Urban Transportation Center

Framework for Assessing the ROI for High-Speed and Intercity Rail Projects

Prepared for:

American Public Transportation Association (APTA)

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1 Introduction

Background. Intercity passenger rail demand in the U.S. has shown an unprecedented surge in the new millennium. Amtrak, the primary intercity rail service provider in the country, reports more than 30 million ridership in 2015, almost 1.5 times of what it was in 2000 (Amtrak, 2017). To accommodate the ever increasing rail passenger demand and to meet the rising expectations of riders for quality rail travel experience, several states have been actively pursuing new high-speed and intercity passenger rail (HS&IPR) services. Prominent examples include the California High-Speed Rail project, the Midwest Regional Rail Initiative (MWRRI), the Florida High-Speed Rail project, and the project to improve intercity passenger rail between North Carolina and Virginia, among others.

HS&IPR service is an appealing alternative to air and auto in intercity travel. Many parts of the national highway and airport systems in the U.S. have been plagued with congestion and deteriorating infrastructure for a long time. In addition, the two modes are under increasing criticism for their considerable negative externalities to the environment. HS&IPR services are environmentally much more sustainable, but the provision requires huge capital investment. A number of prior studies have already been conducted to assess the feasibility of an HS&IPR project. These studies looked at the returns on investment of an HS&IPR project from varying angles, such as the benefit-cost ratio, the economic impact, or the social impact of a project. However, there is a lack of consensus among these studies as to what benefit and cost elements to consider. As a result, much remains unclear or unknown about the true returns on investment of an HS&IPR project. Without a systematic methodology, the decision making aspect associated with High Speed and Intercity Rail could be deemed subjective.

Approach Taken by This Report. To fill this knowledge gap, this study takes an integrative approach to encapsulate all benefit and cost elements involved in conventional benefit-cost analysis (BCA), economic impact analysis (EIA), and social impact analysis (SIA). BCA is an assessment process focusing on the overall benefits and costs incurred in the lifetime of a project and depicting the benefits and costs in terms of the net present value. A positive net present value indicates greater overall benefits than costs thus suggesting the feasibility of a project; whereas a negative value deems the project as undesirable. According to FRA (2017), four criteria are defined to decide which benefits and costs should be included BCA: (i) immediately quantifiable in practical terms, (ii) monetizable, (iii) not duplicative, and (iv) not a transfer effect. However, given that investment in HS&IPR is not just a summation of direct monetary benefits and costs, it assumes an important social context and thus warrants consideration of a broader range of benefits beyond BCA, such as the broader economic and social impact of the investment.

The analysis of the economic impact of an HS&IPR project is not a substitute for BCA. Rather, EIA is a complement to BCA. Effects on economic development, including job generation and income increase, are commonly seen as strategic public policy goals, alongside environmental and social goals. The extent to which an HS&IPR project helps achieve these goals is made use of to justify the investment. EIA shows how an HS&IPR project engenders direct and indirect spending, leading to greater productivity and cost savings in multiple regions impacted by the project.

SIA refers to the measurement of environmental and other social impacts that are of public interest. While it is fundamentally derived from social welfare concepts embodied in benefit-cost analysis, it differs in important ways from the classic BCA calculation method currently practiced by economists. Unlike BCA, SIA may include desirable distributional impacts (e.g., helping disadvantaged populations and economically distressed communities), very long-term impacts (e.g., enhancing land use and the environment for future generations), and quality of life impacts (e.g., making more livable cities with greater mobility and lifestyle options). BCA studies do not normally assign a benefit value for distributional impacts or inter-generational impacts, and also typically do not assign a benefit valuation for the quality of life impacts that may be valued by some but not all stakeholder groups. Thus, SIA provides a means of assessing how a project affects the achievement of long-term public planning or policy objectives that are outside of the efficiency accountability perspective of classic BCA.

This report lays out a framework for presenting the ROI (return on investment) from HS&IPR that explicitly allows for a variety of alternative perspectives: including spatial areas of concern (national, region or local benefits) and the viewpoints of specific stakeholders. The selection of an applicable perspective will depend of "who has standing" in the determination of what constitutes a benefit. Thus, the alternative spatial perspectives enable the measurement of local impacts that are of state and national public policy value (e.g., support for investment in various cities and regions) even if they appear as negligible from an aggregate national measurement.

From any of these perspectives, benefits can also be measured in two ways: in terms of outcomes achieved for a future year and as the present value of a stream of benefits over time. Both views have validity; the former is most useful to view goal achievement for outcomes that are the result of cumulative effects over time (e.g., economic development and air quality effects) while the latter is most useful for viewing recurring benefits (e.g., travel time and cost effects). The viewing of cumulative outcomes can also be important insofar as there is interest in the long-term sustainability of land development patterns, economies and the environment, or intergenerational equity including a desire to avoid precluding future activities by later generations.

This report lays out a comprehensive assessment framework to illustrate the true returns on investment of HS&IPR projects that encompass aspects of three forms of economic analysis -- BCA, EIA and SIA – and also allows for both future outcome measures and time stream benefit measures. The recommended framework also takes into account the need to position and highlight certain benefit categories depending upon the stakeholder group/decision-maker. The report further discusses factors that affect the outcome of benefits estimation as well as factors that are less commonly considered in analysis. The methodology developed here is recommended as a standard approach for evaluating future HS&IPR projects in the U.S. context, which will help federal and state transportation policy makers more informed decisions in passenger rail investment.

Organization of this report. The remainder of the report is organized as follows. Chapter 2 provides the cost elements that need to be considered. The various benefit and impact elements along with a predictive methodology for estimating them and the sources of data required are discussed in Chapter 3. Chapter 4 develops and recommends a consistent methodology for estimating different types of benefits and costs. The assumptions, estimation procedures and data requirement are discussed in detail in this Chapter. Finally, a framework for a Business-case ROI calculation, and the Guidance on using the framework are offered in Chapter 5. The UIC-EDRG team conducted a comprehensive review of existing literature on the topic as well as the estimates of the various benefits and cost elements (Appendix A, B). Appendix C presents applications of the business-case ROI framework to HSR projects in California and the Midwest.

2 Cost Elements

Project costs are the sum of the economic resources required to bring about the expected outcomes of an HS&IPR project (FRA, 2016a). Costs represent the inputs of capital, labor, and materials needed for project preparation, construction, operation, and maintenance. For a given project scenario, there are in general four cost elements that are calculated for all applicable years. They are:

1) Preliminary costs;
2) Capital investment costs;
3) Operating and maintenance costs;
4) Assets replacement and remaining assets life cost.

2.1 Preliminary costs

"Preliminary costs" refers to costs incurred prior to the construction phase of a project. These costs are expended to conduct engineering design and environment review processes, and acquire necessary lands for the project.

