Chapter 6
METHODOLOGY—
COMPARISONS OF BENEFITS AND COSTS

Chapter 3 describes the rationale for going beyond purely commercial considerations to compare the range of benefits and costs attributable to HSGT systems. The present chapter describes the methodologies on which the benefit/cost comparisons are based.

TYPES OF BENEFIT/COST COMPARISONS

The analysis provides for three approaches to comparing benefits and costs:

(1) Total benefits versus total costs

(2) Benefits to HSGT users versus costs borne by users

(3) Benefits to the public at large versus publicly-borne costs

Regardless of the approach employed, the comparison of benefits with costs takes two basic forms: a subtraction (benefits less costs) and a ratio (benefits divided by costs).

The latter two approaches make use of subsets of "total benefits" and "total costs." Tables 6-1 through 6-3 present the constituents of each of these three approaches.

Table 6-1

Total Benefits Versus Total Costs

Types of Benefits and Costs	***Related Analytical Components***
Total Benefits:	
Benefits to HSGT Users:	
Benefits for Which HSGT Users Pay Directly	**Equates to System Revenues (See Chapter 5)**
Benefits for Which HSGT Users Do Not Pay Directly	**Equates to Users' Consumer Surplus (Described in This Chapter)**
Benefits to the Public at Large:	
Airport Congestion Delay Savings	**Described in This Chapter**
Highway Congestion Delay Savings	**Described in This Chapter**
Emissions Savings	**Described in This Chapter**
Total Costs:	
Initial Investment	**See Chapter 5**
Operating and Maintenance Expense	**See Chapter 5**
Continuing Investments	**See Chapter 5**

Chapter 3 explains how the comparison of total benefits with total costs (Table 6-1) enters into the "partnership potential" determination as formulated for this report. However, further benefit/cost comparisons may be of interest to the public and its responsible officials. Specifically, a comparison of the benefits to HSGT users with the costs borne by those users (Table 6-2) reveals the relative importance of the users' consumer surplus, for which—by definition—they pay nothing directly.[1]

Table 6-2

Benefits to HSGT Users Versus Costs Borne by Users	
Types of Benefits and Costs	***Related Analytical Components***
Benefits to HSGT Users:	
Benefits for Which HSGT Users Pay Directly	**Equates to System Revenues (See Chapter 5)**
Benefits for Which HSGT Users Do Not Pay Directly	**Equates to Users' Consumer Surplus (Described in This Chapter)**
Costs Borne by Users	**Equates to System Revenues (See Chapter 5)**

By the same token, a comparison of benefits to the public at large with publicly-borne costs (Table 6-3) provides additional insights on the value of the public investment.

Table 6-3

Benefits to the Public at Large Versus Publicly-Borne Costs	
Types of Benefits and Costs	***Related Analytical Components***
Benefits to the Public at Large:	
Airport Congestion Delay Savings	**Described in This Chapter**
Highway Congestion Delay Savings	**Described in This Chapter**
Emissions Savings	**Described in This Chapter**
Publicly-Borne Costs	**Equates to Total Costs Less Costs Borne by Users (i.e., in practical terms, Total Costs Less System Revenues)(See Chapter 5)**

In most (but not all) illustrative cases, as detailed in Chapter 7, the comparison of benefits to the public at large with publicly-borne costs tends to portray HSGT less favorably than does the comparison of total benefits with total costs. This pattern essentially reflects the absence of

[1] In this comparison, HSGT users are treated as users only, and not as taxpayers. That is, the indirect payments that users may make (in absorbing, via taxes, a portion of the public investment in HSGT) do not figure in the equation.

the users' consumer surplus from the benefits to the public at large, and its inclusion in total benefits. In economic terms, to the extent that the publicly-borne costs exceed the benefits to the public at large in a given case, the consumer surplus may be regarded as a subsidy enjoyed by the users.

"TOTAL BENEFITS" AND "OTHER IMPACTS"

The short-list of "total benefits" in Table 6-1 resulted from a process of elimination, in which potentially includable benefits of HSGT had to satisfy all the following characteristics. Items lacking one or more of these characteristics fell under the rubric of "other impacts" and did not influence the quantitative results of the study.

Immediately quantifiable in practical terms: Within the scope of a nationwide study, data had to be available at a sufficient level of detail, and a straightforward methodology with broadly acceptable assumptions had to be developed, to make the item susceptible to estimation **for this report**. For example, many environmental/energy items (as well as benefits from improvements to commuter service) would theoretically lend themselves to quantification, but only in light of exhaustive, site-specific data gathered at the State and local level.

