THE 1991 STATUS OF THE NATION'S HIGHWAYS AND BRIDGES:

CONDITIONS, PERFORMANCE, AND CAPITAL INVESTMENT REQUIREMENTS

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Table of Contents

Table of Exhibits

Introduction

National productivity in the United States increasingly depends on fast and reliable transportation. For this Nation to compete successfully in the world marketplace and to continue its standard of living, we must ensure the stability of our transportation systems.

Americans use U.S. roads and highways more than any other mode of transportation in this country. Through the years, our roads have served us well. Highways, along with the automobiles and trucks they carry, have provided the United States with the most efficient network for moving people and goods the world has ever known.

U.S. highways carry more than 90 percent of all travel, and three-quarters of the value of all goods and services produced. Growth and productivity in virtually every sector of the Nation's economy depend upon adequate highway transportation.

In the United States, highway transportation is of critical importance. As we move toward the 21st century, the status of our highways and bridges is critical to the future economy of our Nation.

This report, the 1991 Status of the Nation's Highways and Bridges, provides the Congress and other decision-makers with an ongoing appraisal of the current condition and performance of the U.S. highway system. These continual assessments produce valuable information, including these concerns:

- How highway investment is used.
- What revenue levels are needed to meet future demands of social and economic growth.

The Purpose of Highway Capital Investment

The United States has 3.9 million miles of public roadway, which accommodate more than 187 million vehicles travelling beyond 2.1 trillion miles each year. Expenditures for transportation are equivalent to about 17.5 percent of the gross national product (GNP), with almost 85 percent of this, or about 15 percent of GNP, devoted to highway transportation.

- Highway vehicles carry more than 80 percent of domestic intercity passenger miles of travel, and they have done so for every five-year period since World War II.
- The trucking industry carries over 40 percent of all intercity freight tonnage, earning more than 75 percent of all revenues.
- In urban areas, automobiles and transit buses account for over 92 percent of all work trips. About 87 percent of all passenger-miles of travel is highway dependent.
- The household budget for vehicle repair and operation, combined with the highway transport cost for goods and services consumed by the household, consumes as much as 18 to 20 percent of the average household's disposable income. Only outlays for housing and food exceed the amount spent on transportation and vehicle maintenance and operation.

Two components make up the total user cost of highway transportation:

1. The cost to highway users of using the system, including vehicle operating costs, accident costs, and the value of time spent in highway travel.
2. The public cost of highway construction and repair.

While other societal costs relating to community, environmental, and energy impacts must be considered, the primary goal of highway capital investment is to reduce the total cost of transportation, including public costs and total user costs incurred by transportation users.

User costs vary according to highway physical conditions and system performance. These factors are directly affected by the level of highway investment. From the perspective of highway engineering economics, the appropriate level of investment depends on the level of system condition and performance desired.

Highways in poor physical condition cost as much as 25 to 30 percent more to travel on per mile than highways in good condition. Highly congested highways can add as much as 35 percent to the unit operating and time costs of a commercial vehicle. Every 1 percent increase in highway user costs adds about $15 billion to the Nation's total highway bill, including increased vehicle depreciation and maintenance, fuel, oil, and tire consumption.

Direct public costs (that is, the total highway budget) make up only about 8 percent of the total costs incurred for highway usage. Approximately 92 percent of total highway costs are accounted for by the vehicle ownership and operating costs and value of time spent on travel. While these private costs usually occur in small and regular increments, their cumulative effect on the budgets of households and industry is substantial. The relatively small public investment that improves conditions or performance can have a substantial leveraging effect on the large private cost component.

Highway and bridge condition and performance are functions of current conditions, future travel demand, and capital and maintenance commitments to highway and bridge infrastructure. Adequate future highway service will be determined by how closely capital requirements and commitments match. Although highway agencies have been highly successful in addressing the physical deterioration documented throughout the 1970's and early 1980's on both the highway and bridge systems, total investment has not kept pace with all system demands. It is for this reason that system performance has declined. In 1989—

- Approximately 265,000 miles of pavement were at or below accepted engineering standards for cost-effective maintenance.
- Approximately 134,000 bridges were rated as structurally deficient. These bridges were unable to safely carry trucks and buses at the State's legal weight limits or could not safely carry traffic at the speed allowed on the approaching roadway. In 1989, over 5,000 bridges were closed to traffic for either structural deficiencies or bridge repair.
- Congestion introduced over 8 billion hours in delay on the Interstate System and other principal arterials, compared to uncongested conditions—adding billions in cost to interstate commerce.
- For the Nation's 39 largest metropolitan areas, the cost of congestion (including costs for delay and fuel consumption) was estimated to be over $34 billion in 1988.[1]

The cost of keeping roads and bridges in adequate repair and maintaining modest levels of service is generally much lower than the cost imposed on users by poor conditions and performance. Condition and performance assessments and investment requirements estimates are made to provide a benchmark against which to evaluate the effects of current and anticipated investment on system performance.

This report is presented in four chapters.

- Chapter 1 describes recent trends in highway travel and highway system mileage.
- Chapter 2 outlines sources of highway revenue and recent expenditure patterns for Federal, State, and local governments.
- Chapter 3 describes current conditions and performance for highways and bridges. It also discusses selected trends.
- Chapter 4 projects future highway travel demand and estimates capital investment requirements.

The report covers all of the Nation's roads and bridges, including all public highway and bridge infrastructure and all privately owned toll facilities. Future travel forecasts used to estimate investment requirements were developed by the States. All investment estimates are for the period January 1, 1990, through December 31, 2009, and are expressed in 1989 dollars.

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[1] *Roadway Congeston in Major Urbanized Areas 1982-1988*, Texas Transportation Institute in cooperation with the U.S. DOT and FHWA, 1990.

1989 Report Card

Highway and Bridge Finance

- **Total highway** capital and non-capital investment in 1989 was $73.6 billion. State/local capital investment ***increased*** at an average annual rate 6.5 percent above inflation through the 1980's. Federal investment did not keep pace. As a result, the **Federal share** of total capital investment ***declined,*** from 24.8 percent in 1980 to 22.5 percent in 1989.

- **Non-capital investment** ***increased*** from a 51 percent share of total investment in 1980 to 53 percent in 1989. **Capital investment** ***decreased*** in share, from 49 percent in 1980 to 47 percent in 1989. Capital investment is about evenly divided between pavement/safety improvements and new highway capacity.

- **User charges** ***increased*** from 57 percent of total revenues in 1980 to 60 percent of revenues in 1989.

- **Diversion** of user revenue to non-highway purposes ***increased,*** from 3.5 percent diverted in 1960 to 16 percent in 1989.

System Conditions and Performance

- **Pavement** conditions improved throughout the 1980's and ***stabilized*** in 1989, although about half of all arterial and collector mileage had pavement rated in "poor" or "low fair" condition in 1989.

  Highway **performance** ***declined*** throughout the 1980's, most noticeably in, around, and between the larger urbanized areas. Highway delay cost the economy an estimated $120 billion in 1989. Congestion affected 70 percent of all peak-hour urban Interstate travel, a 30 percent increase since 1983. In a sample of 20 urbanized areas, between 1985 and 1988 freeway travel increased by 16.7 percent, while freeway lane-miles increased by only 9 percent.

- **Bridge** conditions were ***mixed.*** The rate of increase in the number of structurally deficient bridges moderated, but the number continues to increase. Of about 575,000 bridges, 134,000 were rated as structurally deficient, up 25 percent since 1984, but only slightly over the past **two years.**

Future Travel Demand and Capital Investment Requirements

- The highway ***travel demand*** growth rate is expected to ***decline,*** from an average of 4.2 percent annually throughout the 1980's to an average of 2.5 percent annually through 2009. In the largest urbanized areas, growth rates should range from 0.8 to 1.8 percent annually. Even under these conditions, **the highway system must accommodate 65 percent more travel in 2009 than in 1989.**

- In 1989, all units of government expended about ***$33 billion, or about 1.2 cents per vehicle mile of travel (VMT) for highway and bridge capital investment.***

- An ***annual*** capital investment level of ***$45.7 billion*** in 1989 dollars, or about 1.8 cents per 1989 VMT, will be required from all sources ***to maintain overall conditions and performance*** through 2009. This includes pavement, safety, and capacity related requirements on all existing roads and bridges, and new construction in suburbanizing areas to accommodate expected growth. At this level of investment, overall conditions and performance can be maintained throughout the country, except for the largest urbanized areas, where demand will continue to exceed available highway supply. This estimate includes **restrictions on the addition of new highway capacity and an aggressive traffic management strategy in urban areas.**

- An ***annual*** capital investment level of ***$75 billion*** in 1989 dollars, or about 3.2 cents per 1989 VMT, will be required ***to improve overall conditions and performance.*** At this investment level, all 640,000 miles of highway currently in "poor" or "low fair" condition would be improved by the year 2009. All existing and future bridge deficiencies would be eliminated and substantial new highway capacity would be added. This estimate also includes restrictions on the addition of new highway capacity and an aggressive traffic management strategy in urban areas.

Chapter 1

Highway and Bridge System Characteristics

Functional Systems

The 3.87 million miles of road in the United States are functionally classified as **arterials, collectors, or local roads.** These broad categories are further divided into rural and urban groupings so we can more efficiently describe, analyze, and develop systems for these roads.

Roads are classified this way based on the type of service they provide. Arterials provide connectivity for serving longer trip needs. These roads usually have higher design standards than other roads, such as wider lanes, multiple lanes, and some degree of access control. Arterials connect urban areas to one another. They also connect highly travelled routes from urban to rural locations. **Arterials make up about 10 percent of total highway mileage, but they carry 70 percent of all highway travel.** The Interstate System, which is part of the arterial system, carries about 22 percent of total highway travel on 1 percent of total highway mileage.

Collectors are usually two-lane roads that serve shorter trips. They collect and distribute travel to and from the arterial systems. **Collectors carry about 15 percent of travel on about 21 percent of highway mileage.** They often provide the highest degree of mobility available or needed for a variety of local travel requirements.

Local roads, which account for approximately 69 percent of mileage, carry about 15 percent of travel. They provide the connections between the highway system and adjacent land uses.

Functional Systems and Tripmaking

The highway systems can be defined as the functional classes working together to provide efficient vehicle movement. A typical highway trip begins on either a collector or a local road, then moves onto an arterial route for the major portion of the trip. Using both classes of roads allows the vehicle to take advantage of the arterial's higher speeds and more direct connections between towns and cities or between sections within a city. The higher design standards used on the arterials—particularly **access control**—result in less travel time, lower accident rates, and lower vehicle operating cost per-mile on arterials compared to travel on collectors or local roads.

Incomplete networks, poor highway or bridge conditions, or serious congestion on higher level systems lead to greater use of lower level systems. Travel on lower level systems results in longer, slower, more expensive, and more dangerous trips. These factors can also cause incompatibilities between the transportation system and adjacent land uses, such as when commuters or trucks use local residential streets to avoid a highway facility that is congested.

Jurisdictional Responsibility

The Nation's highways are managed by Federal, State, and local governments, but no consistent relationship exists between functional systems and jurisdictional responsibility. The Federal Government has direct responsibility for approximately 184,000 miles, mainly in national parks, forests, and Indian reservations. State governments are responsible for approximately 800,000 of the 3.9 million miles of road. Local governments control and are responsible for the remaining 2.9 million miles (Exhibit 1). States usually control the higher functional systems and local governments control lower systems. Still, State and local agreements may authorize States to construct and maintain locally controlled roads under a cooperative reimbursement arrangement.

System Mileage and Travel

The rate of highway vehicle travel has grown more than 3.0 percent annually in every five-year period since 1960, except for the recession years in the early 1980's. Over the last six years, the rate of growth has averaged almost 4.2 percent annually—a rate that would double travel in less than 20 years. Over 2.1 trillion vehicle miles-of-travel are traveled each year. About 60 percent of highway travel is in urban areas, with suburban portions growing most rapidly. Exhibit 2 shows average annual and five-year average rates of growth in total highway travel for selected years.

While travel grew rapidly in the 1980's, total highway mileage changed very little. The main changes in mileage were due to road reclassification. For example, many rural roads were reclassified as urban because of the growth in urban areas. The amount of rural mileage, therefore, has been reduced. Also, some national forest roads were transferred to non-public status.