2.2 Capital Investment Costs

"Capital investment costs" is the sum of the monetary resources needed to build a project and acquire relevant assets (for example, rail cars). Following the FRA guidance on capital cost estimation (FRA, 2016b), capital investment costs can generally be summarized into one of the following Standard Cost Categories:

- Guideway and track elements
- Stations, stops, terminals, and intermodal facilities
- Support facilities: yards, shops, and administrative buildings
- Site preparation work, including to address special conditions
- Systems
- Right-of-way, existing improvements
- Vehicles
- Professional services
- Unallocated contingency

Given that the construction of an HS&IPR project spans multiple years, the capital investment costs are usually in time series. In some cases, a project may expend all capital costs in the first few years, while for others the capital costs may recur throughout most or all of the analysis period.

A longer span for cost spending is typically associated with more uncertainty about when particular parts of a project would be constructed, and thus when portions of the capital costs would be expended. Project sponsors should recognize this uncertainty and use their best judgments to come up with reasonable estimates. The underlying assumptions need to be thoroughly described. Sensitivity analysis may also be necessary, in order to better understand how the uncertainty affects the overall outcome of the BCA (FRA, 2016a).

2.3 Operating and Maintenance Costs

Operating and maintenance (O&M) costs pertain to a wide array of costs that are necessary on a continuous basis to support HS&IPR functions to provide a given level of service. The O&M costs of an HS&IPR project throughout the entire analysis period should be included in the BCA. Common O&M categories include (FRA, 2016a):

- **Train staff and crews**: engineers, conductors, on-board services (OBS), and commissary support
- **Energy**: diesel fuel or electricity needs for train propulsion
- **Stations**: ticket sales, customer information and train dispatching services; utility and maintenance costs for the station building and related facilities (e.g., platforms, parking, landscaping)
- **Rolling stock**: lease payments on equipment
- **Equipment maintenance**: routine planned maintenance of the rolling stock fleet; maintenance or repairs from vandalism and crashes; equipment cleaning
- **Railroad operations and maintenance**: train dispatching and right-of-way (ROW) inspection costs; routine maintenance and repair of vehicles, tracks, and related infrastructure to ensure safe operation and maintain capacity and track class standards
- **General and Administrative (G&A)**: management, marketing, sales and reservations, legal and finance functions, and all other general office expenses

2.4 Assets Replacement and Remaining Assets Life Cost

The railroad project consists of assets whose expected life may be shorter than the period of the BCA analysis. Such assets should be replaced and repurchased which incurs additional cost during the repurchase time. On the other hand, some railroad assets such as bridges and tunnels have expected life exceeding the analysis period. One simple way of accounting the cost of remaining life of such assets is to depreciate the cost linearly over its service life. For example: An asset with an expected life of 70 years would retain half of its value after 35 years in service, while an asset with a 50-year life would retain 30 percent of its value at that point in time.

3 Benefit and Impact Elements

3.1 Impact Elements

There are eleven impact elements for each scenario, that are to be calculated for all applicable years for each scenario, and then input into various forms BCA, EIA and/or SIA studies. They are summarized in the table below. The measurement and use of each one is then discussed in the rest of this section. A few key findings from this table are worth noting:

- First, energy resource use and land development are factors that are often included in SIA (Table 3.1), particularly when viewed from specific community or societal perspectives. However, these elements are usually excluded from BCA and EIA because there are already covered in other measures of user cost or impact on the economy.
- Second, safety, noise and environmental impacts are factors that are often included in BCA and SIA but are typically excluded from EIA studies because, while they are valued by people, changes in these factors do not necessarily lead to changes in the flow of income in the economy.
- Third, factors such as reliability and intermodal connectivity are most often valued in BCA and EIA because they reflect system operations efficiency, but these factors are often excluded from SIA studies insofar as those studies focus most on community social welfare rather than transportation system effectiveness.

Further discussion of the specific application of these factors within BCA, EIA and SROI calculations is discussed later in Sections 4.4, 4.5 and 4.6.

Table 3.1. Elements of HS&IPR Impact that are frequently included in various forms of analysis

Impact Element	Form of Analysis		
	Used in BCA	Used in EIA	Used in SIA
Travel Time	X	X	X
Travel Expenses	X	X	X
Travel Congestion and Reliability	X	X	-
Safety	X	-	X
Noise	X	-	X
Environment	X	-	X
Energy Resource Use	-	X	X
Accessibility	X	X	X
Intermodal Connectivity	X	X	-
Land Development	-	X	X
Service Operator and Facility Owner Impacts	-	X	-

X denotes impact elements that are commonly used in the specified form of analysis

3.2 Travel Time

Definition: An HS&IPR service can change travel time for its users as well as users of the competing modes. For rail users, the travel time can be improved due to increased train speed, greater service frequency (which reduces the difference between a passenger's preferred departure time and the closest train departure time, or passenger schedule delay), and possibly more convenient access to/egress from the train stations. In addition, an HS&IPR service can attract users of the existing competing modes, thereby relieving the congestion at infrastructure facilities (highways, airports, etc.) used by those modes. Thus the remaining users of those modes can also experience reduction in travel times. Note that travel time includes both in-vehicle time, out-of-vehicle time (schedule delay and access/egress time), and the additional buffer times included in one's travel plan to account for the reliability of specific modes.

Inclusion in Analysis: Travel time savings is one of the most important benefits in BCA, EIA, and SROI analysis. Travel time is a localized impact, meaning that travel time saving benefit is associated with travelers in a specific geography (usually only in the project region). Note that the value of changes in travel time is one element of a broader generalized cost metric calculated in BCA accounting.

Application of the methodology: For a given scenario, travel time savings are estimated based on the forecast volume of travelers using each mode and switching between modes – which may include high speed rail, conventional rail, highway, and air users. The forecast of volume and travel time typically comes from the travel demand model used by the HS&IPR project.

Measurement: Travel time savings are measured as the number of person-hours traveled reduced for travelers in business and leisure classes, who differ by value of time (VOT). The differentiation by traveler class allows for the conversion of the savings in person-hours traveled to equivalent dollar amounts, by class and in aggregate. (See "input data" part below for VOT data sources.)

Predictive Methodology: A four-step procedure is adopted for estimating travel time savings: (1) Establish the baseline, and one or two alternative scenarios. (2) Estimate the number of business and leisure travelers taking HSR, highways, and the air transportation system, using the travel demand model. (3) Calculate the travel time savings between an alternative scenario and the baseline, for each traveler class and across all modes. (4) Multiply the travel time savings for each traveler class by the corresponding VOT to yield the dollar values.

Note that for auto travelers, a conversion of vehicle-hours traveled (VHT) to person-hours traveled (PHT) may be needed if the travel demand model outputs VHT rather than PHT. The conversion will be done using an average vehicle occupancy rate. For air travel, the number of passengers shifting to HS&IPR will be divided by the average number of passengers per flight to obtain the number of flights eliminated. The resulting delay reduction at airports can be estimated in two ways: either by performing an airport queuing analysis (for example, Pyrgiotis et al. (2013)) which warrants significant modeling efforts, or using existing statistical models (for example, Zou, 2012) which gives the quantitative relationship between average flight delay and the number of flights at an airport.