Monetizable: The item had to lend itself to expression in dollar terms, also in a straightforward manner.

Not duplicative: The item could not duplicate any other element of total benefits. To allow such duplication would result in a double counting of benefits, thereby skewing the results of the study. For example, total benefits could not legitimately include **both** reductions in congestion-driven airport delay costs to airlines and travelers **and** the value of deferred airport expansions, since these are two ways of measuring the same effect.[2]

Not a transfer effect: The item could not represent a reallocation of infrastructure investments and economic benefits from one geographic area or type of project to another. While such transfers might be of interest to the recipients at the State or local level, they cannot legitimately enter into total benefits from a national perspective. Typical transfers would include the economic multiplier effects of HSGT construction, operations, and station area development.

These criteria pertain specifically to a nationwide study at the Federal level. States may develop a different calculus of benefits because they will have access to much more detailed, corridor-specific information, because their priorities will reflect regional concerns, and because they may enjoy their own local financing sources.

Table 6-4 presents the results of this process of elimination. The following sections present the methodologies for estimating the analytical components of total benefits that Chapter

[2] The same was true of highway delay cost reductions and deferred highway expansions.

Table 6-4
Development of Components of Total Benefits

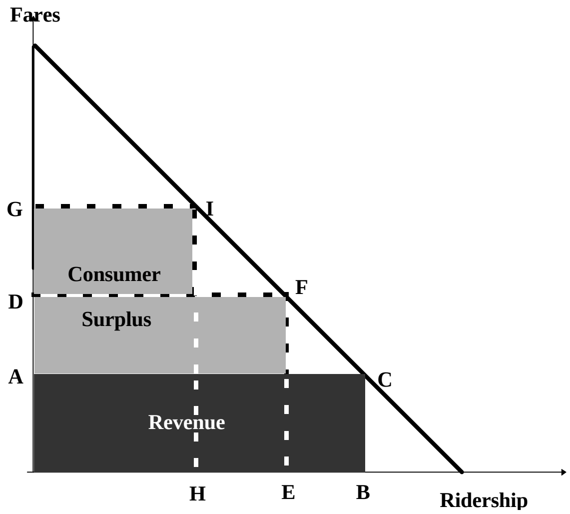
Components	**Criteria for Inclusion in Total Benefits (● means criterion was met. All criteria had to be met for inclusion in Total Benefits.)**			
	Quantifiable	**Monetizable**[3]	**Not duplicative**	**Not a transfer**
Total Benefits				
System Revenues	●	●	●	●
Users' Consumer Surplus	●	●	●	●
Benefits to the Public at Large:				
Airport congestion delay savings	●	●	●	●
Highway congestion delay savings	●	●	●	●
Emissions savings	●	●	●	●
Other Impacts				
Transportation Items:				
Airport investment deferrals	●	●		●
Highway investment deferrals	●	●		●
Commuter rail travel efficiency benefits			●	●
Transportation safety improvements			●	●
Economic Development Items:				
HSGT construction effects	●	●	●	
HSGT operations effects	●	●	●	
Station development effects	●	●	●	
Growth of American HSGT supply industry			●	●
Environmental/Energy Items:				
Noise			●	●
Water quality			●	●
Land consumption			●	●
Community disruption			●	●
Endangered species habitat			●	●
Wetlands			●	●
Energy savings	●	●		●

[3] If an item was not quantifiable, this table regards it as not monetizable.

5 does not treat: the users' consumer surplus and the benefits to the public at large. Finally, the chapter provides background information on "other impacts" that might be ascribed to HSGT.

USERS' CONSUMER SURPLUS

Figure 6-1
Users' Consumer Surplus Concept



HSGT fares in this study are set to maximize net revenue in competition with other modes,[4] not to exact from travelers the full value of each trip to them.[5] The **users' consumer surplus,** then, is the difference between the amount an individual would be willing to pay for HSGT service and the amount demanded of her or him by the HSGT entity. For example, a traveler might be willing to pay $25 for using HSGT to go from City A to City B, but the HSGT operator charges only $20 because that fare yields the maximum net revenue. The $5 difference is what economists traditionally call "consumer surplus."[6,7]

For this study, the users' consumer surplus estimation procedure adopted the steps demonstrated in Figure 6-1. Because the travel demand model is highly sensitive to fare levels (note downward slope of the diagonal line relating fares to ridership), increasing the fare from the base fare "A" to "D" and rerunning the model results in lower ridership ("E"). The lower number of projected HSGT users represents the number of people who would be willing to pay the extra fare for the HSGT benefits, and the added fare times the number of travelers willing to pay it represents the first increment of users' consumer surplus with respect to fare level "A." Increasing the fare again to "G" will result in

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[4] See Chapter 4 for this fundamental assumption.

