.1	$79.1	-34.7%
0.56%	$13.6	$71.2	$3.5	$21.1	$95.8	-20.9%
0.00%	$12.8	$82.2	$3.7	$21.7	$107.6	-11.2%
-0.70%	$11.9	$94.9	$3.9	$22.4	$121.2	**0.0%**
-1.00%	$11.5	$100.6	$3.9	$22.6	$127.1	4.9%
				2008 Baseline Value:	**$121.2**	

[1] The amounts shown represent the average annual investment over 20 years by all levels of government combined that would occur if annual investment grows in constant dollar terms by the percentage shown in each row of the first column.

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

[3] Includes raising, strengthening, and widening investments.

Source: National Bridge Investment Analysis System.

Exhibit 7-17 also identifies the portions of the economic backlog associated with bridge replacement, bridge improvement, and bridge rehabilitation and repair. The bridge improvement portion includes the raising, strengthening, and widening of existing bridges. The bridge replacement portion accounts for most of the backlog because the high capital costs of replacement projects frequently make their benefit-cost ratios lower than for potential improvement, rehabilitation, or repair actions. As a result, NBIAS tends to defer these investments when available funding is constrained.

Impacts of Federal-Aid Highway Investments Modeled by NBIAS

For the bridges on Federal-aid highways, *Exhibit 7-18* shows how variation in the amount invested over the analysis period affects the NBIAS projection for the economic backlog of investment in 2028. With this investment assumed to average $9.4 billion per year—what was actually spent on Federal-aid highway bridges in 2008—the backlog projected for 2028 exceeds the $102.1 billion backlog estimated for 2008 by 6.5 percent. To stop the backlog from growing above the 2008 level, investment would need to grow by approximately 0.40 percent per year, which equates to an average annual investment level of $9.8 billion. Eliminating the backlog by 2028 would require that spending on Federal-aid highway bridges increase 5.36 percent per year in constant dollar terms.

Exhibit 7-18

Projected Changes in 2028 Economic Bridge Investment Backlog on Federal-Aid Highways Compared With 2008, for Different Possible Funding Levels

NBIAS-Modeled Capital Investment on Federal-Aid Highway Bridges		Projected Impact of NBIAS-Modeled Capital Investments on Federal-Aid Highway Bridges	
		Economic Bridge Investment Backlog for System Rehabilitation [2]	
Annual Percent Change in Spending	Average Annual Spending [1] (Billions of 2008 Dollars)	2028 (Billions of 2008 Dollars)	Change Relative to Baseline
5.36%	$17.1	**$0.0**	**-100.0%**
4.86%	$16.1	$13.6	-86.6%
3.51%	$13.8	$45.2	-55.7%
2.88%	$12.9	$58.1	-43.1%
1.31%	$10.8	$87.4	-14.4%
0.56%	$10.0	$99.9	-2.1%
0.40%	$9.8	$102.1	**0.0%**
0.00%	$9.4	$108.7	6.5%
-1.00%	$8.5	$123.7	21.2%
	2008 Baseline Value:	**$102.1**	

[1] The amounts shown represent the average annual investment over 20 years on bridges located on Federal-aid highways that would occur if annual investment grows in constant dollar terms by the percentage shown in each row of the first column. Bridges on roadways functionally classified as rural minor collector, rural local, and urban local are not included in these figures.

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

Source: National Bridge Investment Analysis System.

It should be noted that the NBIAS analyses presented for bridges on Federal-aid highways in this section, as well as those for NHS bridges and Interstate System bridges described below, were each conducted on these specific subsets of the total bridge population, rather than as part of a larger analysis of all bridges. The annual percent changes in spending identified in the exhibits reflect the actual change in investment assumed for each individual year. In contrast, the HERS analyses of the NHS and Interstate highways presented earlier used a different approach, in which the amounts spent on these systems were extracted from analyses of all Federal-aid highways over 20 years, and equivalent annual percent changes were derived.

Impacts of NHS Investments Modeled by NBIAS

NBIAS estimates the economic backlog of NHS bridge system rehabilitation investments to have been $60.4 billion in 2008. All levels of government combined spent $5.4 billion in 2008 on the NHS capital improvements of the types that NBIAS models; as shown in *Exhibit 7-19,* the model projects that if this level of investment were sustained over 20 years in constant dollar terms, the NHS bridge backlog would decrease by 1.8 percent. Eliminating the economic backlog by 2028 is estimated to require an annual spending increase of 4.48 percent in constant dollar terms; which equates to an average annual investment level of $8.9 billion in 2008 dollars.

Exhibit 7-19

Projected Changes in 2028 Economic Bridge Investment Backlog on the NHS Compared With 2008, for Different Possible Funding Levels

NBIAS-Modeled Capital Investment on NHS Bridges		Projected Impact of NBIAS-Modeled Capital Investments on NHS Bridges	
		Economic Bridge Investment Backlog for System Rehabilitation[2]	
Annual Percent Change in Spending	Average Annual Spending[1] (Billions of 2008 Dollars)	2028 (Billions of 2008 Dollars)	Change Relative to Baseline
4.48%	$8.9	**$0.0**	**-100.0%**
4.02%	$8.4	$7.8	-87.0%
2.80%	$7.3	$26.1	-56.7%
2.19%	$6.9	$33.9	-43.8%
0.75%	$5.9	$51.5	-14.8%
0.05%	$5.5	$58.7	-2.8%
0.00%	$5.4	$59.3	-1.8%
-0.09%	$5.4	$60.4	**0.0%**
-0.45%	$5.2	$63.9	5.8%
-0.71%	$5.0	$66.5	10.1%
-0.87%	$5.0	$67.9	12.4%
-1.41%	$4.7	$72.7	20.5%
-2.92%	$4.0	$84.8	40.5%
2008 Baseline Value:		**$60.4**	

[1] The amounts shown represent the average annual investment over 20 years on NHS bridges that would occur if annual investment grows in constant dollar terms by the percentage shown in each row of the first column.

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

Source: National Bridge Investment Analysis System.

Impacts of Interstate Investments Modeled by NBIAS

Exhibit 7-20 describes for Interstate System bridges how the economic backlog projected for 2028 varies with the assumed total expenditure on these bridges for the types of capital improvements modeled in NBIAS. Sustaining this expenditure over 20 years at the 2008 level of $3.3 billion in constant dollar terms is projected to reduce the backlog by 3.6 percent below the $38.1 billion estimated for 2008, or by $1.4 billion. If spending were to increase over this period by 4.39 percent annually, this could completely eliminate the backlog by 2028.

Exhibit 7-20

Projected Changes in 2028 Economic Bridge Investment Backlog on the Interstate System Compared With 2008, for Different Possible Funding Levels

NBIAS-Modeled Capital Investment on Interstate Bridges		Projected Impact of NBIAS-Modeled Capital Investments on Interstate Bridges	
		Economic Bridge Investment Backlog for System Rehabilitation[2]	
Annual Percent Change in Spending	Average Annual Spending[1] (Billions of 2008 Dollars)	2028 (Billions of 2008 Dollars)	Change Relative to Baseline
4.39%	$5.3	**$0.0**	**-100.0%**
3.75%	$5.0	$6.1	-84.0%
3.18%	$4.6	$11.8	-69.0%
2.77%	$4.4	$15.5	-59.4%
2.17%	$4.2	$20.6	-45.9%
1.78%	$4.0	$23.6	-38.1%
0.74%	$3.6	$31.9	-16.1%
0.00%	$3.3	$36.7	-3.6%
-0.05%	$3.3	$37.0	-2.7%
-0.18%	$3.2	$38.1	0.0%
-1.00%	$3.0	$42.8	12.4%
2008 Baseline Value:		**$38.1**	

[1] The amounts shown represent the average annual investment over 20 years on Interstate bridges that would occur if annual investment grows in constant dollar terms by the percentage shown in each row of the first column.