Exhibit 1
1989 Mileage by Functional System and Jurisdiction

	Jurisdiction			
Functional System	Federal	State	Local	Total
Rural				
Interstate	0	33,378	0	33,378
Other Principal Arterial	132	80,691	128	80,951
Minor Arterial	1,522	144,692	1,113	147,327
Major Collector	4,180	208,806	223,198	436,184
Minor Collector	12,231	70,262	211,931	294,424
Local	160,124	168,677	1,801,659	2,130,460
Subtotal	178,189	706,506	2,238,029	3,122,724
Urban				
Interstate	0	11,471	0	11,471
Other Freeway & Expressway	59	7,192	331	7,582
Other Principal Arterial	94	35,393	16,002	51,489
Minor Arterial	65	19,788	54,893	74,746
Collector	48	8,028	70,398	78,474
Local	760	15,029	514,226	530,015
Subtotal	1,026	96,901	655,850	753,777
Total	179,215	803,407	2,893,879	3,876,501

Source: *Highway Statistics*, 1989.

Trends in Functional System Mileage and Travel

Travel increased by an average of 4.2 percent per year between 1983 and 1989. For the most recent period, 1987 through 1989, travel increased by an annual rate of almost 4.7 percent. Between 1983 and 1989, highway capacity increased only 0.1 percent per year. In urban areas, travel increased by 4.8 percent per year, and lane-miles increased by over 2.2 percent per year. In rural areas, travel increased by 3.25 percent per year, and lane-miles decreased by 0.4 percent per year. The Interstate System averaged a travel increase of almost 6 percent each year. Travel on both rural and urban collectors increased by less than 3.0 percent annually over the same period (see Exhibit 3).

The disparity between the growth in highway travel and capacity means that highways are being used very effectively. It also means, however, that **increased highway capacity has not kept pace with increased highway travel demand**. That difference shows up as increasing congestion.

In 1989, urban highway travel was about four times the density of rural travel for similar functional systems. Density of travel is defined as vehicle travel per mile of highway lane. The rate of increase in density of travel has been higher in rural areas than in urban areas in recent years. In absolute terms, however, urban roads remain much more heavily used.

In urban areas, travel on the higher functional systems (Interstates and other freeways and expressways) has increased more rapidly than on other urban systems. Rural travel demand has grown most prominently on the margins of urban areas and in the corridors connecting urban areas. Conditions on these rural highways have begun to mimic urban highway conditions, with reduced headway between vehicles, reduced speeds, and more stop-and-go conditions and delay during the peak demand hours each day.

Federal-aid Systems Mileage and Travel

Approximately 1.2 million miles of roads are functionally classified as either arterials or collectors. Of these, approximately 850,000 miles are also classified as part of one of the four administrative systems currently eligible for Federal-aid: Interstate, primary, secondary, and urban. (The Interstate System, which is functionally

Exhibit 2
Highway Travel for Selected Years, 1960-1990

Year	Total Highway travel (millions of VMT)	Average annual growth rate (%)	5-year average annual Growth Rate (%)
1960	718,762	2.61%	-
1965	887,812	4.91%	4.32%
1970	1,109,724	4.51%	4.56%
1975	1,327,664	3.68%	3.65%
1980	1,527,295	(0.12%)	2.84%
1981	1,552,803	1.67%	2.06%
1982	1,595,010	2.72%	1.69%
1983	1,652,788	3.62%	1.36%
1984	1,720,269	4.08%	2.38%
1985	1,774,179	3.13%	3.04%
1986	1,834,872	3.42%	3.39%
1987	1,921,204	4.71%	3.79%
1988	2,025,586	5.45%	4.16%
1989	2,107,040	4.00%	4.14%
1990 (est.)	2,165,000	2.00%	4.00%

classified as a principal arterial system, is separately classified for administrative purposes.)

Exhibit 4 shows the mileage and travel characteristics of each current Federal-aid system. Federal-aid routes are usually the most heavily travelled portions of the roads within the particular functional system from which they are drawn. These four systems collectively carry about 80 percent of highway travel on about 22 percent of total national mileage. The Interstate and primary systems together carry almost 50 percent of total highway travel.

Travel on Federal-aid systems increased annually by an average of 4.5 percent between 1987 and 1989. **The increase in travel on a per lane-mile basis was more than 14 times higher for Federal-aid compared to non-Federal-aid highways in rural areas, and eight times higher in urban areas.**

The Bridge System

Approximately 577,000 of the Nation's bridges are greater than 20 feet in length. Over 80 percent of these are in rural areas. Of the total number of bridges longer than 20 feet, more than over 275,000 (about 48 percent) are on a Federal-aid system. Of the remaining 300,000-plus bridges off the Federal-aid systems, about 225,000 (75 percent) are on functionally classified local roads.

Exhibit 3
Lane-Miles and Highway Travel Comparison

	Lane-Miles			Travel (millions of annual vehicle miles)		
Functional System	1983	1989	Annual Change 1983-89 (%)	1983	1989	Annual Change 1983-89 (%)
<u>Rural</u>						
Interstate	131,976	134,969	0.37	144,733	191,120	4.74
Other Principal Arterial	201,424	205,818	0.36	139,962	165,993	2.88
Minor Arterial	309,034	308,266	-0.04	133,421	156,626	2.71
Major Collector	867,549	880,650	0.25	156,786	187,182	3.00
Minor Collector	574,554	586,998	0.36	43,806	48,085	1.57
Local	4,442,784	4,260,920	-0.69	81,825	99,877	3.38
Subtotal	6,527,311	6,377,621	-0.39	700,533	848,883	3.25
<u>Urban</u>						
Interstate	53,386	61,854	2.48	191,149	270,652	5.97
Other Freeway & Expressway	30,817	33,739	1.52	86,790	122,055	5.85
Other Principal Arterial	150,892	170,977	2.10	255,327	326,897	4.20
Minor Arterial	172,395	188,218	1.47	188,467	234,863	3.74
Collector	153,118	167,699	1.53	86,593	101,259	2.64
Local	912,270	1,060,030	2.53	140,247	202,431	6.31
Subtotal	1,472,878	1,682,517	2.24	948,573	1,258,157	4.82
Total	8,000,189	8,060,138	0.12	1,649,106	2,107,040	4.17

Exhibit 4
Federal-Aid Systems, Mileage and Travel Characteristics

Federal-Aid System	Miles	Lane-Miles	Travel
Interstate System	44,849 1.2%	196,823 2.4%	461,772 21.9%
Primary System	259,205 6.7%	624,871 7.7%	584,290 27.7%
Secondary System	399,756 10.3%	808,006 10.0%	179,300 8.5%
Urban System	147,904 3.8%	370,309 4.7%	463,341 21.9%
System Totals	851,714	2,000,009	1,688,703
% of National Total	22.0%	24.8%	80.1%

Chapter 2

Highway Finance

Public Sector Highway and Bridge Financing

Revenues for highway finance come from both the public and private sectors and are spent by various levels of government for both capital and noncapital purposes. In 1989, all levels of government provided $73.6 billion for highways programs, including capital and noncapital spending. The Federal Government funded $16.5 billion; the States funded $36.9 billion; and counties, cities, and other local entities funded the remaining $20.2 billion.

Federal monies, coming mainly from the Highway Trust Fund, accounted for 22.5 percent of the total funding for highways in 1989, down from 24.8 percent in 1980. The States provided one-half of all funding, a ratio unchanged over the last decade. The local government share increased from 25.7 to 27.4 percent. After accounting for reserves and debt retirement, $67.7 billion was actually spent on highway and bridge programs.

Exhibit 5 shows expenditure trends in both constant and current dollars. Constant dollar spending on highways decreased from $27.5 billion in 1960 to $24.6 billion in 1980 before increasing to $36.7 billion in 1989. **In constant dollar investment per unit of travel, total expenditures have actually declined by more than one-half since 1960.**

Public Sector Revenue Sources and Trends

Revenues for public sector highway programs come from a variety of sources, including **user charges, nonuser benefit charges, investments and miscellaneous fees, bond issues, and nonhighway based revenue instruments**. Exhibit 6 shows total public sector revenues by both source and level of government.

Motor fuel taxes and motor vehicle taxes and tolls accounted for 60 percent of revenues in 1989, up from 57 percent in 1980. General funds and other types of nonhighway based revenue are the next largest source of revenue, contributing about 16 percent of total spending, a 5 percent decrease since 1980. Benefit charges (including private cost sharing, where identified) provided 9 percent, the same as in 1980. Investment income (which may be considered a user charge) and miscellaneous fees accounted for 8 percent in 1989, and bond issuances for the remaining 7 percent. All highway-based revenue sources, including user charges, benefit charges, investments and miscellaneous fees, and bond issues, provided about $62 billion, or 84 percent of the revenues used for highways in 1989.

In constant dollars, total revenues from user charges increased from $22.8 billion in 1960 to $29.4 billion in 1989. Actual highway expenditures from this source

Exhibit 5
Highway Expenditures

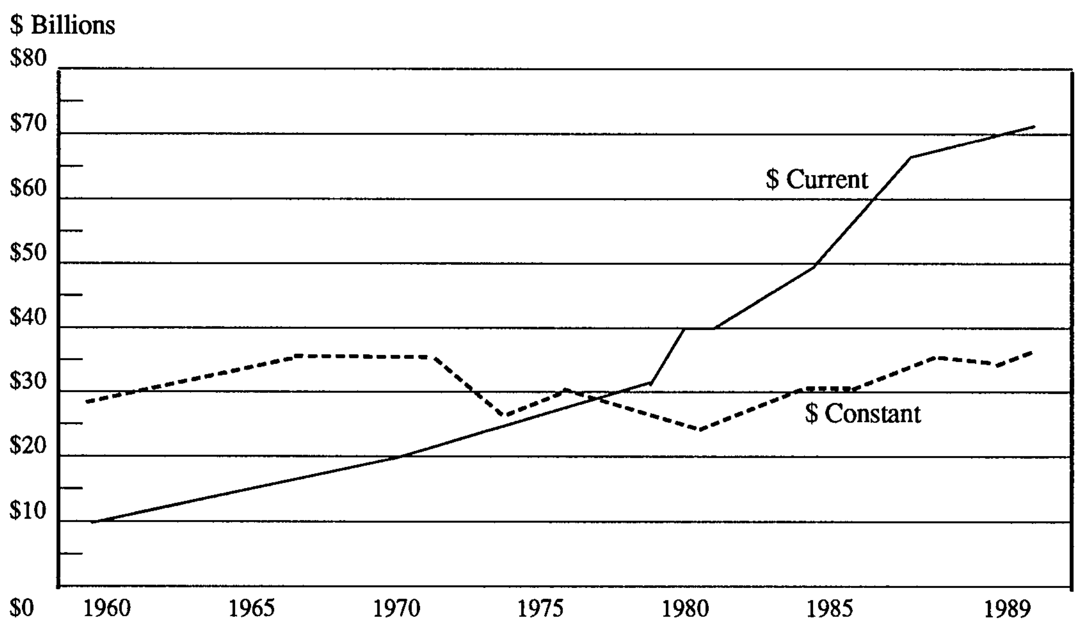


Exhibit 6
Revenue Sources for Public Sector Financing of Highways — 1989
$ in Billions

	Federal	State	Local	Total	Percent
1. User Charges:					
Motor Fuel Taxes	11.92	17.03	0.54	29.49	40%
Motor Vehicle Taxes	2.20	9.32	0.32	11.84	16%
Tolls	-	2.50	0.51	3.01	4%
Subtotal	14.12	28.85	1.37	44.34	60%
2. General Funds and Other Non-Highway Based Revenue Instruments	0.99	1.52	8.95	11.46	16%
3. Benefit Charges:					
Property Taxes and Assessments	-	-	4.54	4.54	6%
Other Taxes and Fees	0.07	1.37	1.01	2.45	3%
Subtotal	0.07	1.37	5.55	6.99	9%
4. Investment Income and Miscellaneous Receipts	1.36	2.09	2.33	5.78	8%
5. Bond Issue Proceeds	-	3.06	2.00	5.06	7%
Total	16.54	36.89	20.20	73.63	100%

Source: *Highway Statistics*, 1989; Table HF-10

grew from $22.0 billion in 1960 to $24.7 billion in 1989, indicating an increase in diversion of user revenues from 3.5 percent to 16 percent. When funds are diverted, they are spent for purposes other than those for which they were originally collected.

Highway Expenditures and Trends

Exhibit 7 shows disbursements for highways by functions for selected years. Noncapital highway expenditures are outlays that fund elements such as

- maintenance and operations of highways,
- administration,
- highway law enforcement,
- safety, and
- debt service on highway bonds and notes.

The noncapital highway bill for the public sector was $38 billion in 1989, up from $21 billion in 1980. Noncapital spending as a share of total highway spending increased from 50 percent in 1980 to 53 percent in 1989. Routine roadway maintenance commands the largest share of noncapital outlays and is not eligible for Federal aid.

