

Chapter 4

EFFICIENCY GAINS DUE TO THE ADHS

Economic efficiency is a legitimate local, regional, state and national goal. If an investment leads to a significant operational cost savings, then there is an economic efficiency rationale for making that investment. If a highway improvement is estimated to create significant efficiencies (road user cost savings), such savings should be considered in deciding whether or not the investment makes economic sense. Therefore, travel efficiency is a relevant criterion for FHWA, the Appalachian Regional Commission, the individual state departments of transportation, and local agencies in making highway investment decisions.

This study analyzed the costs of traveling on the ADHS, compared those costs with the costs of travel in the relevant corridors if the ADHS had not been built, and estimated the magnitude of the economic savings caused by the ADHS investments. These savings are viewed as “efficiency benefits,” and these efficiency benefits are net gains to the economy.

The travel efficiency *benefits* comprise the dollar value of travel time savings, reduced vehicle operating costs, and accident savings that accrue to those who drive on the improved corridors. The *costs* consist of the public sector expenditures associated with building and maintaining the ADHS highway improvements. The travel efficiency *benefits* are compared to the travel efficiency *costs* using standard benefit-cost techniques described in Chapter 2. The results of the benefit-cost analysis, which include benefit-cost ratio, net present value, and internal rate of return indicators, are used to evaluate the various ADHS corridors.

ADHS CORRIDORS INFLUENCE EFFICIENCY

Americans spend great sums of money, time and lives in the act of traveling (or shipping) from one location to another. Investments that will allow them to travel more quickly, more safely or less expensively tend to create travel efficiencies.

The ADHS comprises highways that yield just such results – the ADHS highways are observed to yield faster, safer, and less expensive trips. **Exhibit 4-1** summarizes some of the key characteristics of each of the completed portions of the ADHS. The Exhibit shows that:

- Seven of the ADHS routes are shorter than the roadways they replaced;
- The ADHS investments included the widening of many 2-lane highways to 4-lane (4-lane highways yield considerable travel efficiencies);
- The ADHS investments raised the average speed limit in these corridors from 47 mph to 57 mph (indicating a much quicker trip on the ADHS).

These characteristics indicate that the ADHS has created better access, and considerably superior efficiency.

Efficiency Gains

Exhibit 4-1. Corridor Characteristics

Corridor	States	Length (Miles) ⁽¹⁾		1995 ⁽²⁾	Average No. Lanes ⁽³⁾		Average Speed Limit ⁽⁴⁾	
		Before	After	AADT	Before	After	Before	After
A/A1	GA	28.5	30.4	29,351	2.3	4.0	38	58
B	KY, NC, TN, VA	272.9	249.4	14,931	2.2	4.0	45	56
D	OH, WV	203.6	189.8	9,745	2.0	4.0	47	55
E	MD, WV	107.3	109.2	14,766	2.0	4.0	48	64
F	KY, TN	104.9	99.3	8,440	2.0	3.0	49	52
I	KY	63.3	59.9	8,986	2.0	3.0	43	54
J	KY, TN	212.9	214.5	6,780	2.0	3.0	46	57
L	WV	67.3	60.5	12,233	2.1	4.0	49	54
P	PA	54.4	54.7	15,659	2.1	4.0	49	61
Q	VA, WV	136.3	129.8	13,206	2.0	4.0	44	53
T	NY, PA	<u>226.9</u>	<u>220.3</u>	<u>11,967</u>	<u>2.2</u>	<u>4.0</u>	<u>52</u>	<u>60</u>
All Corridors		1,478.3	1,417.8	11,931	2.1	3.7	47	57

(1) The length of the corridor ADHS segments that have been completed and therefore were included in this study. "Before" length refers to length of the road before the ADHS highway was built; "After" refers to the length of the ADHS segments already built.

(2) AADT = "Average Annual Daily Traffic," which is the daily average traffic volume. It is calculated by dividing daily vehicle miles of travel on the corridor by the corridor length.

(3) Average number of lanes of highway in existence. 2.0 means a two-lane highway, 2.3 means most of the highway length is two lanes, some is three or four lanes. "Before" of 2.0 and "After" of 4.0 means a previously two-lane highway was widened to four lanes.

(4) Average speed limit is average end-to-end speed limit, weighted by traffic volume.

Efficiency Gains

Vehicle Miles of Travel Saved

According to this study's calculations, and as shown on **Exhibit 4-2**, the completed portions of the 12 ADHS corridors combined to save 133,101,000 car miles of travel and 26,214,000 truck vehicle miles of travel annually. This represents a very significant increase in travel efficiency. Some corridors yield a net increase in vehicle miles of travel, due to the longer length of the ADHS (Corridors A/A1, E, J and P), and due to the traffic that is induced by the ADHS.