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

Source: National Bridge Investment Analysis System.

Potential Transit Capital Investment Impacts

This section examines how different types and levels of annual capital investments would likely affect transit system condition and performance by the year 2028. It begins with an overview of the types of capital spending projected by the U.S. Federal Transit Administration's (FTA's) Transit Economic Requirements Model (TERM), which is the primary analysis tool used to assess transit investment needs and impacts in Part II of this report. The section then examines how variations in the level of annual capital spending are likely to impact future transit conditions and performance—both at the national level and for urbanized areas (UZAs) with populations greater than 1 million.

Types of Capital Spending Projected by TERM

TERM is an analysis tool that uses engineering and economic concepts to forecast total capital investment needs for the U.S. transit industry over a 20-year time horizon. Specifically, TERM is designed to forecast the following types of investment needs:

- **Preservation:** The level of investment in the rehabilitation and replacement of existing transit capital assets required to attain specific investment goals (e.g., to attain a "state of good repair") subject to potentially limited capital funding.
- **Expansion:** The level of investment in the expansion of transit fleets, facilities, and rail networks required to (1) support projected growth in transit demand (i.e., maintain performance); and (2) improve existing service quality and speed (i.e., improve performance).

TERM also includes a benefit-cost test that is applied for most analysis scenarios to determine which investments are cost effective and which are not. For scenarios that apply the benefit-cost test (as described in Chapter 8), TERM reports investment costs only for those investments that pass the test.

The data used to support TERM's needs estimates are derived from a variety of sources—including asset inventory data provided by local transit agencies (at FTA's request), fleet investment and transit performance data obtained from the National Transit Database (NTD), and transit travel demand forecast data provided by metropolitan planning organizations (MPOs). Appendix C contains a detailed description of the analysis methodology used by TERM.

Preservation Investments

TERM estimates current and future preservation investment needs by first assessing the age and current condition of the Nation's existing stock of transit assets (the results of this analysis were presented in Chapter 3 of this report). TERM then uses this information to assess both current reinvestment needs (i.e., the reinvestment "backlog") as well as the expected level of ongoing investment required to meet the life-cycle needs of the Nation's transit assets over the next 20 years—including all required rehabilitation and replacement activities.

Condition Based Reinvestment: Rather than relying on age alone in assessing the timing and cost of current and future reinvestment activities, TERM uses a set of empirical asset deterioration curves that estimate asset condition (both current and future) as a function of asset type, age, past rehabilitation

> **What types of capital spending are not modeled by TERM?**
>
> TERM does not project all types of capital spending undertaken by U.S. transit agencies. Specifically, the model does not forecast capital expenditures:
>
> - Aimed at improving the safety or security of a transit asset or system beyond existing levels
> - That address the needs of transportation services for elderly persons or persons with disabilities funded under FTA's Section 5310 program
> - For significant functional improvements (e.g., such as replacement of an existing maintenance facility with a larger and better-equipped structure) to existing transit assets. In other words, TERM replaces most assets "in-kind."
>
> It is important to note that, while TERM does not forecast the types of expenditures described above, some of these investment types (but not all) are included in the actual capital expenditures accounted for in this report, which are taken from information submitted to the NTD by local transit agencies.

activities, and potentially past maintenance and utilization levels as well (depending on asset type). The timing of specific rehabilitation and replacement activities is determined by an asset's estimated condition at the start of each year over the 20-year forecast horizon, with asset condition declining as the asset ages, triggering reinvestment events at different levels of deterioration and leading ultimately to outright replacement.

> **What is the significance of the *Replace at Condition 2.5* threshold?**
>
> The *Replace at Condition 2.5* threshold has been applied in earlier FTA studies, including the *Rail Modernization Study* (released in April 2009) and the *National State of Good Repair Assessment* (released in June 2010). A state of good repair, for the purposes of these studies, was defined using TERM's numerically based condition rating scale of 1 to 5 (poor to excellent) for evaluating transit asset conditions. An asset or a transit system is considered to be in a state of good repair if the asset or system has an estimated condition value of 2.5 or higher (the midpoint between adequate and marginal). The level of investment required to attain and maintain a state of good repair is therefore that amount required to rehabilitate and replace all assets with estimated condition ratings that are less than this minimum condition value.

Financial Constraints, the Investment Backlog, and Future Conditions: TERM is designed to estimate investment needs with or without annual capital funding constraints. When run without funding constraints, TERM estimates the total level of investment required to complete all of the rehabilitation and replacement needs identified by the model, at the time those investment needs come due (hence, there is no appreciable investment backlog with unconstrained analyses after any initial deferred investment is addressed). In contrast, when TERM is run in a financially constrained mode, there may not be sufficient funding to cover the reinvestment needs of all assets, in which case some reinvestment activities are deferred until a future period in which sufficient funds become available. The lack of sufficient funds to address all reinvestment needs for some or all years of the 20-year model run results in varying levels of investment backlog over this time period. Most analyses presented in this chapter were completed using funding constraints. Similarly, TERM's ability to estimate asset conditions—both current and future—provides the ability to assess how future asset conditions are likely to change (either improve or decline) given varying levels of capital reinvestment. Finally, note that TERM's benefit-cost analysis is utilized to determine the order in which reinvestment activities are completed when funding capacity is limited, with those investments with the highest benefit-cost ratio addressed first.

Expansion Investments

In addition to ongoing reinvestment in existing assets, most transit agencies also invest in the expansion of their vehicle fleets, maintenance facilities, fixed guideway, and other assets. Investments in expansion assets can be thought of as serving two distinct purposes. First, the demand for transit services typically increases over time in line with population growth, employment, and other factors. To maintain current levels of performance in the face of expanding demand, transit operators must similarly expand the capacity of their services (e.g., by increasing the number of vehicles in their fleets). Failure to accommodate this demand would result in increased vehicle crowding, increased dwell times at passenger stops, and decreased operating speeds for existing services. Second, transit operators also invest in expansion projects with the aim of improving current service performance. Such improvements include capital expansion projects (e.g., a new light rail segment) to reduce vehicle crowding or increase average operating speeds. TERM is designed to assess investment needs and impacts for both types of expansion investments.

Expansion Investments: Maintain Performance

To assess the level of investment required to maintain existing service quality, TERM estimates the rate of growth in transit vehicle fleets required to maintain current vehicle occupancy levels given the projected growth rate in transit passenger miles. In addition to assessing the level of investment in new fleet vehicles required to support this growth, TERM also forecasts investments in the expansion of other assets needed to support projected fleet growth, including bus maintenance facilities and, in the case of rail systems, additional investment in guideway, track work, stations, maintenance facilities, train control, and traction power systems. Asset expansion investment needs are assessed for all agencies reporting to the NTD on a mode-by-mode basis. However,TERM does not invest in asset expansion for those agency-modes with low ridership (per vehicle) as compared with the national average.

Expansion Investments: Improve Performance

In prior editions of the C&P report, TERM was used to estimate the level of investment required to improve current transit performance by both (1) reducing crowding in higher utilization transit systems and (2) expanding existing investment in rail as a means of improving average operating speeds in UZAs with average operating speeds (across all transit modes) well below the national average. For this edition, the impact of increased investment on system performance is assessed by developing TERM scenarios where the rate of investment in transit asset expansion exceeds the projected rate of growth in transit passenger miles. This difference between the rate of asset expansion and actual growth in travel demand represents projected long-term reductions in in-vehicle crowding and potential increases in average operating speed.