Sources of Input Data: VOT for leisure and business travelers are available in USDOT (2011), in the USDOT (2016a) grant guidance, and also in FRA (2016a) guidance. The traveler value of time in future years can be derived by inflating the baseline VOT at the rate of 1.6% per year. The number of users for each mode will be estimated from the project-specific travel demand model.

Output Results: Dollar values of total travel time savings for users of all modes, each year in the analysis period.

Example of Current use: Travel time savings benefit is typically included in all benefit cost studies. Some of the prominent ones include Cambridge Systematics (2011) and Parsons Brinckerhoff (2014) for California corridor, TEMS (2004) for Midwest and Lynch (1997) for southeast corridor. Further details about these studies can be found at the end of section 3.

3.3 Travel Cost

Definition: For a rail passenger, the direct cost of travel may include out-of-pocket expenses such as fares for line haul intercity rail, fares for access to/from intercity rail via taxi or public transit), and if accessing via car, then all associated costs of fuel, vehicle wear-and-tear, tolls and parking costs. For users of other modes, there are similarly fares for bus or airline travel and vehicle costs if traveling by car. Travelers who switch to HS&IPR have net travel cost changes calculated as the difference in expense between the old and new mode. Travelers of other modes may also see changes if the addition of HS&IPR services lead them to a change in fares or fees.

Inclusion in Analysis: Changes in travel cost is typically included in BCA and EIA, and may also be included in SIA depending on the perspective being adopted. Note that travel expense is one element of a broader generalized cost metric calculated in BCA accounting.

Application of the Methodology: For a given scenario, travel cost changes are estimated based on the forecast volume of travelers using each mode and switching between modes – which may include high speed rail, conventional rail, highway, and air users. The assumption of fares and expenses is usually part of the setup for running the travel demand model used for the HS&IPR project.

Measurement: HS&IPR travel cost benefits are measured in dollar values for each trip before and after the introduction of the HS&IPR project.

Predictive Methodology: A three -step procedure is adopted for estimating travel cost impacts: (1) Establish the baseline, and one or two alternative scenarios. (2) Estimate the number of business and leisure travelers taking HSR, highways, and the air transportation system, using the travel demand model. (3) Calculate the travel expense savings between an alternative scenario and the baseline, for each traveler class and across all modes. This is usually calculated as part of a generalized travel time + cost function used in mode choice models.

Sources of Input Data: Fare, operator service frequency, traveler in-vehicle and out-of-vehicle times can be derived from characteristics of the HS&IPR project and the existing travel information. Fares and fees are then set for the travel models used in each specific project analysis (including analysis of trip generation and mode choice). The cost of operation for rail, air, bus and car travel can be found at Vehicle operating cost data depends on the mode. Estimates of total car operating costs per mile are available from the AAA Driving Cost publication. (See also Barnes and Langworthy, 2003). Bus and other transit operating costs are available from the National Transit Database (NTD). Intercity diesel train costs are available in Amtrak's Financial Plan document. Intercity electric train costs are also shown in the California High-Speed Rail Authority's Business plan.

Output Results: HS&IPR traveler costs are typically measured in terms of dollars per trip or annual for a given mode and class of travelers/.

Example of Current use: Travel cost savings benefit is typically included in all benefit cost studies. Some of the prominent ones include Cambridge Systematics (2011) and Parsons Brinckerhoff (2014)for California corridor, TEMS (2004) for Midwest and Lynch (1997) for southeast corridor. Further details about these studies can be found at the end of section 3.

3.4 Congestion and Reliability

Definition: Reliability relates to the travel time variability (or arrival and departure schedule predictability) of movement. It is well known that highway and road travel times become more variable and less predictable as congestion increases and demand approaches maximum facility capacity. The same can occur to varying degrees for air travel, bus travel, and train travel as a consequence of either terminal congestion or high levels of infrastructure (track, road, runway or airspace) use. The consequence of falling reliability is that travelers and/or operators build in extra "buffer" time (leaving earlier than otherwise necessary) to ensure that on time arrivals even for trains, buses and airplanes. By switching some travelers away from other modes, HS&IPR is often expected to have a positive impact on highway travel times. HSR improvements may have also positive or negative impacts on existing freight and passenger train movements.

Inclusion in Analysis: Reliability benefits are typically included in BCA as a user benefit for all trips, and in EIA as a user benefit for business travel. They may also be included. Besides representing a user benefit, reliability can also affect operator costs. The reason is that operators who adjust their timetables to allow more time per trip may end up with fewer daily trips per vehicle, thus requiring further capital and operating costs to acquire additional vehicles to maintain a level of service frequency throughout the day.

Application of the methodology: The methodology is most commonly applicable for those HSR&IPR projects that attract travelers away from congested highways. There are well developed methods for estimating the buffer times that highway travelers build into their schedules, and the benefit that they receive when congestion is reduced. USDOT maintains a collection of highway reliability and buffer time calculation tools; they are available in FHWA (2016a).

Measurement: Travel reliability benefits are measured as the reduced cost of travel (as a result of shorter scheduled travel time) before and after the introduction of an HS&IPR project. The valuation of buffer time for highway travelers is discussed in the USDOT document "Travel Time Reliability," available in FHWA (2016b).

Predictive Methodology: The methodology is based on estimation of volume/capacity (V/C) ratio for relevant infrastructure. In the case of highways, there are well developed statistical relationships between reliability and the V/C ratio for various types of infrastructure settings. various types of roads, The buffer time (or planning time index) is "a measure of the amount of actual time spent on a trip after incorporating a certain buffer period above and beyond the standard travel time" (PB, 2014). For example, a planning index of 1.3 means that 30% of the actual travel time is buffer. More specifically, if a traveler believes that his/her trip may take a standard travel time of 20 minutes, he/she would incorporate 0.3*20=6 minutes of buffer to make the travel reliable. To implement this approach, two steps are needed: (1) multiply the total travel time savings by traveler class and mode (from section 4.3.1) by the corresponding planning time index minus one. (2) multiply the previous value by traveler VOT and then sum over traveler classes and modes.

Sources of Input Data: The methodology requires inputs of travel time information, traveler VOT, planning time index. The first two types of data come from the travel demand modeling output. The planning time index will draw from empirical findings, such as in the Texas Transportation Institute (2010) report and documentation for the various tools available in FHWA (2016a).

Output Results: Dollar value of reliability benefits each year in the analysis period.

Example of current use: Reliability benefits were an important part of the California HSR study **(**Cambridge Systematics, 2011, and Parsons Brinckerhoff, 2014).

3.5 Safety

Definition: High speed trains generate safety benefits by shifting travelers from automobiles. Vehicle travel results in over 30,000 fatalities each year in the United States, compared with several hundred per year on trains (US DOT). Crash reduction is measured relative to a baseline scenario, and resulting safety benefits are typically monetized.