**Exhibit 4-2. Annual Vehicle Miles of Travel ⁽¹⁾
(Thousand Vehicle Miles), 1995**

Corridor	Corridor Length (Miles)		Car VMT			Truck VMT		
	Before	After	Before	After	Savings	Before	After	Savings
AA1	28.5	30.4	276,385	303,381	-26,995	19,947	22,298	-2,351
B	272.9	249.4	1,262,842	1,191,707	71,135	179,576	167,458	12,118
D	203.6	189.8	615,551	586,869	28,682	93,279	88,224	5,055
E	107.3	109.2	496,440	514,694	-18,254	71,007	73,840	-2,832
F	104.9	99.3	284,810	269,859	14,950	38,343	36,066	2,278
I	63.3	59.9	180,690	169,313	11,377	28,923	27,149	1,774
J	212.9	214.5	449,574	464,506	-14,932	65,408	66,302	-894
L	67.3	60.5	279,743	253,890	25,853	41,939	38,343	3,595
P	54.4	54.7	266,789	277,608	-10,819	33,825	35,025	-1,201
Q	136.3	129.8	591,212	562,717	28,496	66,310	62,933	3,376
T	<u>226.9</u>	<u>220.3</u>	<u>744,790</u>	<u>721,182</u>	<u>23,608</u>	<u>246,390</u>	<u>241,093</u>	<u>5,296</u>
All Corridors	1,478.3	1,417.8	5,448,826	5,315,725	133,101	884,946	858,732	26,214

⁽¹⁾ "After" VMT includes traffic induced by the new highway, therefore, there is more traffic on the "After" ADHS highways than "Before" the ADHS highway. On Corridors B, D, F, I, L, Q and T there is less "After" VMT, meaning the ADHS is shorter than the "Before" road.

Efficiency Gains

Vehicle Hours Saved

By shortening the travel distance, and by increasing the speed limit, and by reducing congestion and by making it easier to pass slow moving vehicles, the ADHS is estimated to save considerable travel time. **Exhibit 4-3** suggests that the studied corridors save 62.2 million car hours and 9.8 million truck hours annually. This is a huge efficiency gain attributable to the ADHS.

Exhibit 4-3. Annual Vehicle Hours of Travel (Thousand Hours) 1995

<u>Corridor</u>	<u>Car Hours</u>			<u>Truck Hours</u>		
	<u>Before</u>	<u>After</u>	<u>Savings</u> ⁽¹⁾	<u>Before</u>	<u>After</u>	<u>Savings</u> ⁽¹⁾
A/A1	9,044	6,027	3,018	774	603	171
B	40,646	25,482	15,164	6,915	4,812	2,103
D	18,583	11,532	7,051	3,373	2,490	883
E	14,575	8,466	6,110	2,790	1,806	984
F	7,806	5,828	1,977	1,301	1,080	222
I	5,027	3,519	1,508	1,069	835	234
J	13,690	8,990	4,700	2,515	1,820	695
L	8,189	4,609	3,580	1,479	1,038	440
P	8,246	5,449	2,797	1,258	849	409
Q	19,137	11,601	7,536	2,663	1,906	757
T	<u>23,890</u>	<u>15,171</u>	<u>8,719</u>	<u>10,241</u>	<u>7,314</u>	<u>2,927</u>
All Corridors	168,834	106,675	62,159	34,379	24,554	9,825

Savings in vehicle hours result from shorter trip distances on shortened ADHS highways, higher speed limits on ADHS, reduced congestion on ADHS, and increased ability to pass other vehicles on ADHS.

TRAVEL EFFICIENCY BENEFITS

These gains in travel efficiency attributable to the ADHS are assigned a monetary value, as described in Chapter 2. The values reflect three types of travel efficiency gains: travel time, travel cost, and accidents.

Travel Time Savings

The first gain of value to the trip maker is the economic benefit associated with the amount of time required to travel through the various corridors. There are potentially three different ways to reduce travel time: (1) reducing mileage to reach one's destination by offering a shorter route, (2) increasing the speed at which one can travel by providing facilities with higher design standards, and (3) reducing congestion (or making it easier to pass) by providing improved or additional facilities.

Each ADHS corridor was evaluated with respect to the estimated travel time savings between the year of opening of the various segments and 1995, as well as the projected savings between 1996 and 2024. Different values of travel time were assigned by trip purpose -- auto-business, auto-non-business, and truck trips (see Chapter 2).

Exhibit 4-4 identifies the expected annual monetary benefits estimated to be attributable to travel time savings for the years 1995 and 2024. In addition, both the mean and median annual benefits were estimated for each corridor. All twelve corridors provide positive annual time savings benefits. Improvements in ADHS Corridors B and T provide the largest overall travel time benefits, in part because these two corridors are the longest. Corridor I provides the lowest overall travel time benefit due to a combination of shorter corridor and lower average ADT. In total, the twelve corridor improvements are estimated to generate an average annual travel time savings of \$1.0 billion.

Exhibit 4-4 also identifies the cumulative total time benefits from 1965 to 2024, and splits these time benefits to contrast those benefits accrued already (1965-1995) with those projected in the future (1996-2025). Overall only about 18 percent of travel time benefits have already occurred while 82 percent are yet to occur. The reasons for this disparity are: (1) few of these corridors actually opened in 1965 but several years later, (2) time savings are linked directly to the amount of traffic using the facilities, and since traffic is increasing in the corridors, time savings per year are also increasing.

Overall, one of the most quantifiable direct benefits to travellers is the time savings estimated to be attributable to the ADHS. Total annual time benefits of \$785.8 million in 1995 and \$2.4 billion by the year 2024 represent significant savings to the residents of and visitors to the Appalachian Region. As a proxy for accessibility, the time saved represents a considerable jump in travel efficiency.