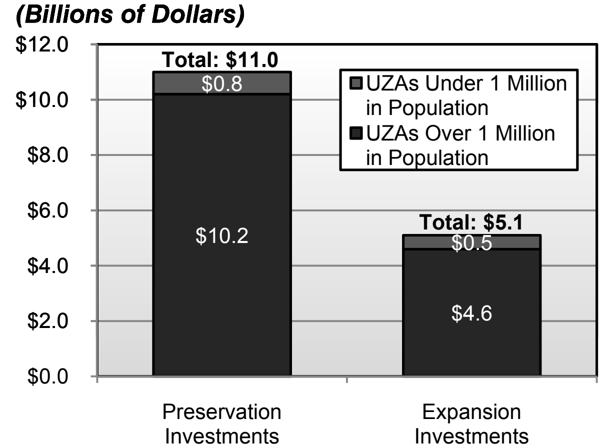
Recent Investment in Transit Preservation and Expansion

Exhibit 7-21 shows the broad composition of the 2008 spending by U.S. transit agencies on capital projects that correspond to the investment types modeled in TERM. Of the total spending amounting to $16.1 billion, $11.0 billion or 68.5 percent was devoted to preserving existing assets, and the rest was spent on expansion investments.

As expected, preservation and expansion spending were concentrated in the large urban systems. In combination, UZAs with populations greater than 1 million in 2008 accounted for 92.4 percent of preservation spending and 91.1 percent of expansion spending. Other urbanized areas and rural areas accounted for the rest.

Exhibit 7-21

2008 Transit Capital Expenditures (Billions of Dollars)



Source: National Transit Database.

Impacts of Systemwide Investments Modeled by TERM

This section uses TERM analyses to assess how different levels of investment in the preservation and expansion of the Nation's transit asset base can be expected to impact transit conditions and performance over the next 20 years. A key objective here is to place a broad range of potential future investment levels—and the consequences of those levels of investment—within the context of both the current expenditures on transit preservation and expansion and of some potential investment goals (e.g., attainment of a SGR (state of good repair) within 20 years). More specifically, these analyses consider the impact of different levels of transit capital expenditures on the following:

- **Preservation Investments**—(1) Average condition rating of U.S. transit assets and (2) SGR backlog
- **Expansion Investments**—Additional ridership (boardings) capacity.

Each of these analyses is completed first at the national level (the remainder of this section) and then repeated (in the following section) for two different segments of UZAs including the following:

- UZAs with populations greater than 1 million
- All other UZAs and rural areas with existing transit services.

Impact of Preservation Investments on Transit Conditions and Backlog

This subsection considers the expected impact of varying levels of aggregate capital reinvestment by all levels of government on the future physical condition and investment backlog (as of 2028) for the Nation's existing stock of transit assets.

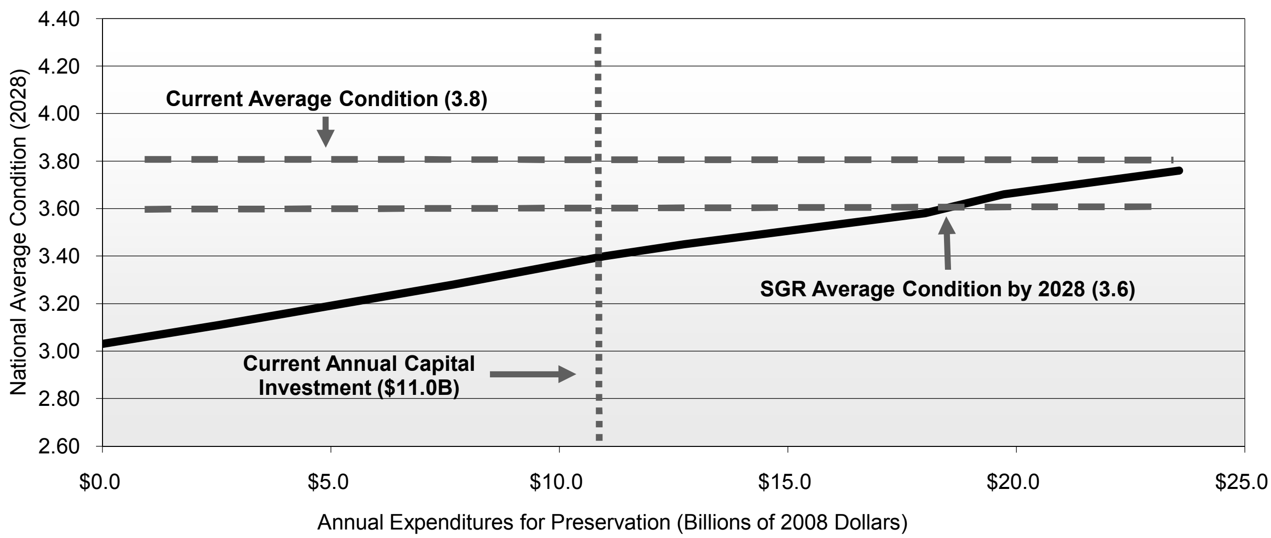
Transit Conditions: *Exhibit 7-22* presents the estimated impact of differing levels of annual rehabilitation and replacement investments on the average physical condition of all existing assets, nationwide, as of 2028. The line chart shows ongoing improvements to the overall condition of the Nation's existing transit asset base from increasing levels of transit capital reinvestment. It should be emphasized here that average condition provides a measure of asset conditions in the aggregate. Hence, while overall conditions improve with additional expenditures, it should nonetheless be expected that the condition of some individual assets will still deteriorate (given the length of asset lives and the timing of their replacement cycles) while the condition of other assets will improve. The value of the aggregate measure lies in providing an overall, single measure of aggregate conditions. Moreover, given the relationship between asset condition and asset reliability, any general improvement in overall asset conditions should also be associated with related improvements to service quality, reliability, and potentially safety as well.

The table portion of *Exhibit 7-22* presents the same investment and average condition information as in the chart. This table also presents the impact of reinvestment on asset conditions for five key transit asset categories (i.e., guideway and track, facilities, systems, stations, and vehicles) as well as the average annual percent change in constant dollar funding from 2008's level to achieve each projected condition level.

Further review of *Exhibit 7-22* reveals several observations. First, note that none of the selected reinvestment rates presented (including the current level of reinvestment, which was $11.0 billion in 2008) is sufficient to maintain aggregate conditions at or near the current national average condition rating of 3.8. Even the highest reinvestment rate presented here of $23.6 billion annually (replacement at condition rating 3.0), which represents a fairly aggressive reinvestment rate, is not quite sufficient to maintain aggregate conditions at current levels. A primary factor driving this result is the ongoing expansion investment in new rail systems over the past several decades, which has tended to maintain or even increase the average

Exhibit 7-22

Impact of Preservation Investment on 2028 Transit Conditions (All Urbanized and Rural Areas)



Average Annual Percent Change vs. 2008	Average Annual Investment (Billions of 2008 Dollars) Total Capital Outlay	Average Transit Conditions in 2028						Notes
		Asset Categories					All Transit Assets	
		Guideway	Facilities	Systems	Stations	Vehicles		
7.0%	$23.6	3.72	3.89	3.76	3.78	3.66	3.76	Unconstrained, Replace at 3.00
5.5%	$19.7	3.69	3.52	3.64	3.76	3.50	3.66	Unconstrained, Replace at 2.75
4.7%	$18.0	3.63	3.17	3.56	3.75	3.43	3.58	Unconstrained, Replace at 2.50
1.4%	$12.7	3.47	2.85	3.46	3.74	3.24	3.45	Maintain Current Backlog
0.0%	$11.0	3.40	2.82	3.37	3.73	3.13	3.40	2008 Capital Expenditures
-3.8%	$7.7	3.33	2.70	3.20	3.71	2.72	3.28	
-20.4%	$2.5	3.18	2.61	2.63	3.67	2.53	3.11	
na	$0.0	3.12	2.58	2.59	3.65	2.25	3.03	

Note that the conditions of individual transit assets are estimated using TERM's asset decay curves, which estimate asset conditions on a scale of 5 (excellent) through 1 (poor), as described earlier in this chapter and in Appendix C of this report. The average national condition is the weighted average of the condition of all assets nationwide, weighted by the estimated replacement cost of each asset.