As shown in Exhibit 8, capital investment on nonlocal roads was almost evenly divided between spending for physical and operational preservation versus capacity improvement. Capital highway expenditures are outlays for

- right-of-way acquisition,
- planning and engineering,
- all forms of construction and reconstruction to increase capacity,
- rehabilitation and restoration (3R) on existing facilities,

Exhibit 7
Disbursements for Highways by Functions for Selected Years, All Units of Government
(in millions of dollars)

Year	Capital Outlay	Maintenance and Operations	Adminis-tration, etc.	Highway Patrol and Safety	Interest on Debt	Subtotal Current Disbursements	Debt Retirement	Total
1960	6,290	2,640	483	327	420	10,160	601	10,761
1964	8,252	3,060	684	474	515	12,985	752	13,737
1968	10,346	4,003	1,017	940	606	16,912	1,071	17,983
1972	12,275	5,443	1,600	1,671	950	21,939	1,270	23,209
1974	13,102	6,573	1,857	2,061	1,079	24,672	1,445	26,117
1976	13,927	7,735	2,209	2,633	1,234	27,738	1,567	29,305
1978	14,938	9,785	2,590	3,160	1,368	31,841	1,593	33,434
1980	20,337	11,445	3,022	3,824	1,456	40,084	1,711	41,795
1981	19,734	12,165	3,439	3,884	1,202	40,424	2,464	42,888
1982	19,052	13,319	3,152	4,068	1,690	41,281	2,046	43,327
1983	20,224	14,240	3,347	4,309	1,872	43,992	2,172	46,164
1984	23,123	15,008	3,604	4,937	1,641	48,313	2,411	50,724
1985	26,647	16,589	4,174	5,241	2,148	54,799	2,737	57,536
1986	29,179	17,643	4,677	5,549	2,505	59,553	2,793	62,347
1987	30,674	18,152	4,973	5,962	2,788	62,549	2,685	65,234
1988	32,883	19,110	4,961	6,108	2,773	65,835	2,755	68,590
1989	33,274	19,679	5,380	6,453	2,871	67,657	3,478	71,135

Source: *Highway Statistics*, HF-12, various years, and HF-10, October 1990.

- construction on new alignment, and
- installation of traffic service facilities.

All governments invested over $33 billion for capital outlays in 1989, up from $20 billion in 1980, a 65 percent increase. In constant dollars, the increase was 50 percent. The Federal Government provided 43 percent of the total highway capital outlays in 1989, an 11 percent decrease in share since 1980 (Exhibit 9). Although real highway capital outlay per mile of travel increased slightly in the 1980's, it has decreased by about 60 percent since 1960 as illustrated in Exhibit 10.

Highway Capital Outlays on the Federal-aid Systems

Of the $33 billion spent on capital outlays by the public sector in 1989, $25 billion was spent on the Federal-aid systems. Federal-aid highway funds, which can only be used for capital improvements on a Federal-aid system, made up about 56 percent of the capital investment on this system. State and local governments provided the remaining funds, an effective matching share rate of 44 percent. This rate was much higher than the 17 percent composite statutory match required for these systems. States, therefore, are also investing independently on the Federal-aid system, either by overmatching on projects receiving Federal-aid or by fully funding projects with their own revenues. Exhibit 11 summarizes this relationship between statutory and effective shares for the various Federal-aid systems.

Spending for capacity improvements on the Federal-aid systems was 54 percent of total expenditures, similar to the spending pattern on all nonlocal roads.

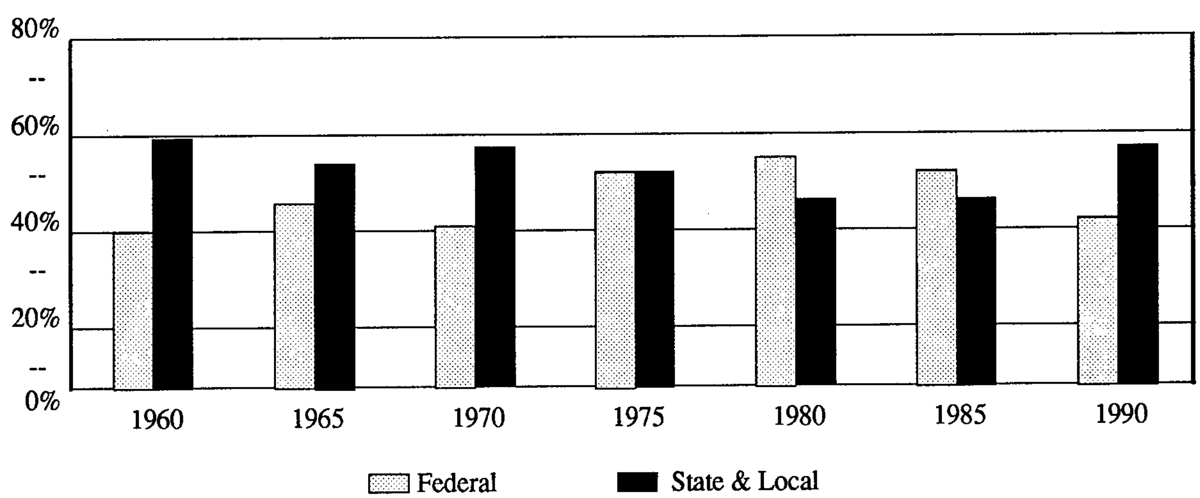
Preliminary Estimates of Private Financing

The private sector is also involved in financing roads. Private investors typically finance development-related (commercial or residential) "on-site" roads as part of the land development process. The value of such local roads

Exhibit 8
Spending by Major Improvement Categories on NonLocal Roads

Major Capital Improvement Category	Estimated 1989 Capital Expenditures (billions)	Percent
Condition Improvements		
Pavement and safety improvements on arterials and collectors	$ 6.7	24%
Bridge replacement and/or rehabilitation on arterials and collectors	4.6	16%
Operational improvements to arterials and collectors	1.7	6%
Subtotal	*13.0*	*46%*
Capacity Improvements		
Capacity additions to arterials and collectors	7.1	25%
New highway/bridge construction on arterials and collectors	7.8	28%
Subtotal	*14.9*	*53%*
Total Capital Spending on Nonlocal Roads	$27.9	100%

Exhibit 9
Highway Expenditures by Level of Government



put in place by private contributions in 1989 is estimated at more than $6 billion.

Public-private cost-sharing for "off-site" collector and arterial improvements is increasing, along with other innovative financing methods (such as impact fees and benefit assessment districts) and by donations of rights-of-way and cash. An estimated $2 to $5 billion in private investments were made on the arterials and collectors during 1989. Approximately one-third of these amounts is already accounted for in the annual *Highway Statistics* report, the basis for this discussion of highway finance.

Although these estimates are preliminary, the "on-site" and "off-site" estimates show an additional $8 to $11 billion for capital investment in highways. If these private funding amounts are included in the total for national capital investment estimates, this figure rises to a possible $40 billion or more for 1989.

Exhibit 10
Highway Capital Outlay per 1000 VMT

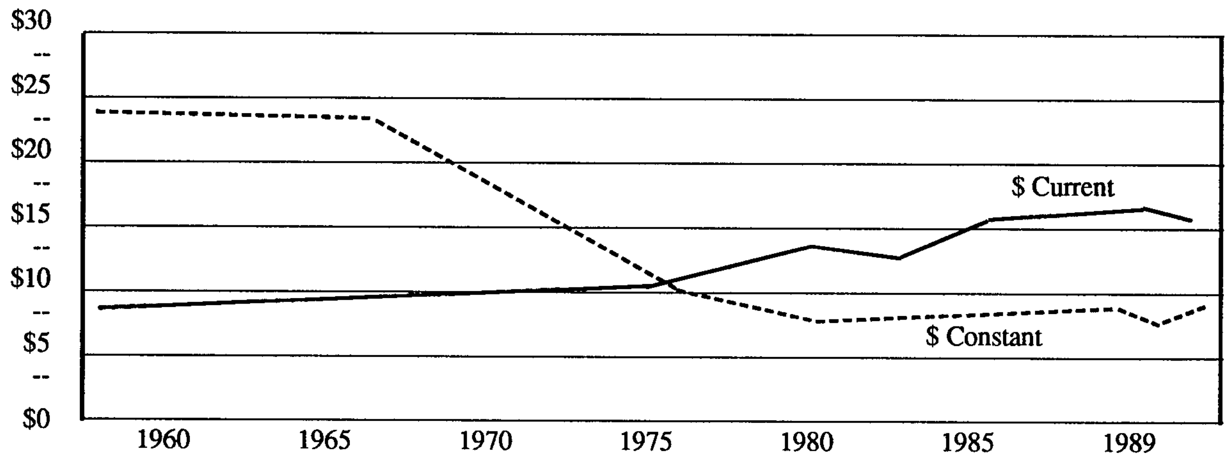


Exhibit 11
Statutory and Effective Federal Share of Investment on the Federal-Aid Systems, 1989

Federal-Aid System	Statutory Federal Share	Effective Federal Share
Interstate	90%	79%
Primary	75%	52%
Urban	75%	33%
Secondary	75%	29%

Chapter 3

Highway Conditions, Performance and Safety

Physical Conditions

Highway physical condition is judged by pavement condition, lane width, horizontal and vertical alignment, drainage adequacy, and other measures that relate to the road's physical integrity or level of safety. Capital investments improve the design of the roadway by bringing it up to modern safe design standards. Because of this continuous improvement, all roadway measures, except for pavement, usually improve over time.

Pavement conditions degrade because of normal use and weathering, increases in traffic or vehicle sizes and weights, and current and past levels of maintenance and capital spending. Current pavement conditions, along with the expected future demand for travel by the various classes of vehicles, are the main features used to determine capital investment requirements.

Pavements are appraised using a present serviceability rating (PSR), a composite rating of overall pavement quality. The rating is made according to the amount of distress evident. The amount and type of distress, and a variety of other conditions, indicate various stages of physical deterioration, ride discomfort, and cost of repair.

The PSR ranges from 0.0 to 5.0, with the higher number representing perfect pavement and the lower number completely deteriorated pavement. Ratings less than or equal to 2.0 are considered "poor" for most roads, although the Interstate System, which is expected to perform at a higher design level, is rated as "poor," with a PSR equal to 2.5 or less. A "low-fair" rating indicates the amount of pavement that is approaching poor and shows that capital investments will be required in the near future.

Pavements rated as poor or low-fair usually require vehicles to travel more slowly than the posted speed limit, with more acceleration and deceleration to avoid bad pavement. Vehicle slowdown and stop-and-go driving reduces fuel efficiency, wears out brakes and shock absorbers more quickly, and can lead to more frequent front end alignments.

Although pavement conditions and trends varied significantly among the States,**average conditions on the Nation's arterial and collector systems improved through the 1980's and appeared to stabilize in 1989.** Before this change, a continuous downward trend in physical conditions was evident in the 1970's and early 1980's.

The overall stabilization can be attributed to several factors:

- Passage of the Surface Transportation Assistance Act of 1982, with the 5-cent increase in Federal gas tax and programmatic incentives for rehabilitating pavement.
- Continued State efforts to set aside additional funds for highway capital investment.
- The development and use of systematic pavement management systems to identify deficiencies and allocate resources in a cost-effective manner.

As a result of these actions, future investment levels for pavement improvements needed to sustain these accomplishments should be lower, assuming that investments are made on a continuing and sufficient basis. Still, about 265,000 miles were rated in poor condition in 1989 and an additional 377,000 miles were rated in low-fair condition (Exhibit 12).

Pavements in poor condition usually require **reconstruction** to restore serviceability. Reconstruction involves removing and replacing paving material down to (and perhaps including) the subbase. Pavements rated as low-fair can be improved by pavement management programs. The life of the highway surface for these pavements can be prolonged with lower cost 3R types of pavement improvements. 3R work (**resurfacing, restoration, and rehabilitation**) usually involves improvements of lower capital intensity to restore serviceability. The unit cost of reconstruction varies between 150 and 250 percent of the cost of 3R.

If investments for repairs are not made when pavements are in the low-fair range, they will seriously deteriorate. The cost of eventual repairs using reconstruction techniques will be much higher than 3R costs, and highway users will pay more in vehicle repair and fuel consumption costs until the repairs are made.

In 1989, the combination of poor and low-fair pavements totaled about 642,000 miles. This means that almost half

Exhibit 12
Pavement Conditions, 1989

	Poor*	Low Fair *	High Fair	Good	Total
Interstate					
Miles	4,228	7,010	7,519	26,092	44,849
(% system)	(9.4)	(15.6)	(16.8)	(58.2)	(100)
Other Arterials					
Miles	21,763	114,549	60,327	165,456	362,095
(% system)	(6.0)	(31.6)	(16.7)	(45.8)	(100)
Collectors					
Miles	239,448	255,732	80,329	233,572	809,081
(% system)	(29.6)	(31.6)	(9.9)	(28.9)	(100)
TOTALS					
Miles	265,439	377,291	148,175	425,120	1,216,025
(%system)	(21.8)	(31.0)	(12.2)	(35.0)	(100)

* Poor is defined for all roads as present serviceability rating (PSR) less than or equal to 2.0, 2.5 for the Interstate. Low fair is less than or equal to 2.5, 3.0 for the Interstate System.

of all arterial and collector roads were at or near the point at which vehicle operating characteristics (and user costs) are significantly impaired by deteriorated conditions.