[5] Exacting the full value at the farebox is, indeed, the purpose of yield management as practiced by Amtrak and the airlines today. However, state-of-the-art demand projection techniques cannot yet deal with the multiplicity of ever-changing fares characteristic of yield management. To the extent that an HSGT entity would be able to manipulate its fares to exact the full value of travel from each passenger, revenues and operating surpluses would increase and consumer surpluses would decrease from the levels projected herein.

[6] In economic terms, to the extent that the publicly-borne costs exceed the benefits to the public at large in a given case, the consumer surplus may be regarded as a subsidy enjoyed by the users.

[7] See Robley Winfrey, *Economic Analysis for Highways*, 1969, and American Association of State Highway and Transportation Officials, *A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements*, 1977. OMB Circular A-94 also addresses consumer surplus in the context of cost/benefit analysis.

even lower ridership (“H”). The new ridership times the fare increase from level “D” represents the next increment in users’ consumer surplus. At some maximum point, the fare level is sufficiently high to discourage almost all riders and no additional increment of users’ consumer surplus can be found. For purposes of this study, a maximum of three times the base HSGT fare (“G” in the schematic) is used as the upper limit. By running the ridership model and increasing fares from the base level “A” to the upper limit, then summing up the increments in users’ consumer surplus at each fare level, the users’ consumer surplus can be calculated for each corridor and technology option.

BENEFITS TO THE PUBLIC AT LARGE

For purposes of this analysis, benefits to the public at large consist of three items—savings from congestion delay at airports and on highways, and emissions savings.

Airport Congestion Delay Savings

As explained in Chapter 2, congestion and delays experienced by aircraft and passengers alike are reaching high levels, especially in California, the Chicago region, and the Northeast Corridor. By diverting passengers from the air mode, HSGT would help to reduce the rate of growth in airport congestion. Such savings would yield two sets of benefits:

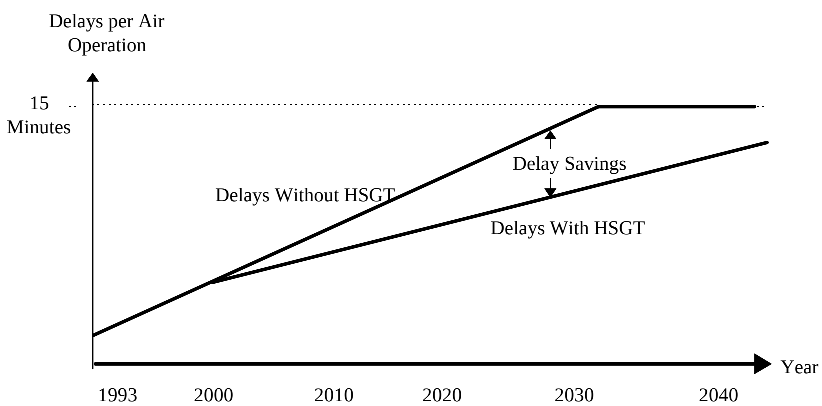
(1) **The change in operating costs, or the incremental savings, to remaining aircraft** when total takeoffs and landings are reduced and airport congestion delay decreased. Various capacity studies at highly congested airports have found significant savings are possible by reducing the hours of delay caused by the capacity-straining growth in operations (takeoffs and landings). For example, the *Los Angeles International Airport Capacity Enhancement Plan,* September 1991, concluded that, in the year 2000, when total annual operations are projected to exceed 711,000, the delay at Los Angeles International due to each additional operation (plane landing or taking off) would be 1.51 hours and add $3,360 to the operating costs of affected carriers.

(2) **The value to remaining air passengers of the travel time saved.** In addition to increasing airlines' operating costs, congestion-related delays increase the overall travel time of passengers. These delays may consist of deviations from scheduled flight departure and arrival times and added time on the taxiway or en route. Most available information pertains to wait time delays at an originating or terminating airport.

Since each airport serves a multiplicity of city-pair markets, most of which will not have HSGT service, the importance of HSGT’s effects on delay would vary with the relative prominence of HSGT markets in the airport's traffic base, and the airport's ambient traffic, capacity, and delay conditions.