Inclusion in Analysis: Safety impacts can be localized or non-localized, meaning that benefits and costs may transpire (1) in a specific geography or (2) regardless of a project's scale. Injuries and fatalities are non-localized because they impact all members of society—not just those living close to crash sites—through their influence on healthcare costs. The most common localized safety impact is property damage resulting from a collision. Safety impacts are commonly incorporated into BCA studies. They are most often left out of EIA studies, unless there is sufficient evidence to suggest that it will affect business operating costs. Safety can be a natural part of RSOI studies that consider it to be a factor in livability.

Application of the Methodology: Crash statistics generally exist for multiple modes and levels of geography given their importance to public health. Rural impacts are of most interest for benefit-cost studies of high speed rail, primarily because trains displace intercity highway travel rather than short-distance, intra-regional flows. There are few instances where safety impacts should *not* be included in benefit-cost analyses of high speed rail, one being when crash statistics are lacking and cannot be measured, and the other when a project is too small to generate noticeable impacts.

Measurement: Safety is measured in terms of fatalities, injuries, and property damage, each of which is generally monetized. A common unit of measurement is the number of occurrences per 100 million vehicle miles traveled. Crashes can be categorized using a taxonomy such as the Maximum Abbreviated Injury Scale (MAIS) if detailed information is available. MAIS categorizes crashes based on their severity; a ranking of 1 indicates a minor injury while a ranking of 6 indicates a fatality. KABCO is a slightly different categorization scheme that uses letter rankings instead of numbers. The value of safety impacts, particularly for injuries and fatalities, is a subject of controversy. Mortality risk valuation, as the practice is known for measuring the value of a "statistical life" (VSL), is measured using stated preference surveys that ask respondents how much they are willing to pay to avoid small reductions in their risk of death.

Predictive Methodology: There is a six-step process for estimating safety benefits: (1) Develop a baseline and one or more alternative scenarios. (2) Quantify the reduction in VMT resulting from high speed rail. (3) Classify reduced VMT by mode, making sure to differentiate between light trucks and heavy trucks, and passenger vehicles and motorcycles. (4) Estimate the number of injuries and fatalities avoided by mode using crash statistics for the specific geography or geographies where VMT were reduced. Also estimate expected high speed rail crashes (dis-benefit). (Use federal statistics if local or state data are not available.) (5) Estimate the number of property damage occurrences avoided. (6) Monetize the injuries, fatalities, and property damage avoided under the alternative scenario(s).

Sources of Input Data: Motor vehicle crash statistics (fatalities and injuries) are available for each state through the National Highway Traffic Safety Administration (NHTSA 2016). National Transportation Statistics tables published by the Bureau of Transportation Statistics provide crash statistics for all other modes, including rail (BTS 2016b). The U.S. Department of Transportation develops values for injuries, fatalities, and property damage, and summarizes each along with their specific sources in its benefit-cost analysis guidance for TIGER grant applicants (USDOT 2016a). These same values are repeated in the FRA (2016a).

Output Results: Results will include a dis-benefit dollar value associated with rail crashes and a benefit dollar value associated with reduced vehicular crashes and property damage. The overall result is usually a net benefit.

Examples of Current Use: The benefit-cost analysis of California high speed rail authority (Cambridge Systematics 2011 and PB 2014) considers cost savings associated with fewer vehicle crashes. The authors obtain state-specific crash rates categorized using the Maximum Injury Abbreviated Scale, and also include a property damage rate. Value of a statistical life amounts come from US DOT and are also categorized using MAIS.

3.6 Noise

Definition: High speed trains (as well as other motorized transportation modes) generate sound that may represent a nuisance to residents of adjacent areas. However, the sound impact must be measured relative to a baseline scenario. The net change may thus be positive or negative depending on whether the new train service is displacing older (and noisier) conventional trains along the same route or displacing some road, rail or aircraft movements that also generate noise elsewhere.

Inclusion in Analysis: Noise impacts are typically considered to be a significant consideration for local area environmental impact studies. They are usually considered to be of far less importance for BCA studies that focus on state and multi-state scale investments. They are not a factor in regional EIA studies, though they may be considered in local community economic impact studies insofar as they may affect the spatial pattern of property values adjacent to tracks and stations. They may be a part of localized SROI studies that consider noise as an element of neighborhood livability.

Application of the Methodology: The analysis requires significant noise impact modeling and hence should only be done if there is expectation of a significant noise impact that warrants the effort. Generally, these impacts are most relevant for denser urbanized areas, and only if there is a significant number of homes immediately adjacent to stations and tracks, at the same elevation as those facilities, and lacking walls, berms or other sound noise barriers. Impacts on vehicle trip volumes for other modes are often sufficiently small so that the noise change impact associated with those modes may also be dismissed as negligible.

Measurement: Noise is measured in terms of decibels (db) at various distances from the source. Because db is an exponential scale, both level and its change must be considered. There is a body of research on "hedonic prices" that relates residential property values to noise levels (e.g., Dekkers and van der Straaten 2009; Monson 2009). There is also a body of "stated preference" survey research that establishes a "willingness to pay" or contingent valuation for avoiding nuisance level noise (e.g., Bristow and Wardman 2004). Either of these two bodies of research can be used to translate changes in db levels into changes in a dollar benefit (or dis-benefit) value. Of course, the frequency of the noise as well as the level of noise should also be considered.

Predictive Methodology: There is a five step process: (1) Determine the train technology to be used, the frequency of service to be added, and the predicted offsetting reduction in highway vehicle, aircraft and conventional train trips due to mode shifts. (2) Determine applicable distance from stations and tracks that are within a nuisance noise impact threshold. (This will depend on the train technology.) Repeat for applicable highway and aircraft modes. (3) Determine the population located within primary affected areas -- which are the areas that fall within a specified noise threshold distance for rail and other affected modes. (4) Apply applicable noise contour models to predict the noise level changes in affected areas, also accounting for changes in vehicle-trip frequency for all affected modes under both baseline and project scenarios.* (5) Apply hedonic price or stated preference factors to translate the noise level changes into per capita dollar benefit (or dis-benefit) values for all affected areas, and multiply that figure by the number of residents in those affected areas.** This sequence may need to be repeated for different years if there is a projection of increasing high speed trains (and increasing mode shifts) in more distant future years.

**A reduction in change in rail or highway activity may be modeled based on VMT reduction rather than vehicle trips*

***In lieu of detailed population values, it is possible to use urban and rural average coefficients, although this is less accurate.*

Sources of Input Data: Procedures and models for estimating noise at various distances from the source are provided for transit, freight trains and high speed passenger trains by the FRA (2016c) and for highways by the Federal Highway Administration FHWA (2016c). Projects involving multiple routes and facilities often require a different model for each mode. To find the population in affected areas within the primary contour threshold, analysts can use the publicly-available American Fact Finder website. The easiest way to do so is to select "Advanced Search" on the American Fact Finder website, select "Geographies", and use the map feature to draw custom shapes. Coefficients for monetizing noise impacts by source and mode are available from the Transportation Benefit-Cost Analysis website section on "Measuring and Estimating Noise" (Transportation BCA 2016). Another resource is the Oregon DOT Mosaic tool. Under the website's Quality of Life and Livability page (located under the Categories & Indicators tab), users can download a document that provides additional resources for estimating noise coefficients (Oregon DOT 2016).