Efficiency Gains

Exhibit 4-4. Value of Travel Time Savings (\$, Thousands)

<u>Corridor</u>	<u>A/A1</u>	<u>B</u>	<u>D</u>	<u>E</u>	<u>F</u>	<u>I</u>
<u>Annual Travel Time Benefits</u>						
Year 1995	\$30,436	\$184,198	\$82,973	\$78,232	\$22,601	\$18,921
Year 2024	66,817	556,498	150,983	177,254	53,203	34,399
Mean (1)	40,535	233,850	81,272	81,792	25,407	19,455
Median (2)	41,727	197,036	86,491	81,647	23,656	19,454

Total Undiscounted Benefits

1965-1995	\$233,573	\$2,403,187	\$1,124,873	\$908,066	\$333,716	\$328,045
1996-2024	<u>1,428,363</u>	<u>10,926,241</u>	<u>3,426,367</u>	<u>3,754,055</u>	<u>1,114,455</u>	<u>780,868</u>
Total	\$1,661,936	\$13,329,428	\$4,551,239	\$4,662,121	\$1,448,171	\$1,108,913

<u>Corridor</u>	<u>J</u>	<u>L</u>	<u>P</u>	<u>Q</u>	<u>T</u>	<u>Total</u>
<u>Annual Travel Time Benefits</u>						
Year 1995	\$58,319	\$41,980	\$34,648	\$83,848	\$149,656	\$785,812
Year 2024	362,347	149,740	129,835	203,444	579,769	2,464,289
Mean (1)	125,355	60,388	54,168	94,561	240,859	1,011,766
Median (2)	79,287	51,270	39,572	85,910	179,319	814,751

Total Undiscounted Benefits

1965-1995	\$642,865	\$427,108	\$600,802	\$1,259,018	\$2,455,499	\$10,716,750
1996-2024	<u>6,251,675</u>	<u>2,833,818</u>	<u>2,432,603</u>	<u>4,225,534</u>	<u>10,791,723</u>	<u>47,965,703</u>
Total	\$6,894,540	\$3,260,925	\$3,033,405	\$5,484,552	\$13,247,222	\$58,682,453

(1) Mean is the average value.

(2) Median is the value wherein half of the other values are above, and half below, the stated median value.

Vehicle Operating Cost (VOC) Savings

The costs of operating motor vehicles are a significant portion of the total cost of transportation. Vehicle operating costs include a number of components, some of which are variable costs (use-related), others of which are fixed costs (insurance and license fees which typically do not vary with use). Only use-related costs -- engine oil, gasoline, maintenance, and tires -- are directly affected by an improved highway. Vehicle operating costs, like travel time, vary with the characteristics of the trip being made including trip length, running speeds, and speed change cycles. Using the same data as for the travel time, vehicle operating costs with and without the ADHS were calculated.

In many cases, vehicle operating costs may increase after completion of a highway improvement; when this occurs it is usually because vehicles traveling at faster speeds are less efficient than vehicles traveling at slower speeds (it costs more to drive a car at 65 mph than it costs at 45 mph). Also, vehicle operating costs may increase if the new road is longer than the road it replaces. On the other hand, improvements completed on corridors with moderate to severe levels of congestion tend to improve vehicle operating costs as vehicles no longer experience a large number of speed change cycles. In addition, if improvements reduce the grades of a corridor, vehicle operating costs decrease, especially for trucks.

Seven (A/A1, D, E, F, L, P, and Q) of the twelve ADHS corridors are estimated to generate increased vehicle operating costs, while the remaining four corridors (B, I, J, and T) generate vehicle operating cost savings. **Exhibit 4-5** depicts both the annual and total vehicle operating cost savings for the twelve corridors under study.

Overall, improvements in the twelve corridors under study resulted in vehicle operating cost increases of \$11 million in 1995 due to the increases in speed. However, as traffic increases, VOC savings due to the relief of congestion increase and by 2024 exceeds speed related VOC increases so that VOC benefits are estimated at nearly \$72 million in 2024. Improvements in ADHS Corridor B result in the largest VOC benefits while corridor D generates the most VOC increases. The 9 percent reduction in corridor B length combined with high traffic explains the results for corridor B. The relatively low traffic on corridor D results in lower congestion reduction to counterbalance the increase in speed due to widening a 2-lane corridor to 4 lanes.

Efficiency Gains

Exhibit 4-5. Vehicle Operating Cost Savings (\$ Thousands) 1995

<u>Corridor</u>	<u>A/A1</u>	<u>B</u>	<u>D</u>	<u>E</u>	<u>F</u>	<u>I</u>
<u>Annual Cost Benefits</u>						
Year 1995	(\$7,564)	\$15,633	(\$11,298)	(\$979)	(\$1,169)	\$625
Year 2024	(11,449)	64,750	(16,690)	(10,492)	(2,105)	928
Mean (1)	(8,328)	23,756	(10,358)	(3,429)	(1,095)	595
Median (1)	(8,770)	17,326	(11,577)	(1,955)	(1,201)	635
<u>Total Undiscounted Benefits</u>						
1965-1995	(\$63,827)	\$163,999	(\$171,541)	(\$24,352)	(\$14,490)	\$11,247
1996-2024	<u>(277,630)</u>	<u>1,190,106</u>	<u>(408,525)</u>	<u>(171,098)</u>	<u>(47,948)</u>	<u>22,669</u>
Total	(\$341,456)	\$1,354,104	(\$580,066)	(\$195,450)	(\$62,437)	\$33,916