Figure 6-2 illustrates the conceptual basis for developing the airport congestion delay savings. For each major airport in a corridor, the study projected traffic growth, assumed a modicum of capacity additions, and developed average delay estimates per aircraft operation, all in the **absence** of HSGT.[8] Average delays were capped at 15 minutes per operation because such crisis-level delays would likely be viewed as intolerable.

Figure 6-2: Concept for Airport Congestion Delay Savings



In the Year 2000, HSGT would begin to divert air traffic and palliate the rate of growth in average airport delays. The "delay savings" pictured in Figure 6-2 would be the difference between the delays without and with HSGT. Thus, over the planning period, the airport congestion delay savings represent the sum of—

- The projected reduction of aircraft-hours of delay, multiplied by the average cost to the airlines of each delay-hour; and
- The projected reduction in passenger-hours of delay for the remaining air travelers, multiplied by the average value of air passenger wait times ($39.03/hour) included in the ridership model for this study. [9]

Highway Congestion Delay Savings

Conceptually similar to airport delay savings, the value of reduced congestion and delay on highways from diversion of auto travelers to HSGT would constitute a potential benefit of HSGT. The benefit was estimated in terms of the value to remaining highway users of travel time

[8] These were the same general assumptions as affected the demand estimates; see Chapter 4.
[9] Charles River Associates, *Market Share Models for Forecasting Ridership on New High-Speed Intercity Transportation*, 1994.

saved when traffic volumes on major highways in HSGT city-pair markets decrease (or grow at a reduced rate) and travel speeds improve. As in the case of airports, the importance of HSGT's effects on highway delay would vary with the relative prominence of intercity travel in the road's traffic mix; the share of HSGT markets in that intercity travel; and the highway's ambient traffic, capacity, and delay conditions.

Traffic removed from highways was based upon ridership model forecasts of diverted auto passengers, converted to vehicles using a vehicle occupancy of 1.2. Highway conditions and the effects of HSGT trip diversion were approximated by extrapolating from the traffic impacts at selected corridor locations including:

- Each major metropolitan area HSGT terminus,
- Each intermediate major metropolitan area, and
- One intermediate rural/low density area between major metropolitan areas.

The decrease in traffic was assumed to have a measurable effect on auto travel speeds only when facilities are significantly congested (i.e., operating at less than free flow speeds). For rural areas, a level of service of "C" or worse, and in urban areas, a roadway congestion index of 1.0 or higher, were established as thresholds for significant congestion .[10] Using relationships of the volume-to-capacity for a roadway and associated travel speeds, the decrease in traffic due to HSGT diversions was converted into a change in highway speeds. The change in speed was converted to travel time savings for remaining auto users, whose in-vehicle travel time was valued at $10.88 per hour.[11,12]

Emissions Savings

The diversion of travelers from auto and air transportation modes to HSGT will create the potential for emissions savings. Regarding emissions, the differences among modes relate to the nature of their respective fuel sources and to the specific power (i.e., per seat-mile and, by extension, per passenger-mile) necessary to overcome inertia and to counteract three classes of force:

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[10] *Highway Capacity Manual*, Special Report 209, Transportation Research Board, 1985 (revised), and *Trends in Urban Roadway Congestion - 1982 to 1991*, Volume 1: Annual Report, Texas Transportation Institute, 1994.

[11] This value of time is derived from studies undertaken by the Texas Transportation Institute for the National Cooperative Highway Research Program, Transportation Research Board, and National Research Council. *Benefit-Cost Evaluation of Highway Improvements, MicroBENCOST Program*, Version 1.0, Texas Transportation Institute, 1993.

[12] Just as this methodology projects congestion reduction benefits for HSGT in the realm of intercity transportation, so has the Federal Transit Administration (FTA) found that metropolitan public transit reduces annual losses from traffic congestion by about $15 billion annually. (FTA, *National Transit Report—1996,* p. 4.) Recent research for FTA by the firm of Hickling-Lewis-Brod indicates that transit markedly improves the point-to-point speed of travel for both transit riders and highway users in severely congested urban travel corridors.

- Air resistance (all modes);
- Gravity (air and Maglev); and
- Contact/rolling resistance (wheeled modes).