The number of pavements in deteriorating condition is no longer increasing so rapidly. A large number of pavements remain in poor or low-fair condition and other pavements currently in high-fair or good condition will continue to deteriorate.

This dynamic means that about 100,000 miles of arterials and collectors must have some type of pavement improvement each year to restore their serviceability.

Performance Characteristics

While physical conditions stabilized in 1989, system performance deteriorated, especially on the Nation's higher level highway systems (Exhibit 13).

By all system performance measures of highway congestion and delay, performance is declining. Congestion now affects more areas, more often, for

Exhibit 13
System Performance
(percent of peak-hour travel)

System	Congested (1) Congested (2)	Highly Congested	Total
Urban Interstate	18.4%	51.2%	69.6%
Other Urban Arterials	14.1%	29.2%	43.3%
Urban Collector	8.4%	11.0%	19.4%

(1) Congested: V/C = 0.8 to 0.95
(2) Highly Congested: V/C >0.95

A volume to capacity ratio (V/C) of 0.8 means that traffic volume has reached 80 percent of the capacity of the facility. Congestion begins to occur at about that point. A V/C ratio of 0.95 means that traffic has almost reach the saturation point of the facility, at which point (V/C of 1.0) "gridlock" occurs.

longer periods, and with more impacts on highway users and the economy than at any time in the Nation's history.

Congestion has three attributes: **severity, duration,** and **extent**. These three attributes affect system **reliability.**

- **Severity.** Almost 70 percent of daily peak-hour travel on the urban Interstate System in 1989 occurred under congested or highly congested (near stop-and-go) conditions. This represents an increase of almost 30 percent since 1983. About 43 percent of travel on other urban arterials also experienced congested conditions, an increase of over 18 percent since 1983. The percentage increase in congested rural Interstate travel was even greater than on urban Interstate routes, although the affected volume was less.

- **Duration.** Based on a sample of urbanized areas of different sizes, the duration of daily freeway travel operating under extremely congested conditions increased 45 percent from 1985 to 1988. (Extremely congested means that traffic flow is approaching a complete breakdown. This state is more commonly known as gridlock.)

  The percent of daily miles of freeway travel affected by congestion increased from 5.2 in 1985 to 6.4 in 1988. This increase was twice the rate of travel increase. Daily travel that faced heavy congestion increased almost five times as fast as added lane-miles of freeway capacity over the same period for these urbanized areas.

- **Extent.** The proportion of total travel under congested conditions was highest in the largest urbanized areas. An estimated 50 to 60 percent of all urban travel delay occurred in the 10 largest urbanized areas. Congestion continued to extend to more areas, especially to suburban areas and to facilities that connect and approach urban areas.

  The greatest increase in congestion among Interstate highways and other freeways has been to those that form the approaches and connections between major urbanized areas. Although congestion is often viewed as a commuter phenomenon, its effects in major cities have not been limited to the peak-periods. Off-peak congestion is becoming more widespread.

Using HPMS data, the Texas Transportation Institute estimated the costs of highway congestion in 39 of the Nation's largest cities to be approximately $34 billion for 1989. Eighteen of the 39 areas studied had congestion indices that placed them in the "undesirable" category. Of these 18 areas, only five showed congestion improvements from the previous year.

For purposes of this study, the Institute defined congestion as delay caused by levels of service at "D" or worse. Level of service D describes the beginning condition of congestion. This level is a cost-effective

The Significance of Non-recurring Delay

Incidents that cause slowdowns and congestion on roads (including vehicle breakdowns and higher incidence of accidents, particularly "fender benders") fall under the category of **non-recurring delay**. This condition—which is strongly linked to high levels of congestion—**produces system unreliability**. When the highway system cannot be considered reliable, the system cannot be used productively. Where congestion levels exceed level of service D, the likelihood of non-recurring delay increases significantly. High levels of non-recurring delay resulting in system unreliability is the economic reason that high levels of congestion should be avoided.

Questionable system reliability can severely restrict the adoption of advanced production and distribution techniques. Just-in-time delivery is only one example of many innovative business ideas in practice that depend on the efficiency and reliability of highways. A description of just-in-time delivery illustrates the importance of dependable highways in increasing the efficiency of America's industries.

Many assembly plants carry a large inventory of parts so that production is not held up because of shortages. These industries often rely on highway deliveries from their parts suppliers to their assembly plants. Large inventory means large warehousing. If these industries could reduce their parts inventory, they could reduce warehousing costs and free up money that could be used for more productive purposes, such as employee training or research and development.

Just-in-time delivery, and many other advanced techniques, work only if a plant manager can be assured that parts delivery will occur within a prescribed amount of time. Although the absolute amount of time taken for a trip is important, what is more important is the assurance that the time for the trip will not be outside a specified time range.

level of operation, but small increases in traffic beyond this point will generally cause operational problems. This level of service means that

- vehicle and pedestrian movements experience poor levels of speed,
- freedom to maneuver is severely restricted, and
- general driving comfort is poor.

Beyond level of service D, delay increases rapidly and system reliability is impaired because of an increase in non-recurring delay. Beyond this level of service, vehicle operating costs, fuel consumption, emissions, and aggravation increase dramatically. Commuting time increases, worker productivity is lost, and trip quality declines. At levels of service D and worse, non-recurring delay is estimated to account for upwards of 50 percent of all highway delay.

Bridge Conditions

Deficient bridges are categorized as either structurally deficient or functionally obsolete (Exhibit 14). Structural deficiency does not always mean that a bridge is unsafe. It usually indicates that a bridge is unable to handle the vehicle loads or speeds that would normally be expected on the highway system where the bridge is located. These limitations are then posted at the bridge approach.

A bridge that is functionally obsolete usually has inadequate width or vertical clearance for its associated highway system. In some cases, bridges are made functionally obsolete because of highway improvements on the approaches to the bridge, such as lane additions or widening of approaching roads. In other cases, bridges may be reevaluated as functionally obsolete if engineering standards have changed.

Of the more than 340,000 bridges on arterial and collector roads, about 112,000 were deficient as of June 30, 1990. Of these deficient bridges, about 15,000 were on the Interstate System, about 40,000 were on other arterial highways, and almost 57,000 were on collector roads. There has been a 1.5 percent increase in the total number of deficient bridges since 1984.

Also since 1984, the number of **structurally deficient** bridges on arterials and collectors has increased by 25 percent. Most recently (between 1988 and 1990), the rate of increase declined, with a 1.5 percent increase over that period. Because certain types of deficiencies were redefined between 1988 and 1990, the number of bridges rated as functionally obsolete increased on the Interstate and other arterial highways but decreased on collectors. Functionally obsolete bridges restrict the efficient use of the system because they act as bottlenecks. Structural deficiencies are particularly onerous, however, since they must be load posted for safety's sake. Although load posting (the imposition of a vehicle weight restriction), typically does not affect auto and light truck users, it does affect trip time and costs for other types of trucks that are required to detour in order to avoid a structurally deficient bridge.

Highway Safety

Steady long term improvements were made in highway safety throughout the 1980's on all highway systems (see Exhibits 15 and 16). Overall, the national highway fatality rate has declined to 2.16 fatalities per 100 million vehicle miles-of-travel in 1989, down from 3.3 in 1980.

The Interstate System was by far the safest highway system, with 1.1 fatalities per 100 million vehicle miles-of-travel. The safety features of the Interstate System are inherent in its higher design standards: full access control, traffic separation, wide lanes, and full shoulders.

Fatality rates in 1989 were lower on urban roads than on rural roads. Rural collectors had the highest fatality rates, at 3.68 per 100 million vehicle miles-of-travel. These roads tend to have deficient geometry, no shoulders or vehicle recovery areas, and, generally, allow poorer emergency response time.

Exhibit 14
Bridge Deficiencies, 1990

Functional System	Structurally Deficient	Functionally Obsolete	Total Deficiencies	Total Bridges on the System
Interstate	3,848	11,360	15,208	53,183
Other Arterial	15,989	23,502	39,491	124,615
Collector	33,056	23,566	56,622	164,300
Local	81,179	33,326	114,505	234,567
Total	134,072	91,754	225,826	576,665

Exhibit 15
Rural Highway Fatality Rates
(fatalities per 100 million VMT)

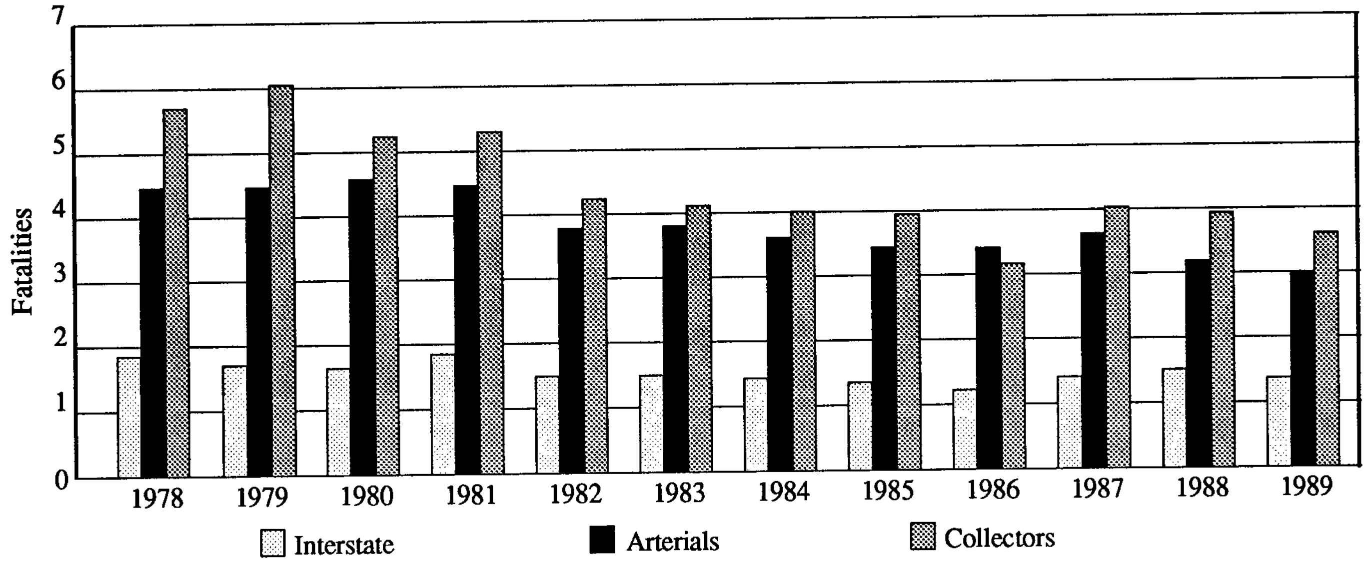
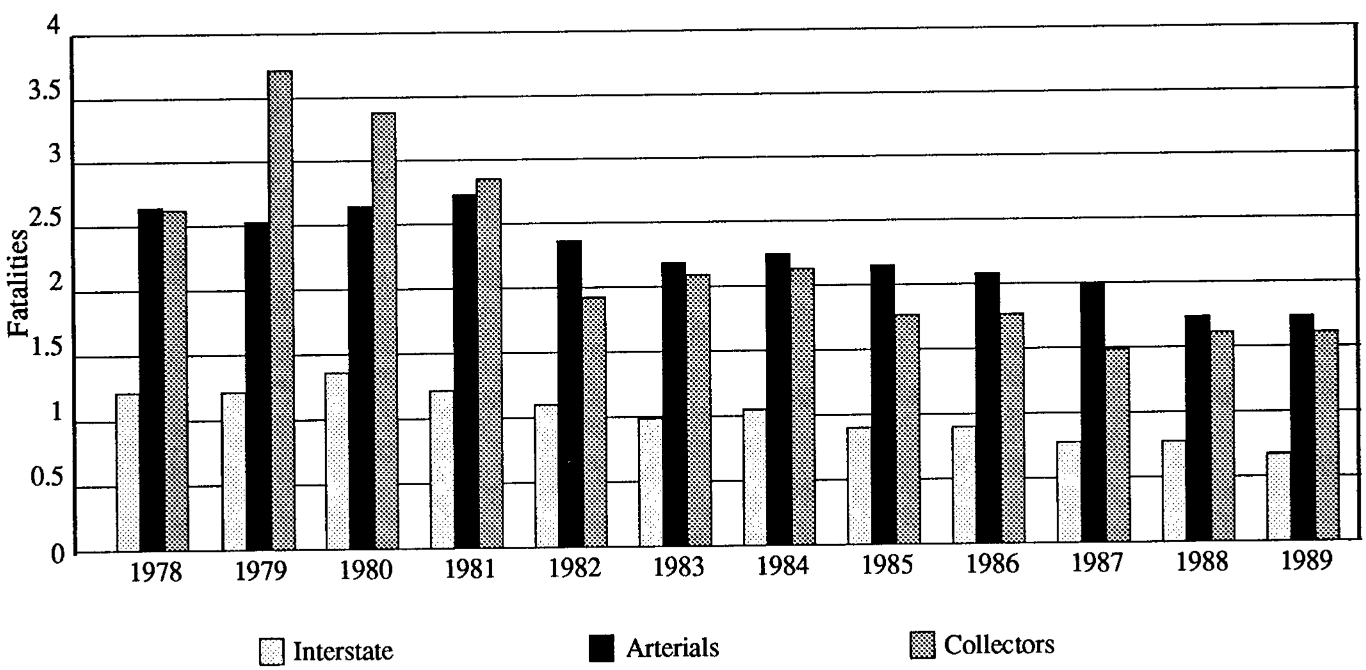


Exhibit 16
Urban Highway Fatality Rates
(fatalities per 100 million VMT)



Chapter 4

Highway and Bridge Investment Requirements, 1990-2009

This report provides estimates of **total capital investments required from all sources to achieve certain specified levels of overall system condition and performance for all highways and bridges** for the period 1990-2009. These estimates include costs to:

- repair deficient pavements and bridges,
- eliminate unsafe conditions, and
- add the capacity necessary to achieve specified levels of system performance.