Note that this preservation analysis is intended to consider reinvestment needs for only existing transit assets (as of 2008), not expansion assets to be added to the existing capital stock in future years.

Source: Transit Economic Requirements Model.

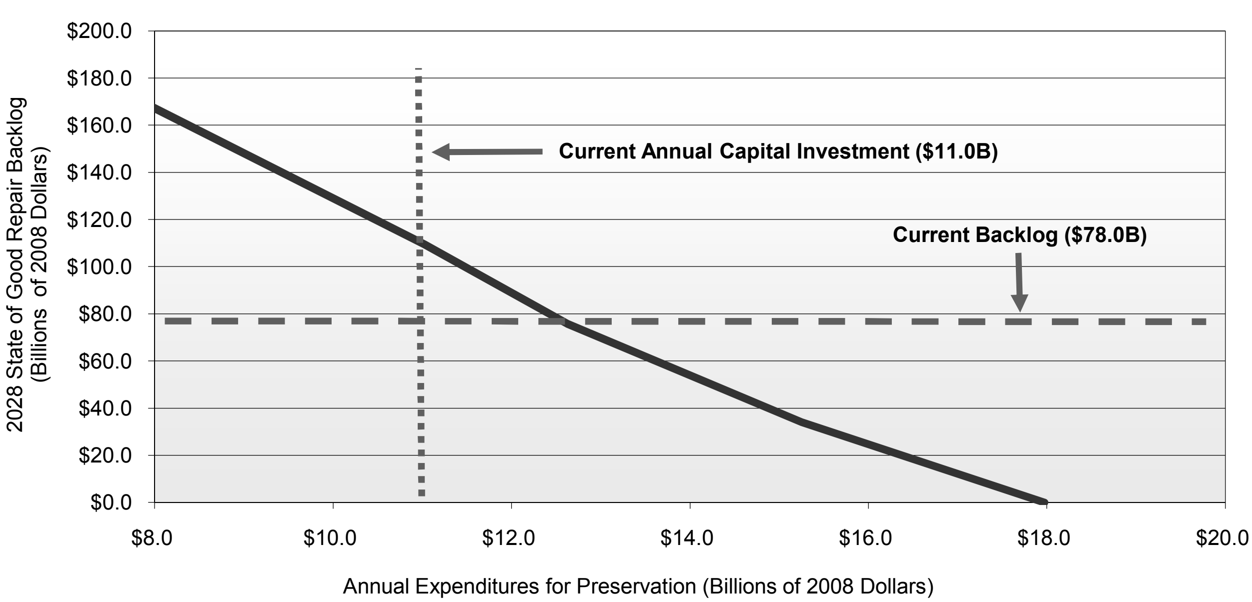
condition rating of assets nationwide (despite the ongoing deterioration of older assets) but has also resulted in an average condition rating that is not sustainable in the long term (i.e., without including the influence of further expansion investments or replacing assets at an unreasonably early age). Second, note that reinvestment at roughly $18.0 billion annually is required to attain a condition of SGR by 2028 and that this level of reinvestment is estimated to yield an average condition value of roughly 3.6 by 2028. Given the definition of the SGR benchmark (described in more detail in Chapter 8), which seeks to eliminate the existing investment backlog and then address all subsequent rehabilitation and replacement activities "on-time" thereafter, the 3.6 value could be considered representative of the expected long-term average condition of a well-maintained and financially unconstrained national transit system. Hence, an average condition value of roughly 3.6 represents a more reasonable long-term condition target for existing transit infrastructure than the current aggregate rating of 3.8.

A third and final observation is that a significant level of reinvestment is required to alter the estimated 2028 average condition measure by a point or more. This result is also driven in part by a large proportion of transit assets with expected useful lives of up to 80 years or more that will not require significant reinvestment over the 20-year period of analysis (regardless of the level of reinvestment). These assets tend to contribute a high weighting in the average condition measure, making the measure somewhat insensitive to the rate of reinvestment (note that a high proportion of reinvestment activity is focused on the replacement of those assets with relatively shorter useful lives, such as vehicles).

Transit Backlog: In contrast to the analysis above, which considers the impact of capital reinvestment on the average condition of *all* transit assets, *Exhibit 7-23* focuses on the impact of reinvestment on those assets most in need of reinvestment. Specifically, *Exhibit 7-23* presents the estimated impact of differing levels of annual capital reinvestment on the expected size of the investment backlog in 2028. The investment backlog is defined here as the level of investment required to bring all of the Nation's assets to a SGR (including the replacement of those assets that currently exceed their useful lives and the performance of all major rehabilitation activities that are currently past due). If future reinvestment rates are insufficient to address ongoing reinvestment needs as they arise, then the size of the backlog will tend to increase over time. In contrast, reinvestment at a rate above that required to address new needs as they arise will ultimately result in elimination of the existing backlog. Note that the current SGR investment backlog is estimated to be roughly $78.0 billion (see Chapter 8).

Exhibit 7-23

Impact of Preservation Investment on 2028 Transit SGR Backlog (All Urbanized and Rural Areas)



Average Annual Percent Change vs. 2008	Average Annual Investment (Billions of 2008 Dollars)	Average Condition Rating in 2028	Backlog in 2028 (Billions of 2008 Dollars)	Percent Change From Current Backlog	Funding Level Description
4.6%	$18.0	3.58	$0.0	-100.0%	SGR Scenario
3.1%	$15.3	3.53	$34.0	-55.1%	
1.3%	$12.6	3.45	$75.7	0.0%	Maintain Current Backlog
0.0%	$11.0	3.38	$109.5	44.6%	2008 Capital Expenditures
-3.8%	$7.7	3.28	$173.4	129.0%	

Note that for this report, assets are considered past their useful lives once their estimated condition in TERM falls below condition 2.50.

Source: Transit Economic Requirements Model.

As shown in *Exhibit 7-23,* TERM analysis suggests that the current rate of capital reinvestment of $11.0 billion is insufficient to keep pace with ongoing rehabilitation and replacement needs and, if maintained over the next 20 years, would result in a larger SGR backlog of roughly $109.5 billion by 2028. In contrast, increasing the rate of reinvestment to an annual average of roughly $18.0 billion will completely eliminate the backlog by 2028. Finally, the annual level of reinvestment would need to be increased to roughly $13.0 billion to maintain the backlog at roughly its current size.

Impact of Expansion Investments on Transit Ridership

While capital spending on preservation primarily benefits the physical condition of existing transit assets, expansion investments are typically undertaken to expand the asset base to accommodate projected growth in ridership and potentially to improve service performance for existing transit system users.