A method was developed to calculate emissions savings based on changes in energy use with and without HSGT. The method accounted for the region of the country, the status of compliance with air quality regulations of counties through which each route passes, and the projection year. Access and egress modes were considered in addition to the line-haul portions of trips. Emission factors from the EPA and manufacturers were compiled for representative air, rail, and auto vehicles over the study period from 2000 to 2040. Based on assumptions about intercity trip characteristics and ridership forecasts, emissions were projected with and without HSGT options in place; the savings ascribed to HSGT represent the difference between the emissions levels "with" and "without" the HSGT mode.

The valuation of emissions savings recognized the attainment status of the impacted counties for all emissions except carbon dioxide (CO_2) and sulfur oxides (SO_x). CO_2 was valued at $15 per ton based on CO_2's impact on the global green-house effect, while SO_x was valued at $600 per ton based on estimates for the value of emission allowances traded on the commodities market. For other emissions, the value reflected control costs in non-attainment counties, with no value assigned for emissions within attainment counties. As a result, the values associated with emissions savings ranged from zero in attainment areas to a peak in Los Angeles of $18,900 per ton of reactive organic gases (ROG), $9,300 per ton of carbon monoxide (CO), $26,400 per ton of nitrous oxides (NO_x), and $5,700 per ton of particulate matter (PM_{10}).[13,14]

OTHER IMPACTS: BACKGROUND INFORMATION

This section provides information on the items that did not qualify, in this study, for inclusion in total benefits.

Transportation Items

The following impacts directly affect transportation system efficiency, costs, and safety.

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[13] Argonne National Laboratory, *Methods of Valuing Air Pollution and Estimated Monetary Values of Air Pollutants in Various U.S. Regions*, U.S. Department of Energy, 1994.

[14] Close linkage of HSGT with existing public transit systems in dense urban areas might enhance the emissions benefits cited in this section. FTA has found that existing levels of transit use annually avoid about 125 million pounds of hydrocarbons and over 150 million pounds of nitrous oxides that would otherwise be emitted by automobiles. (FTA, loc. cit.)

Airport Investment Deferrals

Many commercial airports in proposed HSGT corridors face pressures to expand significantly to accommodate future travel demand.[15] HSGT could divert some traffic from air, thereby mitigating the need for capacity-related improvements at increasingly congested commercial airports. This study could not include these reduced or deferred capital expenditures in total benefits, since they measure the same phenomena as the airport congestion delay savings.

Highway Infrastructure Savings

The diversion of automobile traffic to HSGT would mitigate or defer the need for highway expansion, measured in terms of lane-miles that would otherwise be dedicated to carrying the diverted trips. The costs saved or deferred by not having to expand roadways could not be included in total benefits, since they measure the same phenomenon as the highway congestion delay savings.

Commuter Rail Travel Efficiency Benefits

By enhancing the railroad passenger infrastructure in major metropolitan areas, HSGT could theoretically lead to faster commuter schedules, with time savings for existing riders. The better timings would also attract new riders, thus favorably impacting highway congestion.

In the course of developing the capital program for the HSGT cases, this study calculated the potential trip time savings on appropriate commuter routes. To quantify and monetize the likely future benefits, however, would require detailed site-specific studies because—

- Commuter trains, with their frequent stops, cannot always take full advantage of improved line-haul speeds[16]; and
- While producing secondary benefits in terms of highway congestion relief, the additional commuter patronage could entail significant capital costs and increased operating deficits.

Transportation Safety Improvements

To the extent that HSGT options in the United States actually establish sustained safety records better than those of existing modes, [17] trip diversions to HSGT might ultimately reduce

[15] Cf. Figure 2-3.

[16] Between Baltimore and Washington, for example, the schedules for multi-stop commuter trains in 1995 were not much better than before the Northeast Corridor Improvement Project, although express schedules had shortened. In such cases the benefits will depend on how many people use what types of trains—a fitting subject for intensive local study.

[17] The Federal Railroad Administration's Next Generation High-Speed Rail Program and related research and development efforts aim toward making the HSGT options at least as safe as their European counterparts.

the number of accidents and their attendant fatalities, injuries, property damage, and costs in both human and monetary terms. Because significant methodological and data issues[18] stand in the way of a straightforward, broadly acceptable projection of the safety benefits of HSGT, this study did not include, in total benefits, savings from that source.

Economic Development Items

Since economic development impacts would ordinarily represent transfer effects (as explained on page 6-3), they do not enter into "total benefits" in this report. However, the following impacts could be of some interest at the State and local level:

Multiplier Effects—HSGT Construction and Operations

For one industry to function, its production process requires, as inputs, the goods or services produced (output) by other industries. In addition, wages circulate in the economy as part of household purchases. In this manner, each dollar of spending for transportation stimulates additional spending, affecting other industries in the economy; this is known as a "multiplier" effect. Therefore, expenditures to build and maintain infrastructure and operate transportation services, such as HSGT, could influence a local or regional economy.