Investment requirements are presented in two scenarios:

- The costs to **improve** the conditions and performance on all nonlocal roads and bridges that are deficient or are expected to become deficient through 2009. These costs are based on a specific minimum engineering standard associated with moderate performance.
- The costs to **maintain** current overall conditions and performance on most nonlocal roads (1989) and bridges (1990) through 2009. These costs are based on current conditions and anticipated highway travel growth.

Analytical models are used to make these assessments. The analytical procedures treat individual elements of highway systems and bridges as discrete elements of infrastructure that provide service. These elements, in turn, require maintenance and repair to ensure their performance and physical integrity.

Condition and performance deficiencies are treated independently. Under the maintain conditions scenario, for example, overall pavement conditions and overall levels of highway performance are maintained, where possible. All facility functional classes, administrative jurisdictions, and urban or rural locations receive equal consideration over the entire public road system.

In determining scenario costs, no assumptions were made about the following:

- Policy priorities for the strategic importance of individual facilities or classes of highway.
- Institutional constraints to highway and bridge improvements, such as fiscal capacity or air quality considerations in non-attainment areas.

Certain policy-oriented assumptions were made, however, such as (1) reduced rates of travel growth in highly congested urban areas, (2) application of rigorous supply and demand management strategies before estimating construction costs, and (3) constraints on the amount of new highway capacity in large urban areas.

These policy-oriented assumptions were not made to reflect possible changes in travel levels or travel behavior that might result from external factors, such as environmental or air quality concerns. Their adoption does reflect, however, what the overall cost and system performance effects would be if such changes did take place.

The scenarios are not meant to represent comprehensive alternative national investment policies. They provide general financial and performance benchmarks and a basis for developing and evaluating policy and program options.

Highway and Bridge Investment Analysis Procedures

The highway and bridge estimates were developed using engineering-based investment simulation models. In these models, the need for investments is indicated when current or simulated future conditions for pavement, structure, geometry, safety, or service-related items deteriorate below a set of prescribed minimum condition standards.

The minimum condition standards, improvement strategies, and types of improvements simulated vary according to the system on which the facility is located and follow accepted engineering practices. Unit costs used for each improvement type and for right-of-way acquisition vary by State according to actual project records. Life-cycle costs, defined as the total capital and maintenance costs required over the life of an improvement, are built into the simulation procedure.

Minimum condition, design standards, and simulated improvement strategies are selected to produce a cost-effective and safe highway and bridge system. Simulated pavement improvements reflect the demands of traffic loadings five to seven years into the future. Capacity additions reflect travel growth 20 years into the future.

Investment Philosophy

The deficiency, investment requirements, and investment/performance analyses used in this report view the highway and bridge infrastructure as capital assets rather than as consumer goods. Both the highway and bridge procedures use long-term, rather than short-term, approaches to estimate capital requirements.

The procedures "look ahead" when a deficiency is identified and an improvement type is selected. This allows for consideration of service requirements several years into the future. For example, the highway deficiency procedure may identify a pavement deficiency that requires a resurfacing improvement.

However, if the procedure looks ahead and finds that in a few years the travel demand will call for added lanes, the procedure simulates the capacity improvement at the time resurfacing is needed. This procedure emulates actual State practices in programming projects. Because the investments are made to address upcoming and existing problems, the highway system always has a residual service value.

If capital estimates were made solely to satisfy current system requirements, without regard for future requirements, the result would be constant depreciation of the system's residual value. Such an investment strategy could restrain annual capital requirements over the short run. Over a sustained period, however, this strategy would seriously reduce the residual value of the system. Although the short term capital costs would be lower, the total long term cost of deferring improvements would be substantially higher.

Highway Travel Demand Growth Assumptions

Investment requirements are heavily influenced by future highway travel demand. The rate of growth in highway travel has exceeded 3.0 percent for most 5-year periods since 1960. Exceptions to this trend were influenced by the years of the OPEC cartel in the 1970's and the recession of 1980-82, which affected the five-year rate through 1984.

Over the period of 1983 through 1989, travel increased at an average annual rate of 4.2 percent. Preliminary estimates for 1990, however, indicate only a 2.0 percent increase in highway travel over 1989, attributable to reduced economic growth.

This report assumes that the rate of growth in highway travel beyond 1990 will average 2.5 percent per year. Since travel growth has been robust in recent years, this average suggests that actual rates of travel growth will gradually decline to a level of slightly above one percent by 2009 (see Exhibit 17). Even with this reduction in the rate of travel increase, an average annual rate of 2.5 percent will yield an increase of 65 percent in vehicle miles of travel compared to 1989.

Exhibit 17
Travel Growth Rates

	Forecast* Travel Growth Rates 1990-2009	**Effective*** Travel Growth Rates 1990-2009
Rural Areas	2.58%	2.58%
Small Urban Areas	2.49%	2.49%
All Urbanized Areas	2.45%	1.42% - 1.46%
Top 10 Urbanized Areas	1.99%	1.21%
Total	2.51%	2.14%

* The forecast growth rates are those coded in the 1989 HPMS database. The effective rates, which were actually used in the estimation of capacity requirements, result from the introduction of peak spreading and a 12-lane restriction on facilities in urbanized areas, and the application of a coordinated congestion management program.

Future rates are expected to vary by State, ranging from about 0.5 percent to 5.3 percent growth per year. Growth is expected to track closely with demographic trends in the country, with travel in most Southern and Rocky Mountain States increasing more rapidly than in most Middle Atlantic, New England, and Midwestern States.

Rates are also expected to vary between rural and urban areas, and by size of urban area. Growth in the top 10 urbanized areas is expected to be much lower than in all other urbanized areas, ranging from 0.6 percent to 1.8 percent annually.

Travel Growth Factors

A 2.5 percent average annual growth rate may seem low when compared to historic rates, but some strong evidence supports this forecast:

- First, virtually all licensed drivers currently either have access to a personal vehicle, or are expected to have access in the near future. The total number of vehicles continues to increase, with some drivers having access to more than one vehicle. The average mileage driven per driver, however, which may be referred to as the "travel budget," remains very stable.

  In other words, if a given person has a travel "budget" of 10,000 miles per year, and obtains a license, the Nation's total travel demand will go up by 10,000 vehicle miles of travel. If this person then buys a second vehicle, the driver's desire to travel may increase slightly, but it will not double to 20,000 miles per year. This saturation effect in the driver licensing rates as well as the travel "budget" will be important influences on future travel demand.

- Second, the number of older Americans is increasing. This group has tended to drive fewer miles than the population as a whole. There is some evidence that these older Americans, many of whom have higher levels of disposable income and generally better health than prior generations, may travel more than their predecessors, but that assumption remains to be fully proven and is not reflected in the forecast.

Countering these influences, but not expected to outweigh their effects, will be a continuing growth of licensing and travel rates by female drivers, as well as increasing truck travel.

For purposes of sensitivity analysis, investment estimates have also been developed for an average annual growth rate of 3.0 percent. Estimates for a comparable lower travel forecast have not been included, since the 2.5 percent growth forecast is considered very conservative.

Peak Spreading and Congestion Management

Corridors. Corridor constraints have been incorporated in the estimated future highway demand for capacity-related investment requirements in urban areas. The constraints were incorporated:

- first, through peak spreading, and
- second, by imposing an upper limit of 12 lanes per corridor (not facility).

The peak spreading was simulated to reflect travel behavior in the face of increasing congestion. This modification moved some travel demand from the peak-hour to the hours immediately preceding and following peak-hour. This shift simulates making more effective use of existing capacity before considering the need for building new facilities. The level of adjustment made varied by city size and was based on empirical evidence of actual behavioral changes that occur as congestion increases.

Travel demand factoring. Travel demand was further adjusted downward to reflect widespread application of "congestion management" in urban areas as a cost-effective part of capacity enhancement. The adjustment was done before calculating new construction-based capacity improvements. The simulation process estimates the potential reduction in new highway capacity demand that could be expected through a systematic nationwide application of "supply and demand management."

An aggressive application of comprehensive traffic and freeway operational elements was used, along with a parallel "demand management" program assuming parking management, ridesharing, and transit strategies. These programs were applied uniformly and are assumed to be as effective or better than the best demonstrated experience to date.

Reduced lane-miles of new capacity format. The simulation represents these efficiency and reduced demand assumptions as reduced lane-miles of new capacity required to achieve the system performance goals established by the scenario. The combined changes of (1) congestion management, (2) restriction on capacity additions, and (3) peak spreading, reduce the total new capacity simulated by between **56,000 and 83,000 urban lane-miles of capacity**. Between 30,000 and 45,000 of these lane-miles are in the top 10 urbanized areas.

These lane-miles and capacity costs are not included in the cost analysis. In Exhibit 17, total travel demand is shown under the **Forecast** column. The **Effective** column indicates the amount of travel for which capacity costs have been simulated—that is, the capacity costs to satisfy demand after the congestion management, capacity restriction, and peak spreading strategies have been considered.

The combined assumptions of these constraints and congestion management efforts produce estimates for urban highway systems that will allow most urban highways, on average, to be able to function at today's levels of service with only an 18 percent increase in lane-miles of capacity over the next 20 years. Over that same period, these highways will accommodate a 65 percent increase in demand. This contrast between future demand and future supply additions reflects a highly intensive and cost-effective use of all available highway capacity, as well as selected capacity additions, where warranted.

These assumptions are not without cost, however. In the top 10 urbanized areas, travel demand is expected to outpace existing highway supply and likely supply additions by a wide margin. There is no escaping the fact that the largest urbanized areas—if they experience anticipated travel growth—will be faced with increasingly high levels of congestion. Even with substantial new capacity, effective traffic management, and transit improvements, this seems unlikely to change in the foreseeable future.

Investment Requirements Coverage

The report incorporates a broad range of investment strategies typical of the project types being implemented in many States. Exhibit 18 summarizes the types of highway and bridge improvements addressed in most highway investment programs. The exhibit also shows which of these have been included in this report compared with previous versions:

- **Capacity additions in larger urbanized areas.** These are additions requiring higher cost rights-of-way, grade-separation, or new lanes in parallel corridors—up to a 12-lane total on a corridor-wide basis. Travel demand that would require capacity additions beyond this limit is reported as "unmet lane-miles of demand" and is **not** included in the investment requirements estimates. (The amount of new capacity not included due to this restriction is equal to 37 percent of the total new capacity that is included to maintain or improve levels of service to meet expected travel demand.)
- **Highway and bridge infrastructure in expanding suburban areas.** These improvements are made at locations that have been, and are expected to be, areas of major highway travel demand increases. An estimate is included for new highway capacity required to preserve or improve level of service in areas classified as rural but expected to be urban in character by the year 2009.
- **Local roads.** The report includes an estimate of future capital requirements for the approximately 2.6 million miles of local roads. This information is based on a 1987 survey conducted by the U.S. Department of Agriculture on (1) the physical conditions of local roads and (2) an assessment of current highway capital costs incurred by municipal and county governments.
- **Defense highway requirements.** Approximately 60,000 miles of Interstate and other arterial highways comprise the Strategic Highway Defense Network, or STRAHNET. These highways have higher design specifications in order to accommodate large and heavy military vehicles.