Output Results: Annualized dis-benefit (nuisance) $ value of noise associated with added high speed rail service, and offsetting benefit (noise reduction) value of reducing highway traffic, aircraft activity or conventional train activity. Overall result is usually a net benefit.

Examples of Current Use: A California benefit-cost analysis (California High-Speed Rail Authority, 2014) includes estimates an auto noise reduction benefit resulting from a decline in VMT and rail noise dis-benefit resulting from new train-miles. Most of the studies do not include noise because they are focused on state or regional effects.

3.7 Emissions

Definition: High speed trains as well as all other motorized forms of travel generate emissions that have environmental and public health impacts. They include both pollutants (such as NOx, Sox, VOC and PM) that have regional irritant and health impacts, and greenhouse gas (carbon) emissions that can have more long term and global impacts. HS&IPR projects affect these emissions by affecting the volume of vehicles traveling across the US, the mix of modes and propulsion technologies used, and the speed of movement. The rate of pollutant and greenhouse gas emissions differs by mode, propulsion technology and fuel source.

HS&IPR projects have the potential to particularly reduce emissions by shifting some travel away from cars and light-duty trucks, which constitute most of the transportation sector's contribution to air pollution (US EPA). Emissions reduction is measured relative to a baseline scenario, and resulting environmental benefits are typically monetized.

Inclusion in Analysis: Environmental impacts are commonly included in BCA and SROI studies; they are most commonly not incorporated into BCA studies. Environmental impacts can be localized or non-localized, meaning that benefits and costs may transpire (1) in a specific geography or (2) regardless of a project's scale. Air pollution is non-localized because it impacts entire regions. Greenhouse gas emissions are even less localized, with carbon dioxide traveling far from its place of origin. Localized environmental impacts occur when transportation modes generate "hotspots," or areas of concentrated pollution surrounding a highway, railyard, or bus station. The presence of hotspots introduces environmental justice issues when low income populations and racial or ethnic minorities are disproportionately affected. Because air pollution is a public health concern, the Clean Air Act of 1970 regulates harmful "criteria pollutants" and designates nonattainment zones, or regions that exceed allowable thresholds.

Application of the Methodology: Emission rates generally exist for multiple modes given their importance to public health. Rural impacts are of most interest for benefit-cost studies of high speed rail because trains displace intercity highway travel rather than short-distance, intra-regional flows. Environmental impacts should always be included in benefit-cost analyses of high speed rail because even modest reductions in VMT can generate benefits, especially in localized contexts.

Measurement: Emissions are generally measured in U.S. tons per uncongested mile, congested mile, or hour. The reason for distinguishing between congested and uncongested miles is because pollutants become more localized at lower travel speeds. US EPA provides emission rates for all modes of transportation. Emission rates vary by a vehicle's size, age, and manufacturer (but not by geography), and are typically valued in dollars per U.S. ton.

Predictive Methodology: There is a five-step process for estimating environmental benefits of high speed rail: (1) Develop a baseline and one or more alternative scenarios. (2) Quantify the reduction in vehicle miles traveled and air miles traveled resulting from high speed rail. (3) Classify reduced VMT by mode, making sure to differentiate between light trucks and heavy trucks. (4) Estimate the amount and type of emissions generated by mode using national data, and also expected emissions generated by the high speed (dis-benefit). (5) Monetize the net emissions reduction under the alternative scenario(s).

Sources of Input Data: Emission rates for light-duty vehicles (i.e., passenger cars), light-duty trucks (i.e., minivans, small pickups, and SUVs), heavy-duty vehicles, and motorcycles are available from through the Bureau of Transportation Statistics (BTS 2016c). US EPA produces a fact sheet on emission rates from locomotives (US EPA 2009), and an FAA report provides information on emissions from aircraft (FAA 2015). Recommended emission costs and valuation information is provided in USDOT (2016a, 2016b) and FRA (2016a).

Two additional US EPA websites aggregate a number of useful resources: (1) the Clearinghouse for Inventories and Emissions Factors (CHIEF) pulls together various resources for estimating emissions by source (https://www.epa.gov/chief). (2) The Co-Benefits Risk Assessment Screening Model (COBRA) allows users to estimate the benefits of pollution reductions (US EPA 2015).

Output Results: Results will include a dis-benefit dollar value associated with increased train travel and a benefit dollar value associated with reduced vehicle miles traveled and air miles traveled. The overall result is usually a net benefit.

Examples of Current Use: A benefit-cost analysis of California high speed rail (2014) not only considers emissions reduction, but also impacts on agricultural land and wetlands. The emissions analysis is comprehensive in that it estimates emissions from both mobile sources (automobiles and planes) and stationary sources (electric generating plants that power high speed rail). Off-road vehicle emissions generated during the construction phase are also included.

3.8 Energy Resource Use

Definition: High speed rail generates energy impacts by shifting modes and fuel sources used for travel. Each mode used for intercity travel – trains, buses, cars and aircraft - has different occupancy and energy usage rates. When vehicle miles of travel (VMT) are reduced because of modals shifts to trains, less crude oil is consumed in the form of gasoline (for cars and light-duty trucks), diesel (for heavy-duty trucks), and jet fuel (for planes). A similar effect can occur if VMT is reduced for natural gas fueled vehicles.

As a general rule, trains tend to be more fuel-efficient than on-road vehicles and planes, assuming that they have reasonably high occupancy levels. However, the fuel source of HS&IPR trains can vary widely – depending on whether the trains are fueled by diesel fueled engines or electric engines, and whether the electricity generating plant relies on fuel oil, coal, hydropower, biofuels, wind generators or solar arrays. However, currently most trains rely on diesel fuel.

Inclusion in Analysis: Energy impacts are commonly included as part of the natural resource element of SROI studies. They are not normally included in BCA because energy costs are already included as an element of total transportation costs, so their further inclusion would be a double count. Energy impacts may be included in EIA studies that incorporate regional economic simulation models, insofar as scenarios shift the fuel mix can also affect inter-regional purchase and sales patterns. For both EIA and SROI studies, it can be important to consider the source of electricity used to power high speed rail trains, and where the electricity is generated.

Application of the Methodology: Energy impacts are measured relative to a baseline scenario, and can be monetized in the form of cost savings or reported in physical units (e.g., gallons). There are also harder-to-quantify impacts in the energy security category (related to dependence on foreign oil). High speed trains themselves consume energy, meaning that declines in usage among on-road vehicles and planes must be weighed against increased usage among from high speed rail. Total energy consumption is a function of miles traveled and fuel efficiency, or the amount of energy consumed per mile traveled.