<u>Corridor</u>	<u>J</u>	<u>L</u>	<u>P</u>	<u>Q</u>	<u>T</u>	<u>Total</u>
<u>Annual Cost Benefits</u>						
Year 1995	\$926	(\$4,270)	(\$754)	(\$5,429)	\$3,101	(\$11,178)
Year 2024	23,281	(6,995)	(977)	(12,600)	43,892	71,541
Mean (1)	6,944	(4,135)	(4,135)	(5,976)	13,315	12,092
Median (1)	2,792	(4,505)	(904)	(5,552)	5,914	(1,143)
<u>Total Undiscounted Benefits</u>						
1965-1995	\$19,765	(\$58,602)	(\$26,380)	(\$81,622)	\$30,521	(\$215,282)
1996-2024	<u>362,176</u>	<u>(164,707)</u>	<u>(25,205)</u>	<u>(265,000)</u>	<u>701,785</u>	<u>916,623</u>
Total	\$381,940	(\$223,309)	(\$51,586)	(\$346,622)	\$732,306	\$701,340

Note: (1) Mean and Median calculated from earliest opening year of a corridor segment to year 2024.

Accident Savings

Improvements in highway safety comprise another reason for building highways with higher design standards. Multilane roadways are generally safer than 2-lane highways, so many ADHS improved roadways have reduced accident risks. Also, reducing curves and grades makes highways safer by improving visibility.

National average injury rates by accident type (fatal, injury, property damage only) and by highway facility type (Interstate versus collector for example) were used, as described in Chapter 2. They were adjusted to account for the 2-lane multilane differences and used to calculate accident savings in the various corridors under study. However, they do not account for the likely accident risk reduction due to straightening a highway when no lanes are added. Therefore, the accident savings estimates due to the ADHS are likely underestimated.

Accident risk is measured in accidents per 100 million vehicle miles. As a result, improved corridors which are longer than the ones they replace may increase accidents if the decrease in accident risk, due to better design, cannot overcome the increase in exposure, due to increased vehicle miles.

Exhibit 46 identifies the expected annual safety benefits by corridor for the years 1995 and 2024, as well as the mean and median annual benefits. Improvements in ADHS Corridor B result in the largest overall benefit due to the combination of such factors as the length of the corridor, proportionally large reduction in corridor length, and high traffic volumes. Five ADHS corridors – A/A1, E, J, P - produce negative accident cost savings. In these cases, the improved corridor is longer than the original corridor. Corridor A/A1 shows the largest accident disbenefits because in addition to increased corridor length, a larger proportion of this corridor was already multilane before the ADHS improvements (in such case there is no improvement in accident risk unless the improvements resulted in a change in roadway type).

Overall, the corridor improvements are estimated to generate annual accident cost savings of \$47 million in 1995, and \$80 million in 2024. These translate into cumulative savings of \$2.5 billion for the 1965-2024 time period (not discounted). As is the case with other benefits, the majority of these benefits, 76 percent, will occur in the future.

Efficiency Gains

Exhibit 4-6. Accident Cost Savings (\$, Thousands) 1995

<u>Corridor</u>	<u>A/A1</u>	<u>B</u>	<u>D</u>	<u>E</u>	<u>F</u>	<u>I</u>
<u>Annual Accident Benefits</u>						
Year 1995	(\$6,032)	\$22,564	\$9,753	(\$3,697)	\$2,923	\$1,217
Year 2024	(12,114)	43,035	15,300	(8,251)	5,337	1,727
Mean (1)	(7,742)	21,373	9,154	(3,891)	2,976	1,132
Median (1)	(7,920)	23,270	10,040	(3,854)	3,007	1,235
<u>Total Undiscounted Benefits</u>						
1965-1995	(\$45,218)	\$234,264	\$136,822	(\$42,573)	\$45,712	\$20,332
1996-2024	<u>(272,190)</u>	<u>983,984</u>	<u>375,796</u>	<u>(179,218)</u>	<u>123,907</u>	<u>44,166</u>
Total	(\$317,408)	\$1,218,247	\$512,618	(\$221,790)	\$169,619	\$64,498

<u>Corridor</u>	<u>J</u>	<u>L</u>	<u>P</u>	<u>Q</u>	<u>T</u>	<u>Total</u>
<u>Annual Accident Benefits</u>						
Year 1995	(\$1,256)	\$6,235	(\$743)	\$9,575	\$6,909	\$47,449
Year 2024	(12,648)	16,774	(1,558)	19,077	13,540	80,220
Mean (1)	(3,872)	7,240	(1,016)	9,770	7,501	43,553
Median (1)	(2042)	7,144	(982)	9,739	7,366	48,014
<u>Total Undiscounted Benefits</u>						
1965-1995	(\$4,403)	\$45,807	(\$22,376)	\$136,874	\$105,805	\$611,046
1996-2024	<u>(208,561)</u>	<u>345,138</u>	<u>(34,514)</u>	<u>429,786</u>	<u>306,740</u>	<u>1,915,035</u>
Total	(\$212,964)	\$390,945	(\$56,891)	\$566,660	\$412,545	\$2,526,080

Notes: (1) Mean and Median calculated from earliest opening year of a corridor segment to year 2024.

Efficiency Gains

Total Travel Efficiency *Benefits*

The total travel efficiency benefits include the compilation of the dollar value of travel time saved, reduced vehicle operating costs, and accident savings that accrue to those who drive on the improved corridors. **Exhibit 4-7** summarizes the estimated annual travel efficiency benefits for the years 1995 and 2024.