Exhibit 7-24 shows the relationship between aggregated annual capital spending by all levels of government on expansion investments and the additional number of annual passenger boardings that transit systems would be able to support by 2028. More precisely, this chart presents the level of expansion investment required to ensure that transit vehicle occupancy rates are maintained at current levels over the next two decades for a broad range of the potential rates of growth in transit passenger miles traveled (PMT). As the upward sloping curve of the chart indicates, higher levels of investment are required to support greater numbers of additional riders at a constant level of service. If investment levels are insufficient to fully support the projected growth in ridership, then vehicle occupancy rates will tend to increase, leading to increased crowding on high utilization systems and potentially leading to increased dwell times at stops, reduced average operating speeds, and increased rates of vehicle wear. Conversely, if the rate of transit capacity expansion exceeds the actual rate of ridership growth, then occupancy rates will tend to decline and service performance would likely also improve.

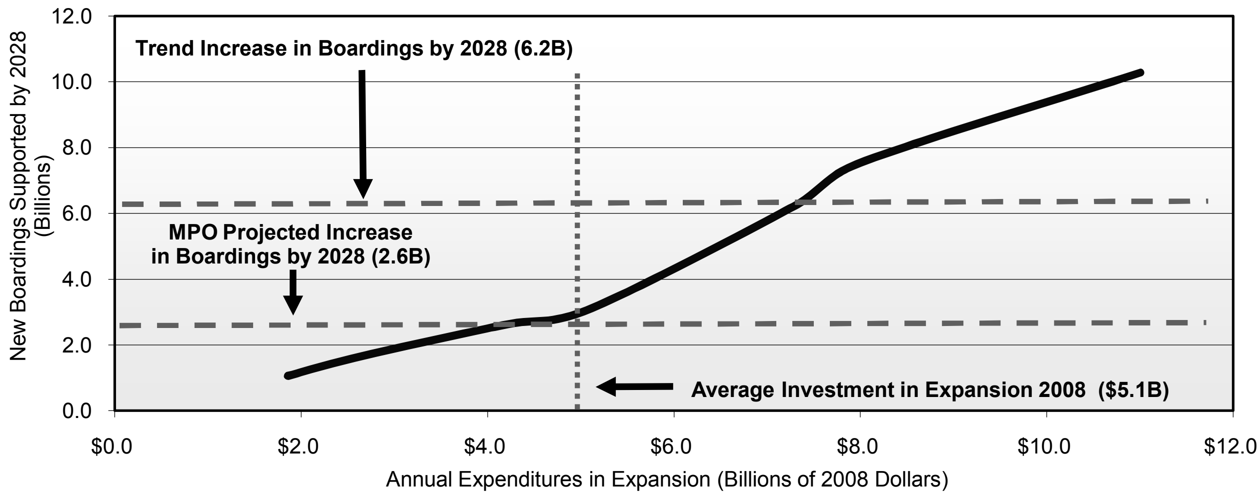
The findings presented in *Exhibit 7-24* suggest the following trends. First, the recent rate of investment in asset expansion ($5.1 billion in 2008) could support roughly 3.1 billion additional boardings by 2028 (approximately a 1.6 percent annual growth in ridership). This amount is greater than that required to support the level of growth projected by the Nation's MPOs (roughly 1.1 percent when adjusted to exclude expansion investments that do not pass TERM's benefit-cost test). As discussed in further detail in Chapter 9, MPO projections of transit growth (which are financially constrained) have typically fallen well short of actual growth in recent years. Assuming the actual rate of ridership growth is closer to the trend rate of growth for the last decade, then an average of $7.3 billion in annual transit capital expansion investment would be required over the next 20 years to support an additional 6.2 billion annual boardings (again after excluding expansion investments that do not pass TERM's benefit-cost test). Hence, while the existing levels of transit capital expansion investment may be sufficient to maintain current service performance (i.e., vehicle occupancy rates) if ridership growth is relatively low, this level of investment is roughly two-thirds of that required to support a level of ridership growth consistent with that experienced over the most recent 10-year period.

Impacts of UZA-Level Investments Modeled by TERM

The remainder of this chapter focuses on how different levels of annual capital investment in the U.S. transit infrastructure affect urbanized areas with dissimilar transit investment needs. Specifically, this section explores the impact of capital expenditures by transit agencies sorted into two distinct UZA groupings: (1) the UZAs with populations greater than 1 million and (2) all other urbanized and rural areas with existing transit services.

Exhibit 7-24

New Ridership Supported in 2028 by Expansion Investments (All Urbanized and Rural Areas)



Average Annual Percent Change vs. 2008	Average Annual Investment (Billions of 2008 Dollars)	Total New Boardings by 2028: New Riders Supported (Billions of Annual Boardings)	Total New Boardings by 2028: Average Annual Growth in Boardings*	Funding Level Description
7.1%	$11.0	10.28	3.5%	
4.3%	$8.0	7.52	2.8%	
3.5%	$7.3	6.23	2.4%	Trend Growth in PMT (1999 through 2008)
0.0%	$5.1	3.07	1.6%	Capital Expenditure for 2008
-2.0%	$4.2	2.62	1.1%	MPO Projected Increase in PMT
-7.2%	$2.7	1.66	0.7%	
-11.8%	$1.9	1.06	0.5%	

* *As compared with total urban ridership in 2008; only includes increases covered by investments passing TERM's benefit-cost test. Note that TERM assesses expansion needs at the agency-mode level subject to (1) current vehicle occupancy rates at the agency-mode level and (2) expected transit PMT growth at the UZA level (hence all agency modes within a given UZA are subject to the same transit PMT growth rate). Note, however, that TERM does not generate expansion needs estimates for agency modes that have occupancy rates that are well below the national average for that mode.*

Source: Transit Economic Requirements Model.

UZAs Over 1 Million in Population

The Nation's largest UZAs own and operate the majority of the Nation's existing transit assets. These UZAs also typically have the highest levels of investment in older rail assets.

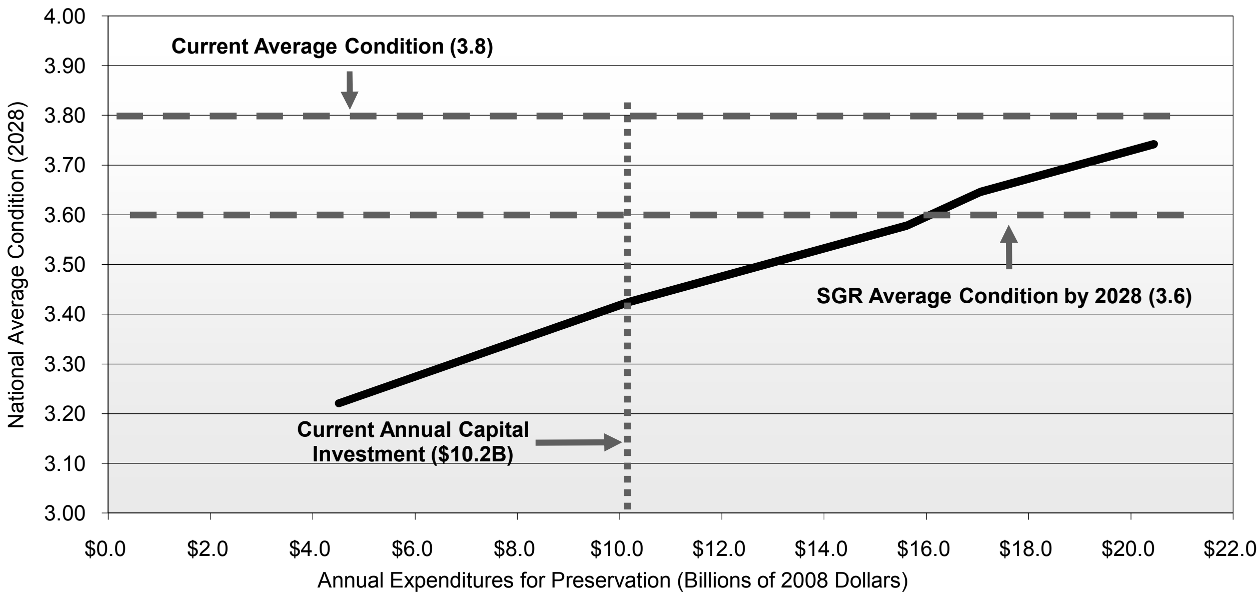
In 2008, transit agencies operating in UZAs with populations greater than 1 million expended $14.8 billion on capital projects, consisting of $10.2 billion on preservation investments intended to rehabilitate or replace existing assets, and $4.6 billion on expansion investments designed to increase service capacity. Following is a discussion of the transit asset preservation and expansion needs of these UZAs with populations greater than 1 million.