Station Development Effects

Development investment, including office, retail, hotel, and some housing, may gravitate to the vicinity of HSGT stations from less attractive locations in the corridor because of HSGT-induced changes in spatial/temporal relationships, as well as the market potential represented by HSGT riders.

Growth of an American HSGT Supply Industry

Most rail passenger car manufacturers are now located outside the United States, although there are local suppliers and assembly facilities to comply with the normal requirement of 50 percent United States content for Federally-funded acquisitions. To the extent that HSGT ultimately expands in the United States to become a consistent and predictable market for transportation equipment, the private sector may be willing to consider long-term investments that would increase the American involvement in HSGT vehicle design and manufacture.

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[18] Such a method would be based on projected passenger diversions among modes. Examples of the issues include: whether to address nonpassenger as well as passenger fatalities; whether to include access/egress fatalities as well as line-haul fatalities; how to treat Maglev, for which no revenue safety experience exists; and what base to use for HSGT fatality rates, since Amtrak's existing annual results— skewed by relatively low passenger-miles in the denominator and marked year-to-year variations in fatalities in the numerator—do not represent the expected performance of the HSGT options, while the safety rates for the various high-speed services overseas may not necessarily apply equally to all American HSGT technologies.

Environmental/Energy Items

Environmental

With the prominent exception of emissions savings (discussed on page 6-8), the proper estimation of most environmental costs and benefits of HSGT options requires detailed, site-specific data and community participation that can only issue from a State-sponsored or regional corridor study. These environmental factors include but are not limited to:

Noise. Noise effects relate directly to the percentages of highway and air passengers diverted to rail, the percentage increase in rail volumes, and the relative exposure of residences to the relevant highways, airports, and railroads.

Water quality. Passenger diversions from highway and air to rail affect both the volumes of polluting traffic and the likely expansion of impervious surfaces for highway and airports. Because railroad ballast filters runoff very well, and because railroads make minimal use of impervious surface, rail passenger facility and service expansions have insignificant direct effects on water quality in comparison with the other transportation modes.

Land consumption. Because land consumption is directly determined by the expansion of transportation facilities, the factors to be considered include percentages of highway and air passengers diverted to rail, the relative degree of congestion on other modes' facilities, and the planned increase in rail right-of-way.[19]

Community disruption. Factors affecting the analysis of community disruption effects include the change in train frequency, the degree of grade separation of rail and highway traffic planned for each technology, the number and location (urban/rural) of grade crossings before improvement, and the total change in delay at grade crossings, including that delay avoided by elimination of grade crossings.

Endangered species habitat; wetlands. These two environmental areas are very similar in treatment; the related impacts are determined by land consumption, incidence and quality of habitat and wetlands, and type of expanding mode.

Energy

Energy savings may result from the diversion of travelers from auto and air transportation modes (propelled by on-board fossil fuels) to HSGT (propelled either by on-board fossil fuels or by a mix of energy sources).

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[19] Close integration of HSGT stations with existing transit systems, particularly in the urban core, could enhance HSGT's potential public benefits as they relate to community planning and development issues.

Although quantifiable and monetizable,[20] the dollar value of energy savings could not enter into total benefits because fuel and power costs already directly affect the operating expenses of the HSGT options, the perceived cost of auto travel, and the economics of the airline industry. It would be double counting to include, within total benefits, the dollar value of reduced use of this ubiquitous material of transport production. Beyond the value of the energy savings per se, lower petroleum consumption due to HSGT might help to wean the Nation from its dependence on foreign oil sources. To translate the intangible concept of "energy independence" into straightforward monetary values would, however, entail international trade and other major policy issues that exceed the scope of this report.

[20] Indeed, in the course of this study and in conjunction with the projections of emissions savings, a methodology was developed to calculate differential energy usage with and without implementation of HSGT. The methodology accounted for the region of the country, the mix of fuels for electricity generation in each, and the projection year. Access and egress modes were considered in addition to the line-haul portions of trips. Energy consumption factors from manufacturers were compiled for representative air, rail, and auto vehicles for the 2000 to 2040 study period; for the HSGT options, the vehicle performance assumptions were those of Chapter 4. Based on demand model outputs for intercity trip characteristics and ridership forecasts, energy savings due to HSGT were projected.