Measurement: Energy usage is typically quantified using physical units that can be monetized. Common physical units in the transportation sector include gallons, British thermal units (Btu), and cubic feet. For electric-powered vehicles, electricity may be quantified using kilowatt-hours (kWh), megawatt-hours (mWh), or tons of coal. Price data is used to monetize operating cost savings and import savings deriving from reduced demand for oil. Energy security typically represents a social benefit, and should be described qualitatively when social impacts are considered.

Predictive Methodology: There is a five-step process for energy impacts of high speed rail: (1) Develop a baseline and one or more alternative scenarios. (2) Quantify the reduction in vehicle miles traveled and air miles traveled resulting from high speed rail. (3) Classify reduced VMT by mode, making sure to differentiate between light trucks and heavy trucks. (4) Estimate the amount and type of energy consumed by mode using national data, and expected energy consumed by the high speed rail (dis-benefit). If possible, the analysis should distinguish between energy consumed in free flow conditions and energy consumed in congestion. (5) Report the change in net energy consumption in physical units or dollars saved/spent.

Sources of Input Data: The Bureau of Transportation Statistics provides data on energy consumption by travel mode in Chapter 4, Section B of the *National Transportation Statistics*. Data on fuel efficiency is provided in Section C of the same chapter. A range of estimates exists for fuel consumption during periods of congestion, one being Zhang et al. (2011).

US EIA provides data on gasoline and diesel fuel costs EIA (2016a) and natural gas prices EIA (2016b), and BTS provides data on airline fuel costs BTS (2016a).

Output Results: Results will include a dis-benefit unit/dollar value associated with increased train travel and a benefit unit/dollar value associated with reduced vehicle miles traveled and air miles traveled. The overall result is usually a net benefit.

Examples of Current Use: A 2014 benefit-cost analysis of high speed rail in California estimates vehicle operating cost savings and oil import cost savings resulting from reduced fuel usage. For the first component, the authors use US EIA fuel price and data and elect to subtract out taxes because they represent transfer payments. For the second component, the authors first estimate the reduction in U.S. petroleum imports resulting from fuel savings. They then estimate the cost of oil imports deriving from monopsony effects, i.e., those occurring when lower demand leads to lower prices.

3.9 Accessibility (Labor, Leisure and Business Visitor Markets)

Definition: High speed rail can also improve accessibility by expanding the scale of health, education, employment and/or recreation opportunities that regional residents and visitors can realistically reach for a day trip. Access to broader markets can also generate economic productivity gains in several ways. Expanded labor markets can provide businesses with enhanced skill matching. Access to broader customer markets for tourism, convention, and business travel can also provide scale or agglomeration economies for operation of those business activities. Access to broader business-to-business "supplier and customer markets" can further enhance regional specialization and help to build broader scale trade as part of mega-regions. Together, these various impacts are sometimes referred to as "agglomeration economies."

To illustrate how high-speed trains can radically change access for same day travel, consider Figure 3.1 which follows. Within a two-hour threshold, conventional rail passengers originating from Chicago can now reach the cities of Champaign, IL, Lafayette, IN, and Milwaukee, WI, the farthest being 130 miles away. Within the same time threshold, high speed rail passengers could in the future reach Cincinnati, Cleveland, Detroit, Indianapolis, Madison and St. Louis, the farthest being 340 miles away. Reaching these same cities via conventional rail could take up to six hours rather than two.

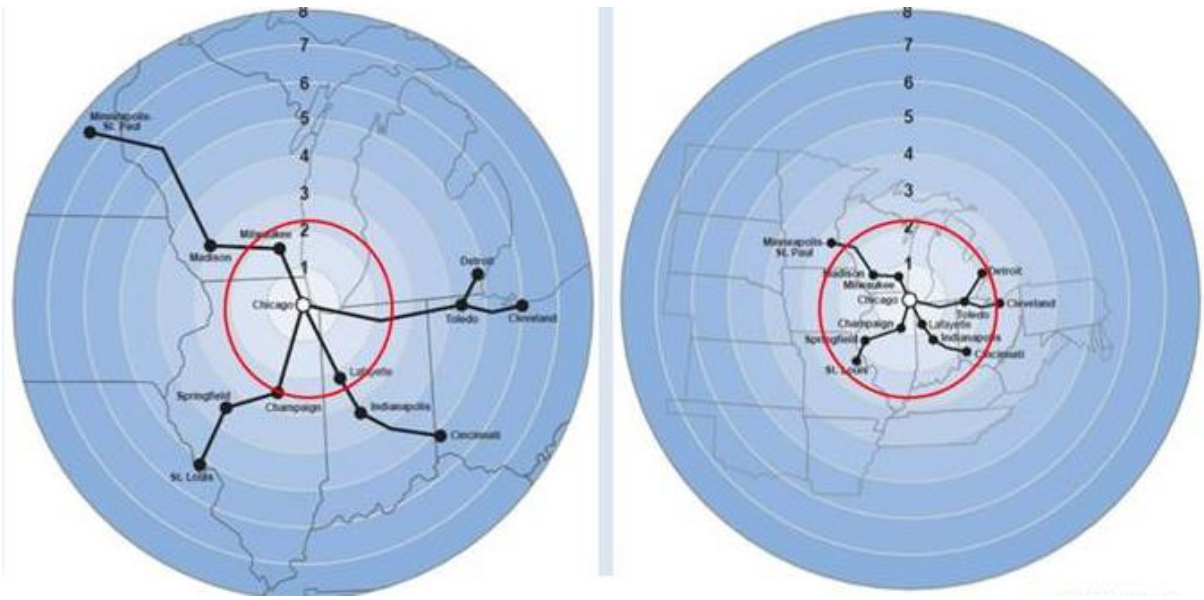

Figure 3.1. Illustrative example of how a change from 72 mph to 220 mph triples the area served by a 2-hour access time to Chicago. Effects of a lesser 110 mph service would be proportionately smaller.

The above example is also illustrative of high speed rail's ability to create megaregions, in which the Chicago manufacturing and finance center could be linked by same day travel to R&D centers at Purdue University (Lafayette), University of Illinois Urbana-Champaign, University of Wisconsin-Madison, and Washington University in St. Louis -- each a research university that is among the top in the nation for R&D spending (National Science Foundation). A second example of this is the Amtrak Northeast corridor that connects the financial center of New York City to both the government center in Washington, DC and the R&D center in Boston. Amtrak's Acela train serves this corridor and enables business transactions throughout the megaregion.

The most common method for valuation of accessibility is the estimation of effects on productivity in the economy. There are regional economic models and statistical methods that can be used to translate accessibility changes into effects on the Gross Domestic Product (GDP) of an affected community or region. These models are discussed in Section 4.3.

Inclusion in Analysis: Accessibility impacts are commonly considered in EIA models – both statistical models and regional economic simulation models. It is also often included in BCA studies, and less often recognized in SROI studies because those studies more commonly focus on social and environmental effects.