Preservation Investments

Exhibit 7-25 shows the estimated impact of varying levels of preservation investments on the future condition of existing transit assets located in UZAs with populations greater than 1 million. As with the earlier chart covering the entire industry, this chart clearly indicates that the current average condition rating for transit assets located in the largest UZAs is not sustainable in the long term without replacing assets on a fairly aggressive schedule (i.e., replacement at condition 3.0 or earlier). At the same time, the 2008 level of reinvestment ($10.2 billion) is less than that required to attain a SGR ($15.6 billion), with the latter supporting a more sustainable long-term average condition rating of roughly 3.6.

Exhibit 7-25

Impact of Preservation Investment on 2028 Transit Conditions (Over 1 Million in Population)



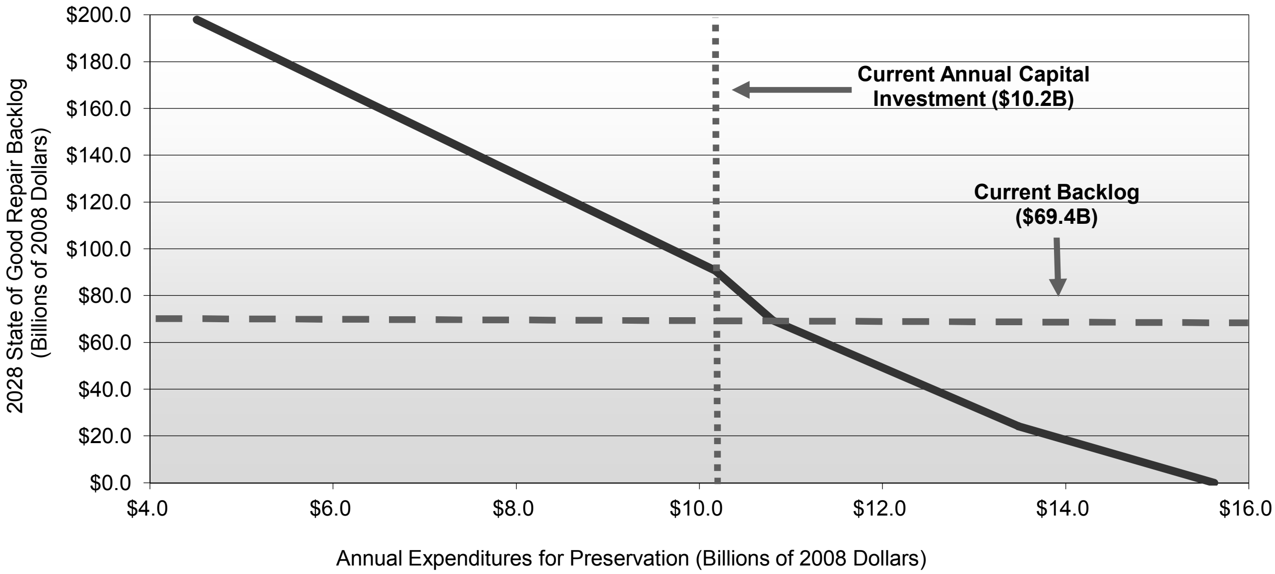
Average Annual Percent Change vs. 2008	Average Annual Investment (Billions of 2008 Dollars) Total Capital Outlay	Average Transit Conditions in 2028						Notes
		Asset Categories						
		Guideway	Facilities	Systems	Stations	Vehicles	All Transit Assets	
5.9%	$20.5	3.68	3.91	3.76	3.78	3.66	3.74	Unconstrained, Replace at 3.00
4.3%	$17.1	3.65	3.41	3.63	3.76	3.52	3.65	Unconstrained, Replace at 2.75
3.5%	$15.6	3.58	3.15	3.55	3.75	3.45	3.58	Unconstrained, Replace at 2.50 (SGR)
0.0%	$10.2	3.38	2.92	3.37	3.73	3.16	3.42	2008 Capital Expenditures
-10.6%	$4.5	3.22	2.75	2.78	3.70	2.80	3.22	

Source: Transit Economic Requirements Model.

As shown in *Exhibit 7-26,* the 2008 level of capital reinvestment of $10.2 billion for the largest UZAs is insufficient to keep pace with ongoing rehabilitation and replacement needs and, if maintained over the next 20 years, would result in a larger SGR backlog of roughly $90.7 billion by 2028 as compared with the current $69.4 billion. In contrast, increasing the rate of reinvestment to an annual average of roughly $15.6 billion will completely eliminate the entire backlog by 2028. The annual level of reinvestment would need to be increased to roughly $10.8 billion to maintain the backlog at roughly its current size.

Exhibit 7-26

Impact of Preservation Investment on 2028 Transit SGR Backlog (Over 1 Million in Population)



Average Annual Percent Change vs. 2008	Average Annual Investment (Billions of 2008 Dollars)	Replacement Condition	Average Condition Rating in 2028	Backlog in 2028 (Billions of 2008 Dollars)	Funding Level Description
3.5%	$15.6	2.50	3.58	$0.0	SGR Scenario
2.3%	$13.5	2.50	3.56	$24.2	
0.4%	$10.8	2.50	3.48	$69.4	Current Backlog
0.0%	$10.2	2.50	3.42	$90.7	2008 Capital Expenditures
-10.6%	$4.5	2.50	3.22	$197.9	

Source: Transit Economic Requirements Model.