Exhibit 4-7. Annual Travel Efficiency Benefits (\$ Thousands)

<u>Corridor</u>	<u>Time</u>	<u>1995</u>			<u>Total</u>	<u>Time</u>	<u>2024</u>		
		<u>VOC</u>	<u>Accident</u>				<u>VOC</u>	<u>Accident</u>	<u>Total</u>
A/A1	\$30,436	-\$7,564	-\$6,032	\$16,840	\$66,817	-\$11,449	-\$12,114	43,255	
B	184,198	15,633	22,564	222,394	556,498	64,750	43,035	664,283	
D	82,973	-11,298	9,753	81,428	150,983	-16,690	15,300	149,593	
E	78,232	-979	-3,697	73,556	177,254	-10,492	-8,251	158,511	
F	22,601	-1,169	2,923	24,356	53,203	-2,105	5,337	56,434	
I	18,921	625	1,217	20,763	34,399	928	1,727	37,054	
J	58,319	926	-1,256	57,989	362,347	23,281	-12,648	372,980	
L	41,980	-4,270	6,235	43,946	149,740	-6,995	16,774	159,518	
P	34,648	-754	-743	33,152	129,835	-977	-1,558	127,300	
Q	83,848	-5,429	9,575	87,994	203,444	-12,600	19,077	209,922	
T	<u>149,656</u>	<u>3,101</u>	<u>6,909</u>	<u>159,666</u>	<u>579,769</u>	<u>43,892</u>	<u>13,540</u>	<u>637,201</u>	
All									
Corridors	\$785,812	-\$11,178	\$47,449	\$822,083	\$2,464,289	\$71,541	\$80,220	\$2,616,050	

Exhibit 4-8 summarizes the total present value of the efficiency gains, 1965-2024. From these two exhibits a number of conclusions are apparent regarding the ADHS and its ability to create economic efficiency.

Efficiency Gains

Exhibit 4-8 PRESENT VALUE OF TOTAL TRAVEL EFFICIENCY BENEFITS (\$Thousands)

<u>Corridor</u>	<u>Travel Time Savings</u>	<u>Vehicle Operating Cost Savings</u>	<u>Accident Savings</u>	<u>Total Efficiency Gains</u>
A/A1	\$105,069	(\$24,497)	(\$21,244)	\$59,328
B	1,049,252	83,937	102,100	1,235,290
D	430,767	(63,663)	54,341	421,445
E	387,641	(12,623)	(18,653)	356,366
F	131,034	(5,318)	18,125	143,841
I	130,097	4,440	8,353	142,891
J	386,875	17,518	(8,721)	395,672
L	222,867	(20,963)	28,459	230,363
P	261,422	(10,412)	(10,354)	240,656
Q	501,308	(31,755)	55,153	524,706
T	<u>1,072,564</u>	<u>31,299</u>	<u>40,120</u>	<u>1,143,984</u>
Total	\$4,678,898	(\$32,037)	\$247,680	\$4,894,541

ECONOMIC EFFICIENCY FINDINGS

1. Every ADHS corridor that has been completed to date has created economic efficiency benefits.
2. These benefits range from \$16.8 million annually in 1995 (Corridor A/A1) to \$664.3 million annually in 2024 (Corridor B).
3. Travel time savings comprise the largest single form of efficiency gain attributable to the ADHS.
4. The cost savings (vehicle operating costs) are generally not yet occurring, but are estimated to occur in the future on four corridors.
5. Accident savings occur on seven of the corridors, with total annual savings of \$47 million in 1995.
6. The total annual efficiency gains in 1995 for the twelve corridors are \$822 million annually, increasing to over \$2.6 billion annually by 2024. These are very significant efficiency gains.
7. The total present value of the efficiency gains for the twelve corridors combined are valued at \$4.89 billion. Clearly the ADHS is contributing to the efficiency of the Appalachian Region.

ECONOMIC EFFICIENCY BENEFIT/COST RESULTS

To gauge the extent to which the completed portions of the ADHS may have constituted a good investment from the efficiency perspective, the efficiency gains (cost savings) were compared with the costs (construction plus maintenance) in the form of a benefit/cost analysis.

An example (Corridor B) of the way in which the life cycle costs and benefits were handled 1965-2025, is shown on **Exhibit 4-9**. This exhibit depicts the flow of costs and benefits, by year. It shows, for example:

- **Construction Costs** – Incurred every year 1965-1995, at 1995 price levels.
- **Maintenance Costs** – The net increase in costs incurred by the state departments of transportation responsible for maintaining the roads.
- **Time Savings** – The increase in time savings, as traffic builds up on the highway. These are at constant 1995 values of time, and comprise the largest form of direct efficiency gain attributable to the ADHS.
- **VOC Savings** – Vehicle Operating Cost Savings which are true net savings in this corridor. These also increase over time, in real terms.
- **Accident Savings** – The monetary value of the lives saved and the accidents reduced, due to the Corridor B improvements.
- **Total** – The total “not discounted” benefits or costs over the analysis period.
- **Discounted Total** – The sum of the discounted costs and benefits 1965-2025. All are discounted at 7% per year. It is the discounted numbers that are used in the benefit/cost evaluation.

Exhibit 4-9 is an example (Corridor B). Similar tabulations for all corridors are contained in Appendix B.