Exhibit 18 also compares the estimated 1989 capital expenditures by all units of government for all types of improvements with the expanded coverage supplied in this report. The report covers an estimated 85 to 90 percent of improvements for which highway agencies make capital investments. The only major component not included is new construction for economic development purposes. Private investment, possibly accounting for $8 to $11 billion, is not included in this table.

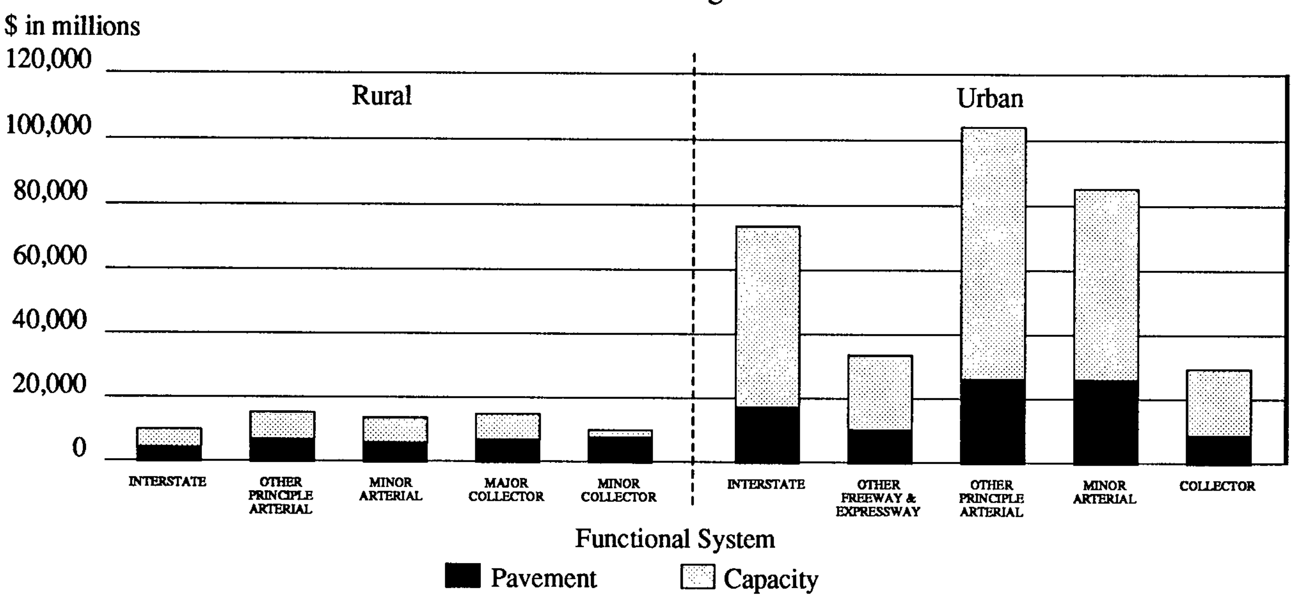
Highway Investment Requirements, 1990-2009

This report addresses two estimates of investment requirements — the cost to improve conditions and performance **or** to maintain overall conditions and performance. Each scenario addresses both backlog and accruing deficiencies.

Exhibit 18
Program and Report Coverage

Highway and Bridge Improvements Addressed by State and Local Highway Agencies	1989 Report	1991 Report	Estimated 1989 Total Capital Expenditures (billions)
Pavement and safety improvements to arterials and collectors	yes	yes	$6.7
Capacity additions to existing arterials and collectors	some	yes	$7.1
New arterial and collector highway and bridge construction	no	limited	$7.8
Capital improvements to local functional class, including new construction	no	yes	$5.4
Bridge replacement and rehabilitation on arterials and collectors	yes	yes	$4.6
Defense highway and bridge requirements	no	yes	included in other categories
Operational improvements	no	yes	$1.7
Total			$33.3

Exhibit 19
1989 Backlog Needs



Highway and Bridge Backlog Deficiencies

- The **backlog** is the cost of bringing the current system up to at least minimum standards from its existing conditions and performance status.
- An **accruing** requirement is a cost for repairing deficiencies that will occur in the future, as the result of travel demand and system deterioration due to traffic loads and normal weathering.

Highway Backlog Deficiencies

As of December 31, 1989, the cost of eliminating the backlog of highway deficiencies was estimated at $400 billion for all existing arterials and collectors. The cost of deferring improvements on roads identified as deficient in 1987—and that remained deficient in 1989—added $8 to $12 billion to the backlog estimate in 1989. This difference in cost is the additional cost of **reconstructing** roads that were previously identified in 1989 as needing **resurfacing** or some other type of lower cost pavement improvement. (See "The Cost of Deferring Capital Investment"). Exhibit 19 presents total highway backlog deficiency costs.

About 28 percent of the backlog estimate is pavement cost. The remaining 72 percent is the cost of adding capacity to restore system performance to or above the minimum level of service. Backlog requirements in urban areas are twice as high as those in rural areas, mostly due to inadequate highway capacity.

Each of the two investment scenarios treats backlog deficiencies differently:

- The **improve conditions** scenario includes investments to eliminate backlog as well as to respond to accruing deficiencies.
- The **maintain conditions** scenario does not eliminate the backlog as a goal, but makes investments selectively on both backlog and accruing deficiencies so that **overall** conditions and performance remain essentially unchanged.

Maintain means that at the end of the analysis period, 2009, the backlog of deficiencies will be about what it is today. The exact mix of deficient highways and bridges would probably be different, but the total size would remain essentially unchanged.

Bridge Backlog Deficiencies

As of December 31, 1989, backlog requirements on the Nation's inventory of arterial, collector, and local road bridges were $91 billion. Of this amount, between 60 and 75 percent was the cost attributable to structural deficiencies. The remainder was the cost attributable to functional obsolescence. The cost of eliminating the backlog of bridge deficiencies could increase to as much as $131 billion, depending on the number of years required to meet that objective, because of the deferred capital cost of bridge repair.

The "Improve Overall Highway Conditions and Performance" Scenario

This scenario provides cost estimates for achieving and maintaining predefined minimum condition standards for physical conditions and performance on all arterial and collector highways that (1) are currently deficient or (2) are expected to become deficient at some point during the 1990-2009 analysis period. These standards reflect high levels of roadway safety by

- eliminating unsafe highway curves and grades and narrow lane widths,
- establishing efficient life-cycle costs for physical preservation through a sustained cost-effective level of pavement condition, and
- identifying more productive peak-period service levels, just above stop-and-go conditions.

The "Improve Overall Conditions and Performance" scenario supports improved conditions and performance for both urban and rural roads across all functional systems on a uniform basis nationwide. The scenario allows for improved system performance except in the largest urbanized areas, where performance cannot be significantly improved because of capacity restrictions discussed earlier. Since the complete backlog of deficiencies would be eliminated, this scenario represents a **significant** improvement in condition and performance on the majority of highways. (Backlog is the cost of eliminating all deficiencies that exist on the highway and bridges at the beginning of the analysis period, 1990.)

The scenario establishes no particular priorities regarding cost-effectiveness and is not intended to represent an optimum recommended investment strategy. For example, it includes pavement improvements on lower volume roads and substantial urban capacity additions in high cost areas. These improvements range from highly cost-effective to highly debatable. In reality they might never be made because of siting problems, constrained highway budgets, or environmental and air quality concerns.

The scenario uses a consistent frame of reference. It measures the total capital costs of providing a desirable level of highway and bridge infrastructure on all facilities using good engineering practices.

An average annual investment of between $60.4 to $68.4 billion will be required to repair all backlog deficiencies and keep arterials and collectors above minimum condition and performance level standards through 2009. A range of costs is given because costs will vary depending on the number of years needed to repair backlog deficiencies. The estimate takes into account all sources of funding. It also includes the capital savings of an aggressive congestion management program, estimated to eliminate about $3.4 billion in new construction costs annually.

This scenario would require an average investment of about 3.2 cents per 1989 vehicle mile of travel, compared to about 1.2 cents (or approximately $22 billion) invested in 1989 for corresponding capital improvements on the same highways.

If future travel increases at a 3.0 percent average annual rate, the estimate for this scenario would be from $68 to $74 billion annually.

Exhibit 20 shows investment requirements for **improving conditions and performance** for the period 1990-2009. The exhibit shows total 20-year investment requirements categorized as pavement and capacity improvements, and gives annualized totals. The annualized total is the 20-year total divided equally.

Under this scenario, approximately two-thirds of total investment would occur in urban areas. Capacity improvements would account for over 70 percent of urban investment, and over 60 percent of total investment. The cost of eliminating the backlog of deficiencies would be approximately 30 percent of total investment.

Exhibit 21 shows the current and future number of lane-miles of highway facility by functional class in both rural and urban areas under this investment scenario. The 2009 values are shown in two columns: lane-mile requirements for capacity expansion and lane-mile requirements for new right-of-way/higher cost capacity. No facility is simulated to have more than a total of 12 lanes of existing plus new capacity combined.

System Conditions and Performance Impacts

Implementing the **improve conditions and performance scenario** would result in only modest improvements in overall pavement conditions on the higher functional systems. Between 85 and 90 percent of these pavements already meet the minimum standards of pavement condition. This scenario would **significantly** improve conditions on minor arterials and collectors. On these roads, the backlog of condition problems is higher, and all of these deficiencies would be improved, regardless of the amount of travel on the facility.

As shown in Exhibit 22, this scenario would also **significantly** improve system performance on many urban and some rural highways, supporting at least

Exhibit 20
Improve Conditions and Performance Scenario
2.5% VMT Growth Rate
(Billions of 1989 Dollars)

Improvement Type	Capacity	Pavement	Total
Rural			
Interstate	38.8	26.1	64.9
Other Principal Arterial	45.2	28.9	74.1
Minor Arterial	31.2	43.1	74.3
Major Collector	30.6	77.4	108.0
Minor Collector	15.2	45.0	60.2
Subtotal	161.0	220.4	381.5
Urban			
Interstate	169.0	45.2	214.2
Other Freeway and Expressway	68.2	16.8	85.0
Other Principal Arterial	176.8	60.3	237.1
Minor Arterial	127.6	56.5	184.2
Collector	56.6	49.0	105.6
Subtotal	598.3	227.8	826.0
Total	759.3	448.2	1,207.5
Annual	38.0	22.4	60.4

minimum performance standards during the daily peak-period of demand.

If the **improve conditions and performance** scenario were implemented, most highly congested conditions could be eliminated. Also, performance on high volume highways projected to soon become congested would improve. In effect, this investment scenario builds a "reserve" of capacity to that would accommodate future travel at the minimum conditions standard-levels-of-service over a 20-year period.

This scenario does not imply system perfection. Conditions and performance would be superior to today's, but pavements would not be "like new" nor would traffic be free flowing. The amount of congestion would be reduced by nearly one-half, but the 12-lane capacity limitation described earlier means that several larger metropolitan areas would have high levels of "latent demand." Latent demand is travel demand that is desired (see the earlier discussion on "travel budget"), but for which insufficient capacity is available. No section of road would be in "poor" physical condition, although large amounts of pavement in fair condition would remain.

Unmet Demand

The **improve conditions and performance** scenario would leave about 49,000 lane-miles of unmet demand in future years, because of the 12-lane constraint assumed for the analysis. About half would be concentrated in the Nation's ten largest urbanized areas. The other half would be distributed throughout the Nation, mainly in urbanized areas of at least 500,000 population.

Because of the assumed constraint on the addition of capacity, **performance in the larger urbanized areas can be expected to deteriorate in future years. This deterioration would continue even with the aggressive congestion management strategy assumed in this scenario.**

The "Maintain Current Overall Highway Conditions and Performance" Scenario

This scenario estimates the cost of maintaining both current overall physical conditions and current levels of performance, as traffic increases over the 20-year analysis period. While current physical conditions vary widely, as shown in Exhibit 14, average conditions are rated "fair."

As with the "improve" scenario, overall system performance would not be maintained in the largest urbanized areas, even with an aggressive traffic management program, because of the amount of travel increase expected. Under the funding levels associated with this scenario, however, States could improve conditions of the higher priority routes.

Exhibit 21
Total Lane-Mile Requirements - Improve Conditions
(2.5% annual VMT growth rate)

Functional System	1989	2009 Lane-Miles Required		
		Expansion Capacity	New ROW Higher Cost Capacity	Total
Rural				
Interstate	132,717	184,442	4,987	189,429
Other Principal Arterial - High	72,834	140,626	9,575	150,201
Other Principal Arterial - Low	129,917	87,333	443	87,776
Minor Arterial	307,757	327,089	7,562	334,651
Major Collector	880,342	892,352	4,739	897,091
Minor Collector	587,157	589,558	300	589,858
Subtotal	2,110,724	2,221,400	27,606	2,249,006
Urban				
Interstate	62,428	78,481	6,691	85,172
Other Freeway & Expressway	34,379	42,190	5,034	47,224
Other Principal	169,439	200,960	31,203	232,163
Minor Arterial	187,761	216,478	29,169	245,648
Collector	168,134	178,860	13,616	192,476
Subtotal	622,141	716,970	85,713	802,683
Total	2,732,865	2,938,370	113,319	3,051,689

Note: In rural areas, high OPA's have AADT of greater than 6,000. Low OPA's have AADT less than or equal to 6,000.