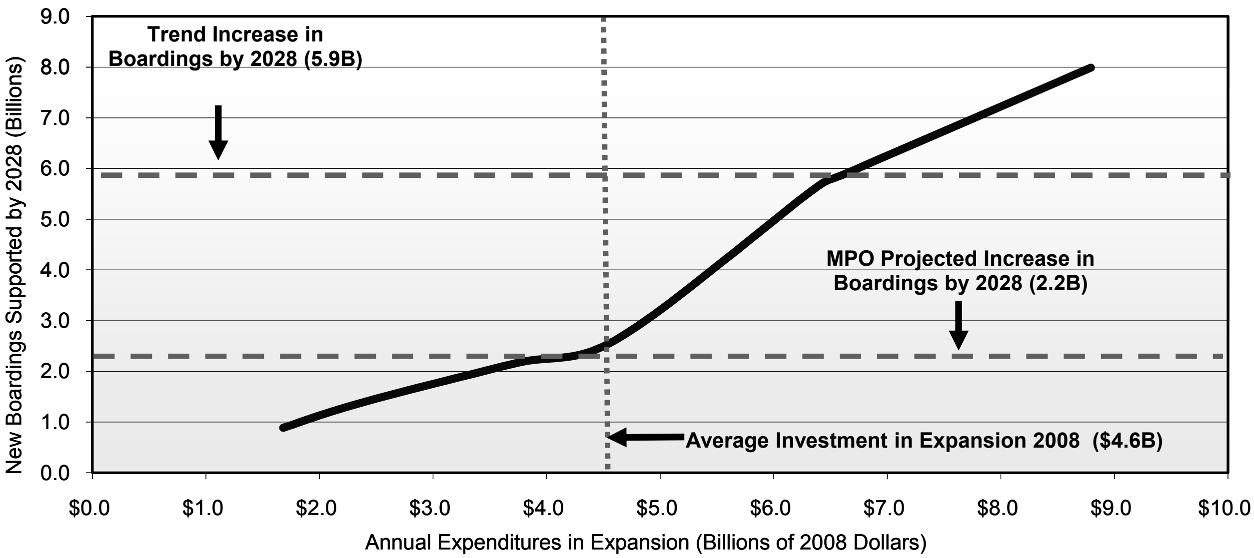
Expansion Investments

While UZAs with populations greater than 1 million tend to be dominated by cities with slower rates of increase in population and transit ridership (e.g., Boston, Philadelphia, and Chicago), this group also includes urbanized areas—including Los Angeles, Atlanta, Seattle, and other smaller cities—expected to experience relatively high rates of growth in transit boardings and PMT over the next two decades. Given the high numbers of existing riders and transit capacity in these higher-growth, large UZAs, they will require significant increases in expansion investments to maintain current service performance over this time period.

Exhibit 7-27 presents estimates of the level of expansion investment required to support varying levels of growth in transit demand while maintaining current performance levels (as measured by vehicle capacity utilization) for these larger UZAs. Note that the 2008 level of investment for these UZAs ($4.6 billion) was more than that required to support the rate of increase in transit demand as projected by the Nation's MPOs (low growth) but well short of that required to support a rate of growth comparable to the trend rate of increase as experienced over the most recent decade.

Exhibit 7-27

New Ridership Supported in 2028 by Expansion Investments (Over 1 Million in Population)



Average Annual Percent Change vs. 2008	Average Annual Investment (Billions of 2008 Dollars)	Total New Boardings by 2028		Funding Level Description
		New Riders Supported (Billions of Annual Boardings)	Average Annual Growth in Boardings*	
11.1%	$8.8	7.99	3.2%	
9.8%	$6.6	5.91	2.5%	Trend Growth in PMT (1999 through 2008)
8.3%	$6.4	5.63	2.4%	
5.9%	$4.6	2.65	1.3%	Capital Expenditure for 2008
4.6%	$3.7	2.15	1.1%	MPO Projected Increase in PMT
0.0%	$2.4	1.38	0.7%	
-3.1%	$1.7	0.89	0.5%	

* *As compared with total urban ridership in 2008; only includes increases covered by investments passing TERM's benefit-cost test.*

Source: Transit Economic Requirements Model.

Other Urbanized and Rural Areas

The following analysis considers the combined preservation and expansion needs of UZAs under 1 million and those of all rural areas with existing transit service. This diverse group therefore includes a large number of mid- and small-sized urbanized and rural transit operators offering only bus and/or paratransit services.

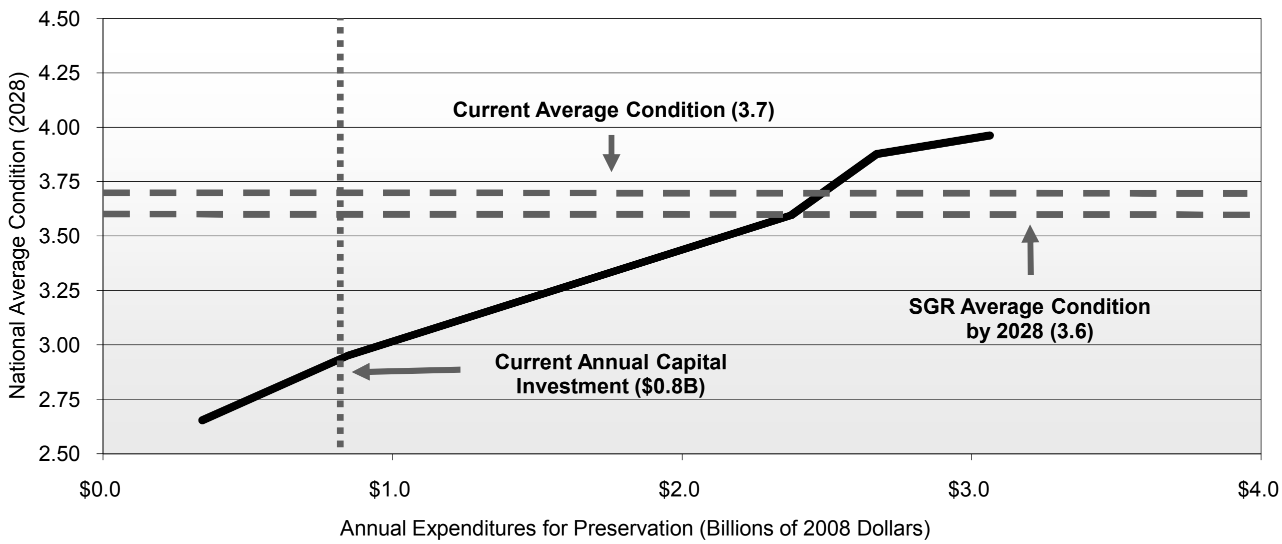
In 2008, transit agencies operating outside of the largest UZAs expended $1.3 billion on capital projects, consisting of $0.8 billion on preservation investments intended to rehabilitate or replace existing assets, and $0.5 billion on expansion investments designed to increase service capacity. Following is a discussion of the transit asset preservation and expansion needs of transit agencies in these areas.

Preservation Investments

Exhibit 7-28 shows the estimated impact of varying levels of preservation investments on the future condition of existing transit assets located in UZAs with populations less than 1 million and in rural areas. As with the earlier analyses for the largest UZAs, this chart also indicates that the current average condition rating for transit assets in these smaller urbanized and rural areas is not sustainable in the long term without replacing assets on a fairly aggressive schedule (i.e., replacement at condition 3.0 or earlier). At the same time, the 2008 level of reinvestment ($0.8 billion) is significantly less than that required to attain a SGR ($2.4 billion), with the latter supporting a more sustainable long-term average condition rating of roughly 3.6.