Application of the Methodology: Impacts deriving from accessibility improvements should be included in benefit-cost analyses of high speed rail whenever possible. Speed improvements achieved over Amtrak and highway travel could make accessibility one of the largest benefit categories for high speed rail. Accessibility should be measured using a generalized cost concept that considers both distance and time.

Measurement: There are two primary methods for measuring accessibility. One is to measure the scale of opportunities as a count of the number of workers, residents, customers or business suppliers that can be reached within a given threshold of reasonable travel time and cost. The other is to calculate a composite index in which there is no single threshold for counting opportunities but instead a formula that measures market opportunities with a "gravity model" exponent to gradually reduce the importance of more distant opportunities. Either way, network skims can be used to measure travel times between zones, and mapping tools that include highway and rail networks can be sued to establish distance and time thresholds.

Among the two approaches, the fixed threshold approach can be subject to some imprecision associated with the fact that a small change in travel time may or may not cross the threshold. However, it is also true that some types of travel markets (e.g., the market for same day business trips and same day tourism) are indeed subject to rules of thumb concerning what constitutes a reasonable travel time. In that case, a gradual gravity decay formulation may also be inaccurate.

Predictive Methodology: There is a four-step process for estimating the accessibility impacts of high speed rail: (1) Develop a baseline and one or more alternative scenarios. (2) Count the number of jobs and people located within various time or cost thresholds for the baseline and each alternative, using 3-4 hours as a rule of thumb for same-day trips. (3) If not using fixed thresholds, use a gravity model to create a composite weighting scheme. (4) Use an elasticity or simulation economic model to estimate the GDP and productivity impacts associated with improvements in accessibility.

Sources of Input Data: Accessibility metrics are normally generated via travel network skim trees. Several mapping products also provide the data necessary to model changes in accessibility. For instance, ESRI Business Analyst Online is a powerful tool that allows users to adjust distance and travel time thresholds and analyze how improvements in accessibility expand the number of reachable cities and businesses. Business Analyst is limited to highway networks, however. Google Maps can also be used to estimate travel times, and the software now includes some rail networks. Measures of jobs and people, whether arrived at using fixed thresholds or a composite approach, form the inputs used in economic models.

Output Results: Accessibility is typically measured in terms of a "market scale" or "effective density" metric, and then translated into a percentage productivity impact that can also be expressed in terms of annual GDP gain.

Examples of Current Use: Accessibility impact has been a component of several past region-scale studies of high speed rail impacts. A study published by The United States Conference of Mayors estimates the economic impact of high speed rail on four U.S. metro areas (EDR Group 2010). The study measured megaregion accessibility in terms of increasing population markets for same day travel, and applied the TREDIS regional simulation model to calculate implications for GDP growth in the four areas. It also discussed how high speed rail will tie together regional economies from Albany to New York City, along the "Space Coast" in Florida, and throughout the Midwest and Southern California. A Midwest High Speed Rail study applied the TEMS RENT™ Model to estimate productivity benefits accruing from similar improvements in accessibility across Midwestern states (TEMS 2006). The approach "[identifies] changes in accessibility that [create] new commercial development opportunities...[in turn causing] an increase in household income and property value." A California study also applied a regional economic forecasting and simulation model to estimate market access (agglomeration) improvements and their impacts on GDP growth (PB 2012).

3.10 Intermodal Connectivity

Definition: High speed rail provides an additional accessibility benefit through its connections with airports. Same-day travel thresholds become larger when out-of-state business and leisure travelers can fly into a regional airport and then take high speed rail to their destination. This intermodal connectivity represents an added accessibility benefit because travel thresholds are typically measured for surface transportation only. Connections between high speed rail and airports provide access to long-distance destinations or outlying market areas that were previously inaccessible within the same travel time. This expansion translates into increased business productivity and visitor spending.

Measurement: NCHRP (2014), *Assessing Productivity Impacts of Transportation Investments*, describes the economic benefits of intermodal connectivity. Additionally, Alstadt (2012) quantifies the impact connectivity to intermodal terminals has on economic growth and productivity across multiple industries.

Examples of Current Use: A study for the United States Conference of Mayors calculated productivity benefits of connecting city pairs, as well as visitor spending impacts of enabling airport connections to high speed rail, for Orlando and Chicago (EDR Group 2010). The Orlando case noted that international visitors who do not wish to drive would be attracted by the ability to fly into Orlando International Airport and then take a high speed rail to Disney or Space Coast destinations. The Chicago case noted that the high speed rail terminal in downtown Chicago would encourage outside visitors to stay longer to see various downtown visitor destinations, something that does not occur when visitors fly into the O'Hare International Airport area.

3.11 Land Development

Definition: High speed rail stations generate land development impacts because their increased activity levels and greater accessibility both makes surrounding property locations more desirable as a place to live or work. That can lead to increased attraction of residential investment and business activity into the area – thus generating localized economic (job and income) impacts. The attraction of greater density and a more diverse mix of activity can also help to make surrounding areas become more livable and walkable— thus generating further SROI impacts. Land development impacts are inherently local, and a function of the degree of change in a station's service level and use level. High speed rail stations have the potential to stimulate development, particularly when those stations are in central business districts. This is because tourists and business travelers are more likely to spend additional time in a lively downtown area than hotels surrounding an airport at the fringe of a large metropolitan region.

Inclusion in Analysis: Effects on increased land development, residential building investment, and business activity around high speed rail stations -- with associated population, employment, income and tax generation -- are generally considered to be localized economic impacts. As such, they are often included in small area EIA studies but not in large area EIA studies. They are not considered in BCA studies because station-area investment often represents a shifting of economic activity among areas within a broader region (i.e., providing no net regional benefit). However, impacts on enhancing development density, encouraging mixed use activity and less sprawled development can all be recognized in SROI studies.

Care must be taken in the characterization of increased property values as a benefit. Clearly, property value impacts can reflect the higher income generating potential of an area or its greater amenity as a place to live. Increased property values can also generate greater tax revenue that can be used to fund local public facilities. However, it would be double counting within BCA and even SROI to consider adding together the value of property value appreciation and the value of access and amenity factors that were also calculated on the basis of property value growth. In addition, higher property values for residential and commercial property can mean higher housing prices and higher commercial land rents – and nobody considers higher prices to be a benefit for those buying or renting the properties. In fact, without an adequate supply of affordable housing, areas surrounding transit stations can become inaccessible to low-income segments of the population.

Application of the Methodology: The calculation of land development and land value impacts can be done in two ways. The more accurate way is via a market analysis which considers (a) the projected regional increase in *demand* for housing and business sites, (b) the *supply* of land and building sites in the vicinity of rail stations and further away from them, and (c) the attractiveness of siting new buildings in the rail station area relative to competing sites. A combination of interviews and real estate statistics can be used to make this determination.

The alternative approach is to apply coefficients, derived from past statistical studies of land value impacts of new rail services, to estimate the likely extent of new land development and appreciation of land values. These are known as "hedonic price models." The research coefficients may be calibrated to adjust for the magnitude of service being introduced, or the magnitude of customer access enhancement. However, they generally do not reflect local real estate market (supply and demand) features.