Efficiency Gains

Exhibit 4-9. Travel Efficiencies Benefit Cost Analysis Corridor B - KY, NC, TN, VA Undiscounted 1995 \$1,000

Year	Construction Costs	Maintenance Costs	TOTAL COSTS	Time Savings	VOC Savings	Accidents Savings	TOTAL SAVINGS	NET BENEFITS
1965	5,984	0	5,984	0	0	0	0	(5,984)
1966	33,033	0	33,033	0	0	0	0	(33,033)
1967	63,167	0	63,167	0	0	0	0	(63,167)
1968	93,052	(110)	92,942	4,043	686	370	5,099	(87,844)
1969	125,380	(6)	125,373	4,416	693	412	5,521	(119,852)
1970	86,661	47	86,708	10,919	(484)	1,098	11,533	(75,175)
1971	133,986	450	134,436	17,563	605	488	18,656	(115,780)
1972	139,398	771	140,169	22,928	736	2,020	25,685	(114,484)
1973	141,786	1,212	142,998	26,351	864	2,862	30,078	(112,920)
1974	94,710	1,410	96,120	35,379	1,767	3,384	40,530	(55,590)
1975	75,728	1,591	77,319	42,094	2,005	3,410	47,509	(29,810)
1976	64,509	1,825	66,333	44,991	2,047	3,576	50,614	(15,719)
1977	64,854	2,021	66,874	49,149	1,343	3,712	54,203	(12,671)
1978	68,621	2,187	70,808	52,100	1,354	3,876	57,329	(13,479)
1979	63,946	2,267	66,214	56,664	1,783	4,770	63,216	(2,998)
1980	75,310	2,258	77,569	64,120	826	5,752	70,698	(6,871)
1981	45,543	2,396	47,939	68,334	1,153	6,546	76,032	28,093
1982	70,822	2,561	73,383	75,170	1,041	7,718	83,929	10,546
1983	149,357	2,858	152,215	92,826	5,645	8,320	106,791	(45,425)
1984	59,264	3,130	62,394	103,499	7,086	9,454	120,039	57,645
1985	26,260	3,422	29,681	111,711	7,271	10,702	129,684	100,002
1986	33,775	3,686	37,461	117,178	7,571	11,162	135,912	98,451
1987	34,177	3,831	38,008	129,782	10,855	14,931	155,568	117,560
1988	13,964	3,917	17,881	136,034	11,427	15,714	163,175	145,294
1989	20,890	3,956	24,846	142,286	11,999	16,498	170,783	145,937
1990	10,166	3,995	14,161	148,539	12,571	17,281	178,391	164,230
1991	9,803	3,995	13,798	154,791	13,143	18,064	185,998	172,200
1992	14,077	4,013	18,090	163,052	14,215	19,911	197,178	179,088
1993	3,677	4,031	7,708	169,375	14,793	20,715	204,882	197,174
1994	2,000	4,049	6,049	175,698	15,371	21,518	212,587	206,538
1995	1,351	4,126	5,477	184,198	15,633	22,564	222,394	216,918
1996	0	4,184	4,184	197,036	17,326	23,270	237,632	233,448
1997	0	4,242	4,242	209,874	19,020	23,976	252,869	248,627
1998	0	4,300	4,300	222,712	20,714	24,682	268,107	263,807
1999	0	4,300	4,300	235,550	22,407	25,388	283,344	279,044
2000	0	4,300	4,300	248,387	24,101	26,093	298,582	294,282
2001	0	4,300	4,300	261,225	25,795	26,799	313,820	309,519
2002	0	4,300	4,300	274,063	27,488	27,505	329,057	324,757
2003	0	4,300	4,300	286,901	29,182	28,211	344,295	339,995
2004	0	4,300	4,300	299,739	30,876	28,917	359,532	355,232
2005	0	4,300	4,300	312,577	32,570	29,623	374,770	370,470
2006	0	4,300	4,300	325,415	34,263	30,329	390,007	385,707
2007	0	4,300	4,300	338,253	35,957	31,035	405,245	400,945
2008	0	4,300	4,300	351,091	37,651	31,741	420,482	416,182
2009	0	4,300	4,300	363,929	39,344	32,447	435,720	431,420
2010	0	4,300	4,300	376,767	41,038	33,152	450,957	446,657
2011	0	4,300	4,300	389,605	42,732	33,858	466,195	461,895

Efficiency Gains

2012	0	4,300	4,300	402,443	44,426	34,564	481,433	477,132
2013	0	4,300	4,300	415,281	46,119	35,270	496,670	492,370
2014	0	4,300	4,300	428,119	47,813	35,976	511,908	507,608
2015	0	4,300	4,300	440,957	49,507	36,682	527,145	522,845
2016	0	4,300	4,300	453,795	51,200	37,388	542,383	538,083
2017	0	4,300	4,300	466,633	52,894	38,094	557,620	553,320
2018	0	4,300	4,300	479,470	54,588	38,800	572,858	568,558
2019	0	4,300	4,300	492,309	56,281	39,505	588,095	583,795
2020	0	4,300	4,300	505,146	57,975	40,211	603,333	599,033
2021	0	4,300	4,300	517,984	59,669	40,917	618,570	614,270
2022	0	4,300	4,300	530,822	61,363	41,623	633,808	629,508
2023	0	4,300	4,300	543,660	63,056	42,329	649,046	644,746
2024	0	4,300	4,300	556,498	64,750	43,035	664,283	659,983
2025	(456,568)	0	(456,568)	0	0	0	0	456,568
Total	1,368,683	194,415	1,563,098	13,329,428	1,354,104	1,218,247	15,901,780	14,338,682
Discounted								
Total	879,537	23,972	903,569	1,049,252	83,937	102,100	1,235,290	331,721

Net Present Value(\$1000)	331721
IRR (%) :	8.66
Benefits/Costs Ratio :	1.37

The results of the benefit/cost analysis for all corridors are shown on **Exhibit 4-10**. The key indicators are the NPV (Net Present Value), IRR (Internal Rate of Return), and B/C (discounted Benefit/Cost Ratio). These should be interpreted as follows:

- An efficient project has a positive Net Present Value (NPV), an Internal Rate of Return (IRR) equal to or greater than the discount rate (7 percent), and a Discounted Benefit/Cost Ratio (B/C) of 1.0 or higher.
- The higher the NPV, IRR and B/C the more efficient the project.