Exhibit 22
System Performance Impacts of the
Improved Conditions and Performance Strategy

System		1989		2009	
		Capacity (V/C>0.8)	Pavement (Poor)	Capacity (V/C>0.8)	Pavement (Poor)
Rural	Interstate	23%	9%	15%	0%
	Other Principal Arterial	9%	5%	5%	0%
	Minor Arterial	6%	5%	1%	0%
	Major Collector	4%	10%	0%	0%
	Minor Collector	1%	12%	0%	0%
Urban	Interstate	70%	10%	45%	0%
	Other Freeway and Expressway	60%	3%	35%	0%
	Other Principal Arterial	43%	6%	25%	0%
	Minor Arterial	34%	9%	20%	0%
	Collector	21%	18%	10%	0%

The average annual cost to maintain overall 1989 conditions and performance on existing arterials and collectors through 2009 is estimated at $33.1 billion. This estimate also includes an estimated $3.4 billion capital savings from an aggressive congestion management program.

This scenario requires an average investment of about 1.8 cents per 1989 vehicle mile of travel, compared to about 1.2 cents invested in 1989 for similar capital improvements on the same highways.

If future travel increases at a 3.0 percent average annual rate, the cost to maintain overall conditions and performance would be $38.8 billion annually.

Exhibit 23 shows investments required to **maintain current condition and performance** for each functional system. The actual conditions and performance levels maintained in this scenario were presented as the 1989 baseline for the **improve conditions and performance** scenario in Exhibit 22.

Under this scenario, approximately 55 percent of total investment would occur in urban areas, compared to about two-thirds in urban areas under the **improve conditions scenario.** Capacity improvements would account for less than 60 percent of urban investment, compared to over 70 percent of urban investment under the **improve conditions scenario.** Capacity would account for about half of total investment, compared to slightly over 60 percent of total investment under the **improve conditions** scenario.

System Conditions and Performance Impacts

The **maintain conditions and performance** scenario represents an investment level that would substantially halt the trend toward system performance deterioration and maintain the current condition and performance levels. These system improvements would take place **despite a 65 percent increase in travel demand over the next 20 years.**

Under this strategy, the condition and performance of some roads would improve and some would deteriorate. In general, however, conditions and performance would remain about the same. The overall backlog of highway deficiencies would remain essentially the same over the 20-year analysis period. Some backlog deficiencies

Exhibit 23
Maintain 1989 Conditions and Performance
2.5% VMT Growth Rate
(Billions of 1989 Dollars)

Improvement Type	Capacity	Pavement	Total
Rural			
Interstate	35.6	23.9	59.5
Other Principal Arterial	26.4	22.9	49.4
Minor Arterial	24.1	34.7	58.8
Major Collector	28.6	64.1	92.7
Minor Collector	11.4	26.5	38.0
Subtotal	126.2	172.1	298.3
Urban			
Interstate	52.6	27.6	80.2
Other Freeway and Expressway	28.6	14.9	43.5
Other Principal Arterial	58.5	36.8	95.4
Minor Arterial	43.2	40.6	83.8
Collector	25.6	35.5	61.1
Subtotal	208.6	155.4	363.9
Total	334.8	327.5	662.2
Annual	16.7	16.4	33.1

would be remedied depending on how cost-effective the repairs would be compared to other accruing problems.

Under the maintain conditions scenario, the current number of miles of poor and fair pavements would remain almost constant, although highway agencies would likely improve 999 higher volume facilities while delaying needed improvements to lower volume facilities.

System performance would be kept at current levels, where possible. Even with rigorous demand management, about 70 percent of urban Interstate peak-hour travel and over 40 percent of other urban arterial peak-hour travel would remain congested or highly congested. These figures might actually increase for the largest urbanized areas.

This scenario would produce a shortfall of about 22,000 lane-miles of unmet demand in larger urbanized areas.

The capacity expansion constraints discussed under the improve conditions scenario would again be in effect. Under the maintain conditions scenario, performance in some larger urbanized areas could not be maintained, even though the capital improvement program and congestion management strategy are applied. Exhibit 24 shows current and future lane-miles for this investment strategy.

Because of the current distribution of conditions, high levels of congestion, and the expected demands on the system from aging and travel demand, a maintain conditions strategy represents an improvement over recent trends in condition and performance. Keeping conditions stable and making selective improvements in current performance measures is preferable to the continuation of widespread deterioration.

Exhibit 24
Total Lane-Mile Requirements
Cost to Maintain 1989 Condition and Performance

		2009 Lane-Miles Required		
Functional System	1989	Expansion Capacity	New ROW Higher Cost Capacity	Total
Rural				
Interstate	134,969	179,809	4,062	183,871
Other Principal Arterial - High	74,095	135,021	4,209	139,230
Other Principal Arterial - Low	131,723	87,309	71	87,380
Minor Arterial	308,266	323,339	5,891	329,230
Major Collector	880,650	892,222	4,835	897,057
Minor Collector	586,998	588,767	274	589,057
Subtotal	2,116,701	2,206,467	19,342	2,225,809
Urban				
Interstate	61,854	77,415	8,889	86,304
Other Freeway & Expressway	33,739	42,226	3,600	45,826
Other Principal Arterial	170,977	190,020	19,175	209,195
Minor Arterial	188,218	211,133	18,076	229,209
Collector	167,699	182,982	12,388	195,370
Subtotal	622,487	703,776	62,128	765,904
Total	2,739,188	2,910,243	81,470	2,991,713

Note: Maximum number of lanes = 12. High principal arterials carry greater than 6,000 vehicles per day. Low principal arterials carry less than or equal to 6,000 vehicles per day.

Bridge Investment Requirements, 1990-2009

The "Improve Bridge Conditions" Scenario

The average annual investment required to repair all backlog and accruing bridge deficiencies on all arterial, collector, and local road bridges over the period 1990-2009 is between $6 and $8.5 billion, depending on the number of years taken to repair backlog deficiencies.

At these investment levels, all backlog bridge deficiencies would be eliminated through bridge replacement, rehabilitation, or major widening. All accruing requirements would be met through 2009. Bridge investment requirements are relatively insensitive to future travel growth.

Between 50 and 75 percent of bridge deficiencies are attributable to structural deficiencies. If bridge structural and deck deficiencies are not identified and repaired in timely fashion, further deterioration could require major rehabilitation or bridge replacement. These actions cost significantly more than highway repair on a unit-cost basis. In addition, deferred investment on deficient bridges may impose public safety hazards more dangerous than the risks of deferred highway improvement. For this reason, the deferred capital cost of bridge improvements is significantly higher than similar costs for highways.

The "Maintain Current Bridge Conditions" Scenario

The average annual cost to maintain overall bridge conditions as they were reported on December 31, 1989 is estimated at $4.2 billion annually through 2009. This investment level would maintain the current total number and distribution of structurally deficient and functionally obsolete bridges.

Exhibit 25 summarizes 1990-2009 investment requirements to eliminate all backlog and accruing bridge deficiencies for all bridges greater than 20 feet in length, including those on local roads. All box culverts are also included, regardless of length. Exhibit 26 summarizes the cost to maintain bridge conditions as they were reported on December 31, 1989.

The Cost of Deferring Capital Investment

When highway and bridge deficiencies are identified, the cost of improvement assumes that the improvement will be made at that time. If insufficient funds are available, or for some other reason the improvement is not made, the deficiency is likely to worsen. The difference between the cost of fixing the problem when it first develops or waiting until a later date is the cost of deferral. The total cost of deferral has three components:

1. The capital cost associated with a generally more expensive improvement to repair a more significant problem.
2. The highway vehicle operating costs and lower speeds imposed on highway users over the time between identification of the problem and the time of improvement.
3. The increased user cost incurred during the improvement, consisting of detouring, delay, and potentially higher numbers of accidents through and around construction zones.

Deferring any highway improvement beyond the point at which its condition and/or performance warrants the improvement will increase the cost that must ultimately be paid by highway users to restore the road's serviceability. Between the time that a need for improvement is identified and the time action is taken, the roadway continues to deteriorate and may require a more costly improvement.

If the problem identified happens to be a physical one (such as pavement cracking or rutting), delaying the needed improvement can expose the pavement to continued deterioration. If remedial action is taken in timely fashion a simple resurfacing may be all that is required to restore the road's serviceability. If, on the other hand, action is delayed, further deterioration can allow the surface pavement stress to extend into the road's base and subbase.

Pavement damage from freeze/thaw action on damaged pavement is a common condition that results from a delay in repair. When this happens, a more costly pavement reconstruction improvement may be required, at a cost as high as three times the cost for resurfacing. Not only will the cost be higher, but the time and public inconvenience of major reconstruction far exceeds that required for simple resurfacing.

Exhibit 25
Cost to Improve Bridge Conditions
1990-2009

Functional System	Number of Repaired or Replaced Bridges	1990-2009 Requirements (billions)	Annualized Requirements (billions)
Rural			
Interstate	11,871	11.1	0.56
Other Principal Arterial	10,828	7.2	0.36
Minor Arterial	11,924	7.1	0.36
Major Collector	56,639	8.0	0.40
Minor Collector	25,940	3.5	0.18
Subtotal Nonlocal	117,202	36.9	1.85
Local	127,291	12.0	0.60
Total	244,493	48.9	2.45
Urban			
Interstate	20,156	32.1	1.61
Other Freeway & Expressway	5,682	9.0	0.45
Other Principal Arterial	11,302	15.6	0.78
Minor Arterial	8,370	8.2	0.41
Collector	6,786	3.0	0.15
Subtotal Nonlocal	52,297	67.9	3.40
Local	8,480	3.5	0.17
Total	60,777	71.4	3.57
Total Nonlocal	169,499	104.8	5.24
Total	305,270	120.3	6.02

Exhibit 26
Cost to Maintain Bridge Conditions
1990-1992

Functional System	Number of Repaired or Replaced Bridges	1990-2009 Requirements (billions)	Annualized Requirements (billions)
Rural			
Interstate	8,293	7.8	0.39
Other Principal Arterial	6,099	4.1	0.20
Minor Arterial	2,131	1.3	0.06
Major Collector	7,570	1.1	0.05
Minor Collector	19,598	2.6	0.13
Subtotal Nonlocal	43,691	16.8	0.84
Local	76,188	7.2	0.36
Total	119,879	24.0	1.20
Urban			
Interstate	19,983	31.8	1.59
Other Freeway & Expressway	5,540	8.8	0.44
Other Principal Arterial	8,977	12.4	0.62
Minor Arterial	3,820	3.7	0.19
Collector	1,629	0.7	0.04
Subtotal Nonlocal	39,949	57.5	2.87
Local	6,195	2.5	0.13
Total	46,144	60.0	3.00
Total Nonlocal	83,639	74.3	3.71
Total	166,022	84.0	4.2

Other Highway Investment Requirements

Suburban Growth

The procedures used in this report calculate future urban highway requirements based on current urban boundaries. As urban areas grow, however, rural land adjacent to urban areas takes on the land use and travel character of urban fringe, and fringe areas take on the character of suburban areas.

The basic highway and bridge infrastructure requirements to support expanding suburban areas were not included in the earlier highway discussion. To incorporate these requirements, a procedure was developed to simulate the expected growth in urban areas and to calculate new lane-miles of roadway that will be required to accommodate the growth at minimum conditions standards. Exhibit 27 summarizes the lane-mile requirements resulting from this procedure.

Local Roads

The earlier discussion of highway requirements does not cover conditions or capital investment requirements for the approximately 2.6 million miles of roads functionally classified as local roads. By Federal Highway Administration standards, between 35 and 50 percent of all local rural roads are currently in "poor" condition. These roads will require significantly higher levels of continuing maintenance or capital improvement to restore serviceable conditions or prevent serious deterioration with normal travel demand and weathering. The estimated cost to improve all local roads that are at or near failure is between $8.5 and $12 billion through 2009, or between $425 and $600 million annually in 1989 dollars.

An annual investment of this size would restore serviceable conditions to between 900,000 and 1.3 million miles of local roads that are now deficient or will become deficient through 2009. The lower estimate is shown in Exhibit 28, the investment summary table, as the local road investment associated with the **maintain conditions and performance** scenario. The higher estimate is associated with the **improve conditions** scenario.