Exhibit 7-28

Impact of Preservation Investment on 2028 Transit Conditions (Under 1 Million in Population)



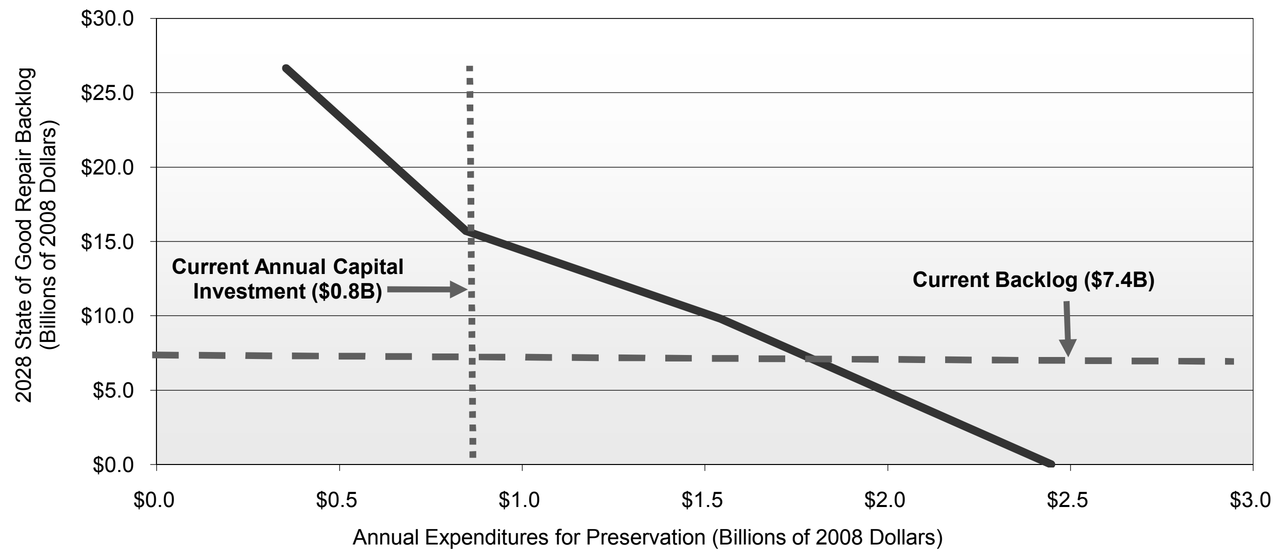
Average Annual Percent Change vs. 2008	Average Annual Investment (Billions of 2008 Dollars) Total Capital Outlay	Average Transit Conditions in 2028						Notes
		Asset Categories					All Transit Assets	
		Guideway	Facilities	Systems	Stations	Vehicles		
10.9%	$3.1	4.52	3.85	3.89	4.07	3.66	3.96	Unconstrained, Replace at 3.00
9.5%	$2.7	4.45	3.89	3.79	3.90	3.36	3.88	Unconstrained, Replace at 2.75
8.5%	$2.4	4.47	3.24	3.75	3.90	3.35	3.59	Unconstrained, Replace at 2.50
0.0%	$0.8	3.74	2.48	3.15	3.55	2.93	2.95	2008 Capital Expenditures
-5.4%	$0.3	3.70	2.43	3.07	3.45	1.94	2.65	

Source: Transit Economic Requirements Model.

As shown in *Exhibit 7-29,* the 2008 level of capital reinvestment of $0.8 billion for rural areas and smaller UZAs is insufficient to keep pace with ongoing rehabilitation and replacement needs. If maintained over the next 20 years, this rate of investment would result in a larger SGR backlog of roughly $15.7 billion by 2028, as compared with the current backlog of $7.4 billion for this group. In contrast, increasing the rate of reinvestment to an annual average of roughly $2.4 billion will completely eliminate the entire backlog by 2028. The annual level of reinvestment would need to be increased to roughly $1.8 billion annually to maintain the backlog at roughly its current size.

Exhibit 7-29

Impact of Preservation Investment on 2028 Transit SGR Backlog (Under 1 Million in Population)



Average Annual Percent Change vs. 2008	Average Annual Investment (Billions of 2008 Dollars)	Replacement Condition	Average Condition Rating in 2028	Backlog in 2028 (Billions of 2008 Dollars)	Funding Level Description
8.5%	$2.4	2.50	3.59	$0.0	SGR Scenario
6.3%	$1.8	2.50	3.19	$7.4	Current Backlog
5.5%	$1.5	2.50	3.06	$9.8	
0.0%	$0.8	2.50	2.95	$15.7	2008 Capital Expenditures
-5.1%	$0.4	2.50	2.65	$26.7	

Source: Transit Economic Requirements Model.

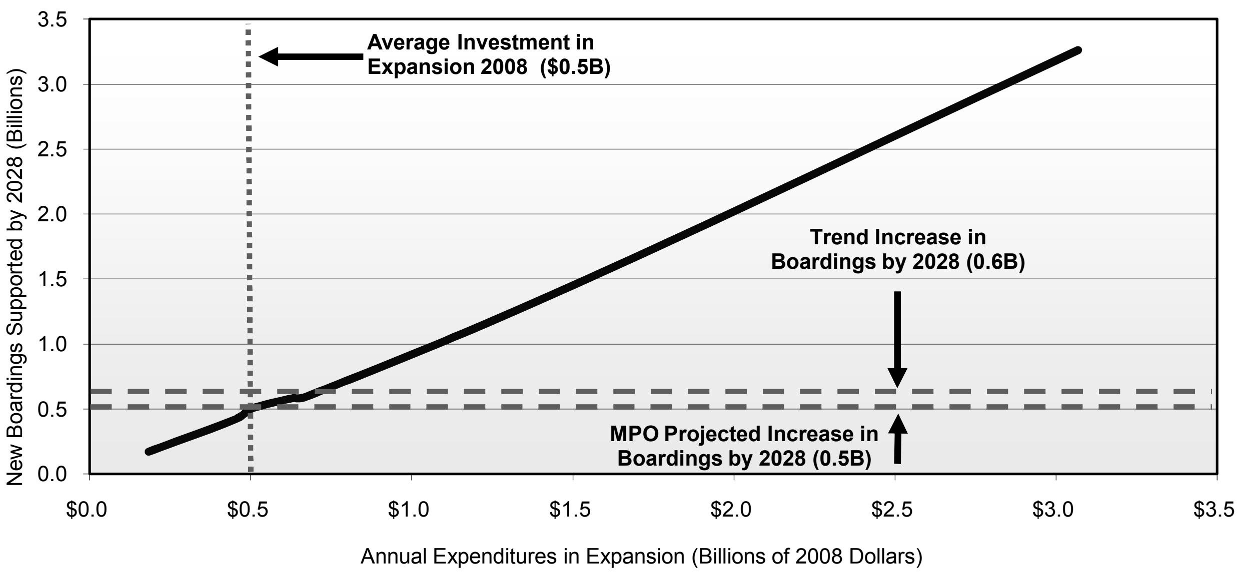
Expansion Investments

While the urbanized and rural areas in this group represent a smaller number of riders and a smaller existing transit asset base, these areas are also expected to have a higher projected rate of increase in transit ridership.

Exhibit 7-30 presents estimates of the level of expansion investment required to support varying levels of growth in transit demand while maintaining current performance levels (as measured by transit passenger miles per peak vehicle) for the smaller urbanized and all rural areas. Note that the 2008 level of investment for these areas ($0.5 billion) was the same as that required to support the rate of increase in transit demand as projected by the Nation's MPOs and slightly less than the trend rate of increase as experienced over the last several years. Such investments should yield both improvements in transit performance in these UZAs and also help promote transit-led urban development in UZAs subject to above average rates of population and transit growth.

Exhibit 7-30

New Ridership Supported in 2028 by Expansion Investments (Under 1 Million in Population)



Average Annual Percent Change vs. 2008	Average Annual Investment (Billions of 2008 Dollars)	Total New Boardings by 2028: New Riders Supported (Billions of Annual Boardings)	Total New Boardings by 2028: Average Annual Growth in Boardings*	Funding Level Description
	$3.1	3.26	4.5%	
	$1.5	1.45	4.1%	
	$0.7	0.59	2.1%	Trend Growth in PMT (1999 through 2008)
	$0.6	0.58	2.1%	
	$0.5	0.50	1.8%	MPO Projected Increase in PMT
0.0%	$0.5	0.42	1.5%	Capital Expenditure for 2008
	$0.2	0.17	0.7%	

* *As compared with total urban ridership in 2008; only includes increases covered by investments passing TERM's benefit-cost test.*

Source: Transit Economic Requirements Model.