The benefit/cost analyses suggest a number of conclusions regarding the completed portions of the ADHS and their role in aiding the efficiency and productivity of the Appalachian Region. These conclusions include the following:

1. The corridors combined have a constant dollar (exclusive of inflation) annual rate of return of 7.87%. This is really quite good, and is indicative of a good investment.
2. In efficiency terms, the economy is better off by some \$755 million (the NPV), as a result of the ADHS.
3. A combined benefit/cost ratio of 1.18 is good, given that the “economic development” implications of the ADHS are not included in this calculation.
4. Five of the corridors have positive economic efficiency results. This is excellent, given that the real purpose of these highways was economic and social development, rather than efficiency.

Efficiency Gains

5. Even the corridor ranking last in terms of return on investment (Corridor E) has a constant dollar return of 5.44% which is pretty good (if inflation were 5% and were included, the return would be 10.44%).
6. The total 1995 price level present value cost of these ADHS corridors is \$4.1 billion; the total efficiency benefits are \$4.9 billion. This is indicative of a prudent investment in Appalachia's future.

Exhibit 4-10. Travel Efficiencies Benefit Cost Benefits

<u>Corridor</u>	Present Value ⁽¹⁾		Net Present	IRR ⁽²⁾	Benefit/Cost Ratio
	Total Costs (3) <u>(1995 \$1,000)</u>	Total Benefits <u>(1995 \$1,000)</u>	Value ⁽¹⁾ <u>(1995 \$1,000)</u>		
A/A1	\$59,437	\$59,328	-\$109	6.99%	1.00
B	903,569	1,235,290	331,721	8.66	1.37
D	537,746	421,445	-116,301	5.83	0.78
E	482,524	356,366	-126,158	5.44	0.74
F	194,003	143,841	-50,162	5.50	0.74
I	164,191	142,891	-21,300	6.20	0.87
J	263,380	395,672	132,292	8.84	1.50
L	270,059	230,363	-39,696	6.34	0.85
P	257,930	240,656	-17,274	6.64	0.93
Q	328,163	524,706	196,543	9.82	1.60
T	<u>677,797</u>	<u>1,143,984</u>	<u>466,187</u>	<u>10.06</u>	<u>1.69</u>
All Corridors	\$4,138,798	\$4,894,541	\$755,743	7.87%	1.18

(1) Present values in 1965 calculated using 7% discount rate.

(2) IRR: Internal Rate of Return.

Efficiency Gains

(3) Total Costs include construction costs, residual values and maintenance costs.

NOTE: An "economically justified" investment, when using these benefit/cost results, exists when:

- * The Net Present Value is positive
- * The Internal Rate of Return is 7% or greater
- * The Benefit/Cost Ratio is 1.0 or greater

Sensitivity Tests

This study's calculations suggest that the ADHS sections that have been completed overall comprise a good, economically based investment. Based on travel efficiency alone, the ADHS investments yielded \$1.18 for each \$1.00 invested (a 7.87% return on the ADHS investment).

While every attempt was made in this study to be realistic and even conservative, the calculations are in part based on assumptions, any of which could be open to question. Therefore, to depict the possible effect of these assumptions on study conclusions, five sensitivity tests were conducted. The sensitivity of study conclusions to variations in discount rate, travel time savings, and accident calculations were all analyzed.

Discount Rate – Exhibit 4-11 compares study results at 4%, 7%, and 10% discount rate. At 7% (the constant dollar discount rate called for by OMB), the highways are economically justified. At 4%, the highways are even more justified (benefit/cost of 2.35). At 10% the benefit/cost is .7. A 10% real discount rate is unusually high, however, and perhaps unrealistic. Study results are therefore shown to be sensitive to the discount rate selected. However, since the study used the 7% discount rate required by the Office of Management and Budget, study conclusions based on the discount rate appear to be appropriate.

Efficiency Gains

Exhibit 4-11. Travel Efficiencies Benefit Cost Sensitive Results Variation in Discount Rates