Defense Highways

The Nation's highway and bridge systems are an integral part of the national defense transportation system. The military relies on the highway system for peacetime transit of military shipments, as well as for wartime or emergency mobilization and deployment of military units. The STRAHNET, which consists of the Interstate System and about 16,800 miles of other principal arterials, is the primary network of defense concern.

An estimated $600 million total, or $30 million annually, will be required to meet defense costs on STRAHNET. This is the estimated additional cost of constructing 12-foot lane-widths on roads not included as improvements under the earlier highway discussion. Defense Connector Systems are not included.

Total Investment Requirements

Exhibit 28 summarizes annual investment requirements to meet each scenario target for all urban and rural areas. The local roads, defense highways, and new construction in suburban areas estimates have been included in this summary table. These separate estimates give a more complete picture of total national highway and bridge investment requirements. The estimates include, by functional system, the capital savings associated with the congestion management assumptions.

Summary

Historically, total actual investments have been less than the amounts needed to maintain the overall serviceability of roads. The average condition of roads has deteriorated slightly. In the 1970's and early 1980's, the condition of the Nation's highways had steadily deteriorated until increased spending was made possible by the Surface Transportation Assistance Act of 1982. Pavement conditions, on average, are now tolerable, although almost 640,000 miles of arterial and collector pavements remain near or below a cost-effective level of condition.

Throughout the 1980's, system performance has deteriorated significantly. Heavy congestion, until recently restricted to a handful of major urban areas, is now a daily phenomenon in numerous areas, including some smaller urban areas. The backlog of needed improvements has increased, and the nature of future improvements to remedy expected problems has changed.

The cost of deferring improvements to roads that were identified as being deficient in 1987, and remained deficient in 1989, added between $8-12 billion to today's $400 billion backlog cost estimate. Future deferred costs could be as high as $8 billion annually, depending on the timeliness of addressing backlog deficiencies.

Total capital investment has not kept pace with system demands. For this reason, highway and bridge conditions and performance continue to decline.

Future investments must address many concerns, including:

Exhibit 27
Suburban Highway System Requirements, 1990-2009

Functional System	New Lane-Miles	Costs ($billions)
Freeways	12,100	18.8 - 37.7
Other Principal Arterials	15,200	17.5 - 35.4
Minor Arterials	16,400	15.2 - 30.5
Collectors	8,100	8.8 - 17.7
Local Roads	300,000	60.0 - 90.0
Total (average annual)	351,800 (17,590)	120.3 - 211.3 (6.0 - 10.5)

(1) **The continuing effort to maintain adequate physical conditions on all highways.** About 100,000 miles of arterial and collector highways require capital investment each year to restore their serviceability; delaying needed improvements can increase costs as much as 200 percent.

(2) **The need to address the rapidly deteriorating performance of our highest types of arterials, both within, around, and between major urbanized areas.** Unnecessary delay added about $35 billion to the cost of interstate commerce in 1989; overall, delay cost Americans about $120 billion and 8 billion wasted hours in 1989.

An additional 12,500 lane-miles of new highway capacity each year are needed to meet existing and future travel demand, even assuming a declining rate of travel growth increase and rigorous system management improvements. In 1989, less than 4,000 lane-miles of new capacity was added.

(3) **The need to replace or rehabilitate deficient bridges, especially structurally deficient bridges that pose a potential safety hazard and major impediment to efficient interstate commerce and defense preparedness.** Over the next decade, between 20,000 and 25,000 Interstate System bridges will reach a point in their design lives that will require major rehabilitation or deck replacement to restore their serviceability.

(4) **The need to put in place an adequate highway network and capacity to support growth and development.** About 2,600 new lane-miles of arterial and collector facilities and 15,000 miles of local roads and streets need to be provided each year as basic infrastructure to support growth of urban/suburban areas. Economic development highways, which are not addressed in this report, will continue to be of concern in many States, in an effort to improve regional economies and to tap underdeveloped labor markets.

(5) **The need to address a variety of other requirements faced by highway agencies, including the removal of road hazards, improvement of rail/highway crossings, and mitigation of adverse environmental impacts of highway projects, among others.**

The extent to which these investment requirements are addressed, and the relative priority assigned to each, will in large measure determine the future quality of highway and bridge service that we can expect. Although the cost estimates seem high, they represent a marginal increase over current capital investments for highways and bridges, especially if the investments are phased in over time.

In real terms, highway and bridge capital investment per vehicle mile-of-travel in 1960 was 2.6 times what it is today. The early 1960's were fast-paced years for new highway construction, with extensive Interstate System projects underway throughout the Nation. Today, new construction is no longer the emphasis in the highway program. System preservation is now the watchword, including preservation of both system physical integrity and operating characteristics.

Preservation of highways and bridges for preservation's sake is not the point. The Nation's mobility is at stake here. For Americans to enjoy the same level of highway service in the future that they have enjoyed in the past, total investment must increase. Users will pay to improve our economic competitiveness and standard of living in one of two ways—either in investment in the system or in additional vehicle operating cost, delay, and lost opportunities. In the long run, adequate investment in the system will be much less expensive.

Exhibit 28
Summary of Annual Highway and Bridge Investment Requirements
1990-2009
(Billions of 1989 Dollars)

Functional System	Cost to Maintain 1989 Conditions and Performance	Cost to Improve 1989 Conditions and Performance
Rural Highways		
Interstate	3.0	3.3
Other Principal Arterial	2.5	3.7
Minor Arterial	2.9	3.7
Major Collector	4.6	5.4
Minor Collector	1.9	3.0
Local Roads	0.2	0.2
Rural Subtotal	15.1	19.3
Urban Highways		
Interstate	5.0	11.7
Other Freeway & Expressway	2.6	4.7
Other Principal Arterial	6.0	13.1
Minor Arterial	5.3	10.3
Collector	3.7	6.0
Local Roads	3.8	3.8
Urban Subtotal	26.4	49.6
Urban and Rural Subtotal	41.5	68.9
Bridge	4.2	6.0
Total Annual Highway and Bridge Requirements	45.7	74.9

Glossary

Accruing Deficiency—A highway or bridge condition that will exceed the minimum condition standards in a future year. Accruing deficiencies are a function of normal pavement and bridge deterioration, travel demand, age, capital investment, and the adequacy of maintenance.

Ad Valorem Tax—Taxes based on value of commodity.

Annual Average Daily Traffic (AADT)—Average daily traffic, averaged over a full year.

Backlog Deficiency—A highway or bridge condition that violated one or more minimum condition standards at the beginning of the analysis period; in this report, 1989 for highways and 1990 for bridges.

Bridge, Functionally Deficient—A bridge on which the deck width, vertical clearance, or waterway is not adequate to accommodate the traffic demand on the bridge or the volume of water under the bridge.

Bridge, Structurally Deficient—A bridge that is not able to carry the truck loads expected of the highway system of which the bridge is a part.

Capacity—The theoretical maximum number of vehicles that has a reasonable expectation of passing over a given section of a lane or a roadway in one direction (or in both directions for a two-lane or three-lane highway) during a given time period under prevailing roadway and traffic conditions.

Cost to Improve Overall Conditions—The average annual total capital cost, usually expressed in constant dollars, of eliminating the backlog of highway and bridge deficiencies over the analysis period, as well as meeting accruing requirements.

Cost to Maintain Overall Conditions—The average annual total capital cost, usually expressed in constant dollars, of keeping the highway or bridge system as good or bad, overall, as it was in the base year, 1989 for highways, 1990 for bridges. Some facilities will be better and some worse than today but, overall, the condition and performance will remain approximately the same. Conditions in the largest urbanized areas cannot be maintained at the investment levels shown because there is insufficient right-of-way to build the capacity called for by existing and expected travel demand.

Deficiency—A highway condition or performance element that is below a specified acceptable level. These minimum levels represent a consensus of technical expertise within the highway engineering discipline.

(Expenditures, disbursements, costs)—Used interchangeably.

Federal-Aid System—The designated systems including the Interstate System (FAI), Primary System (FAP), rural and urban, Urban System (FAU), and the Secondary System (FAS).

Highway Capital Outlay—includes right-of-way and related costs, preliminary and construction engineering, and construction.

Highway Construction—Includes new roads/bridges, road and bridge relocation, highway rehabilitation, restoration, and resurfacing traffic service facilities, safety construction, and environment improvements.

Highway Maintenance and Operations—Costs to keep roads/bridges in serviceable condition, plus roadway lighting, traffic control systems, snow removal, toll collection, etc.

Highway-User Imposts—Includes taxes, fees, charges and tolls levied on motor vehicles and their usage. These include motor fuel taxes (gasoline, special fuel, diesel), motor vehicle registration fees, operators licenses, motor carrier fees (ton-mile) or any charge specifically targeted to road-users. Does not include broad based taxes such as sales, property, or income taxes.

Indexing—A tax mechanism linking tax rates to some independent variable such the price of motor-fuel or highway cost.

Lane-mile—A measure of highway distance that takes into account the number of lanes. The amount of lane-miles for a given highway section is equal to the length of the section (in miles) multiplied by its number of lanes.

Level of Service (LOS)—Qualitative description of operational conditions within a traffic stream. The six levels of service are briefly described below.

A—Free flow, with drivers unaffected by other vehicles in the traffic stream.

B—Stable flow, but there is enough traffic to slightly affect the freedom to maneuver.

C—Stable flow, but traffic operation is significantly affected. Both speed and freedom to maneuver are affected.

D—High-density stable flow. Speed and freedom to maneuver are severely restricted. Small increases in traffic flow cause operational problems.

E—Operations at or near the capacity of the facility. Speeds are reduced to a low value. Freedom to maneuver is extremely limited. Operation is usually unstable, because small disturbances in the traffic stream will cause breakdowns in the flow.

F—Breakdown flow. Occurs when the amount of traffic exceeds the volume which can traverse a given point. Traffic is stop and go.

Minimum Condition Standards—A series of physical and operating system performance indicators used to determine acceptable and unaccepatable highway conditions. These standards are determined consensually by Federal and State highway engineers and represent cost-effective minimum standards.

Nominal or current dollars—Actual amounts without any adjustment for inflation.

NonCapital Costs—Includes maintenance and operation, administration, traffic law enforcement, highway safety, motor vehicle inspection, truck size and weight enforcement, and bond and note interest and redemption.

NonUser Revenues—Appropriations of general funds or use of broadbased taxes such as sales, income, and property taxes.

Personnel Property Tax—Based on the value of personnel property such as motor vehicles.

Present Serviceability Rating (PSR)—An index used to rate the quality of the pavement surface. The rating is based on a visual inspection of the surface and an assessment of ride quality compared to an established scale that ranges from 0 to 5, where 0 indicates the worst possible pavement condition and 5 represents pavement that is in perfect condition. See Figure IV-8 for a more complete definition of the PSR rating scheme.

Private Contributions—Taxes or fees charged exclusively to private parties including commercial and industrial landowners, private sector donations, impact fees paid by developers, and privately owned and operated toll facilities. Exactions maybe required or negotiated developer fees.

Property Tax on Motor Vehicle—An annual fee based on the value and age of motor vehicles.

Real dollars—Also means constant dollars. Amounts adjusted to remove the effects of inflation.

Real Property Tax—Real estate taxes.

Stub connection—A section of roadway that acts solely as a connector for some facility to a highway.

Titling Tax on Motor Vehicles—A tax on the value of motor vehicles purchased or registered initially in the States—a defect sales tax.

Traditional Road-User Taxes—Taxes and fees universally applied to users including motor fuel excise taxes, motor vehicle registration (tag) fees plus motor carrier weight-distance (ton-mile, etc.) fees and tolls.

VMT—Vehicle miles-of-travel, i.e., one vehicle traveling one-mile.

Vehicle-Miles-Traveled (VMT)—A measure of travel taking place on a specified highway system or systems. VMT is the sum of all miles traveled by all vehicles during a fixed period of time, usually for a year. DVMT is daily vehicle miles of travel.

Vehicle Miles Traveled (VMT)—An aggregate measure of travel taking place on all or part of a highway system. It is the summation of all miles traveled by all vehicles during a fixed period of time on a fixed expanse of highway.

Volume—The number of vehicles that pass over a given point of a lane or roadway during a specified time period.

Volume to Capacity Ratio (V/C)—A factor used in determining congestion levels on a section of highway. V/C compares the volume of traffic on a particular section of highway to its theoretical service flow for a particular time period. A V/C ratio of 0.80 or higher usually indicates congestion, with unstable traffic flow conditions. A V/C of 0.95 and greater indicates severe congestion, accompanied by traffic flow breakdown and increases in the amount of nonrecurring delay.

Weighted Average Motor Fuel Tax—The average of all taxes on motor fuel giving weight to the consumption of motor fuel as opposed to the arithmetic average.