<u>Corridor</u>	<u>Net Present Value</u> ⁽¹⁾				<u>Benefit/Cost Ratio</u>		
	<u>4%</u>	<u>7%</u>	<u>10%</u>	<u>IRR</u> ⁽²⁾	<u>4%</u>	<u>7%</u>	<u>10%</u>
A/A1	\$99,627	-\$109	-\$22,748	6.99%	2.20	1.00	0.49
B	2,059,397	331,721	-138,489	8.66	2.73	1.37	0.80
D	357,141	-116,301	-239,154	5.83	1.54	0.78	0.46
E	242,279	-126,158	-199,585	5.44	1.36	0.74	0.46
F	101,912	-50,162	-84,110	5.50	1.41	0.74	0.45
I	111,929	-21,300	-60,424	6.20	1.57	0.87	0.57
J	845,811	132,292	39,200	8.84	3.23	1.50	0.79
L	305,749	-39,696	-117,847	6.34	1.90	0.85	0.46
P	270,435	-17,274	-84,620	6.64	1.79	0.93	0.57
Q	862,674	196,543	-6,670	9.82	3.09	1.60	0.97
T	<u>2,034,674</u>	<u>466,187</u>	<u>4,995</u>	<u>10.06</u>	<u>3.30</u>	<u>1.69</u>	<u>1.01</u>
All Corridors	\$7,353,361	\$772,829	-\$979,143	7.88%	2.35	1.18	0.70

(1) Thousands of 1995 dollars discounted at 7 percent.

(2) IRR: Internal Rate of Return.

Variations in Value of Travel Time – Although both the values of time and the methods of calculating the amount of time saved are based on conventional techniques, other values and techniques could have been used. To test study conclusions sensitivity to travel time, benefit/cost calculations were run using a 20% reduction and then a 20% increase in travel time benefits. The results are presented on **Exhibit 4-12**.

Efficiency Gains

At the time values used in the study, the ADHS is economically justified. If the time savings or values were 20% greater, the benefit/cost would increase from 1.18 to 1.41. If values of 20% less were used, the benefit/cost would be 0.96. In other words, time values of 20-50% less would be needed in order for the ADHS to have questionable travel efficiency value. This is unlikely.

Exhibit 4-12. Travel Efficiencies Benefit Cost Sensitivity Results

Variation in Time Savings

Corridor	Net Present Value ⁽¹⁾			IRR ⁽²⁾			Benefit/Cost Ratio ⁽³⁾			
	-20%	Base	20%	-20%	Base	20%	-20%	Base	20%	
	A/A1	-\$21,123	-\$109	\$20,905	5.33%	6.99%	8.24%	0.64	1.00	1.35
B	121,871	331,721	541,572	7.64	8.66	9.61	1.13	1.37	1.60	
D	-202,455	-116,301	-30,148	4.83	5.83	6.71	0.62	0.78	0.94	
E	-203,687	-126,158	-48,630	4.29	5.44	6.43	0.58	0.74	0.90	
F	-76,369	-50,162	-23,955	4.59	5.50	6.32	0.61	0.74	0.88	
I	-47,319	-21,300	4,720	5.15	6.20	7.17	0.71	0.87	1.03	
J	54,917	132,292	209,667	7.83	8.84	9.73	1.21	1.50	1.80	
L	-84,269	-36,696	4,878	5.51	6.34	7.08	0.69	0.85	1.02	
P	-69,558	-17,274	35,010	5.47	6.64	7.71	0.73	0.93	1.14	
Q	96,282	196,543	296,805	8.46	9.82	11.09	1.29	1.60	1.90	
T	<u>249,509</u>	<u>466,187</u>	<u>674,550</u>	<u>8.74</u>	<u>10.06</u>	<u>11.29</u>	<u>1.37</u>	<u>1.69</u>	<u>2.01</u>	
All Corridors (\$160,957)	\$755,743	\$1,706,616	6.80%	7.88%	8.86%	0.96	1.18	1.41		

(1) Thousands of 1995 dollars discounted at 7 percent.

(2) IRR: Internal Rate of Return.

(3) Discounted at 7 percent.

Sensitivity to Accidents – The final sensitivity test questioned results in four corridors where the number of accidents were estimated to increase due to the ADHS. In **Exhibit 4-13** no

Efficiency Gains

accident increases were included in the analysis. As shown, study results are not sensitive to this accidents issue.

Exhibit 4-13. Travel Efficiencies Benefit Cost Sensitivity Results

Excluding and Including Negative Accident Values

Corridor	Net Present Value ⁽¹⁾		IRR ⁽²⁾		Benefit/Cost Ratio ⁽³⁾	
	Including Negative Accident Values	Excluding Negative Accident Values	Including Negative Accident Values	Excluding Negative Accident Values	Including Negative Accident Values	Excluding Negative Accident Values
A/A1	-\$109	\$21,135	6.99%	8.27%	1.00	1.36
B	331,721	331,721	8.66	8.66	1.37	1.37
D	-116,301	-116,301	5.83	5.83	0.78	0.78
E	-126,158	-107,506	5.44	5.69	0.74	0.78
F	-50,162	-50,162	5.50	5.50	0.74	0.74
I	-21,300	21,300	6.20	6.20	0.87	0.87
J	132,292	141,690	8.84	8.95	1.50	1.54
L	-39,696	-39,696	6.34	6.34	0.85	0.85
P	-17,274	-6,920	6.64	6.85	0.93	0.97
Q	196,543	196,543	9.82	9.82	1.60	1.60
T	462,030	463,529	10.06	10.08	1.69	1.69

(1) Thousands of 1995 dollars discounted at 7 percent.

(2) IRR: Internal Rate of Return.

(3) Discount at 7 percent.

Economic Development Impacts by Year

2018	45510	85413	1375.15	2210.9
2019	46564	87956	1449.35	2284.11
2020	47579	90428	1525.75	2356.28
2021	48608	92859	1606.87	2429.9
2022	49690	95295	1694.54	2508.26
2023	50779	97727	1787.58	2587.95
2024	51855	100150	1884.72	2667.89