The Economic Rent Model that was used in the Midwest study is a variant of the statistical coefficient model approach. This model derives a measure of regional accessibility gain, calculates expected GDP growth impact, and then calculates the likely capitalization of that GDP growth in terms of property value gains.

Measurement: Land development impacts may be measured in terms of the increased density of population and employment located (per acre or per 1000 building square feet) nearby stations. They may also be measured in terms of building space per acre, or in terms of land values per square foot.

Sources of Input Data: Land value impacts are currently calculated on the basis of (a) the daily traveler volumes going into and out of each station, and (b) the improvement in market access enabled by the advent of high speed rail service.

Output Results: Outputs generated from hedonic pricing models or similar methods could include changes in property value and tax revenue. Dollars of visitor spending and employment are both additional outputs. Land development impacts of high speed rail will generally represent a net benefit, especially when stations are in urban areas.

Examples of Current Use: A report published by The United States Conference of Mayors estimates station area development impacts in each of four cities with planned high speed rail: Albany, Chicago, Los Angeles, and Orlando (EDR Group 2010). These impacts include spending associated with new passengers originating from and destined for downtown high speed rail stations, and associated opportunities for transit oriented development. The *Midwest Regional Rail Initiative Project Notebook*, published in 2000, estimates the economic benefits derived from induced commercial development around high speed rail stations. These benefits are referred to as economic rents, and include increased property value, income, and jobs.

3.12 Service Operator and Facility Owner Revenues and Expenses (all modes)

Definition: HS&IPR projects can affect net operating costs and revenues for infrastructure owners and service operators across all modes of travel -- including rail, air, bus and car travel. This occurs insofar as the projects can shift demand (volumes of passengers and vehicles) among different modes of travel. This includes the following:

- cost of operations/maintenance and fare revenues for rail operators and track owners
- cost of operations/maintenance and fare revenues for bus operators
- cost of operations/maintenance and fare revenues for airline and airport operators

- cost of operations/maintenance (and toll revenues if applicable) for public and private highways

For instance, a shift of demand from car travel to HS&IPR may reduce total vehicle volumes on highways and hence reduce wear and tear (reducing maintenance cost) for those congested facilities. A reduction in highway or aircraft delays may also reduce fuel consumption and labor-hours wasted for bus service operators, trucking services, and airline operators. Of course, a shift in demand to HS&IPR can also lead to a loss of revenue for bus operators, airlines and or toll road operators.

Inclusion in Analysis: For BCA, changes in costs and revenues are typically summed across all operators and owners, for all modes. That enables a calculation of net societal cost or gain. However, it is recognized that in some cases, these factors represent a net transfer of money among parties (between travelers and operators), in which case there may be zero net gain for society. For EIA, these factors are typically classified in terms of outflow (costs) and inflow (income) accruing to various specific sectors of the economy including households, government and business sectors. FOR SIA, the inclusion varies. These transfer effects may be included in a multiple account evaluation, but they are often skipped in the case of a study focusing on local community impacts or broader environmental impacts.

Measurement: The revenue or cost change is typically measured in annual revenue and expenditure dollars for each affected party – rail, bus, airline, airport and highway service operators and owners.

Predictive Methodology: For each type of owner or operator, the change in total revenue is typically calculated by multiplying the fare or fee paid by the number of affected parties added or subtracted. This is typically done by origin-destination and vehicle type segment, insofar as there are different per capita fares and fees for each of those market segments. The corresponding change in total expenditures is typically calculated by multiplying per unit operating costs by the amount of use (in terms of daily operating vehicles, vehicle trips or vehicle miles).

Sources of Input Data: The data for revenue calculation are traveler forecasts, vehicle occupancy and fare values for each mode and origin-destination market. The data come from both travel demand model outputs (ridership and occupancy forecasts) and model inputs (assumed fares structure by mode). The data for operating cost calculation are vehicle volume, trip and mileage forecasts for each mode, along with unit (per vehicle, per vehicle-trip. or per vehicle-mile) operating cost averages for those modes. For highway maintenance, see NCHRP (2011). For airline operating costs, see FAA (2004).

Output: Dollar values of system revenue and expenditures by mode and operator type (service operators and facility owners) for each year of the analysis period.

4 Benefits Estimation Approaches

Overview. This chapter lays out methods for assessing the economic and broader public benefits of high speed rail and intercity passenger rail (HS&IPR) projects. It covers the three primary forms of economic analysis – all of which provide dollar-based measures of impact: 1) benefit-cost analysis

(BCA); 2) economic impact analysis (EIA); and 3) social impact analysis (SIA). The reason for presenting three forms of analysis is that no single form of analysis can be relied upon to show the full range of effects that people may consider to be desirable and beneficial.

4.1 Benefit-Cost Analysis

Methodology Objective and Approach. "Benefit Cost Analysis" (BCA) refers to the estimation of the social welfare effects from a project. It requires the calculation of a stream of benefits and costs the project accumulates over a specified period, in the form of discounted present values. As mentioned in section 4.1, BCA adopts a "all of society" perspective, and is used widely for making the investment decision for a project.

To get an efficient and unbiased result, it is critical to include all the relevant cost and benefit items in the BCA and ensure that none of the benefits is double counted. The FRA's Benefit Cost Guidance for Rail Projects FRA (2016) is available at https://www.fra.dot.gov/eLib/Details/L17471. The guidance specifies elements of BCA calculation that should be included and describes how to avoid double counting of costs or benefits. It allows for benefits and costs for users, operators, the environment and broader benefits for productivity and infrastructure "state of good repair." Any benefits that do not meet these criteria should not be included in the BCA, but may be considered in economic impact analysis (EIA) and/or social return on investment (SROI) (see sections 4.5 and 4.6).

4.2 BCA Accounting Systems: Analysis Steps

There are five steps for the benefit-cost analysis:

1) Establish a baseline condition for the project. The baseline condition represents how the world would look without the project. It is the condition for which all future forecasts will be compared against. Specification of the baseline condition includes travel demand, its split between existing modes, and the current service quality such as travel time, cost, and service frequencies.

2) Define project scenario(s). For a project scenario, it pertains to specification of the project location and the costs involved in the planning, construction, and operations and maintenance phases of the project. The specification also includes the service characteristics provided by the HS&IPR project once it is complete, including train speed, travel time, and fare.

3) Define the time horizon for analysis. The time horizon for BCA of an HS&IPR project typically goes multiple decades. According to the recent guidance by FRA (2016a), the analysis period of a BCA consists of the full construction period of the project, plus at least 20 years after the completion of construction during which the full operational benefits and costs of the project can be reflected in the BCA. This approach is also consistent with the BCA guidance issued by the U.S. DOT's TIGER Program, and with the FRA's requirement that its Federal funding recipients ensure that project outcomes achieved with Federal funds are maintained for a minimum of 20 years from the date a project is put in service.

4) Estimate the value of total costs and total benefits for future years. Costs are those specified in section 4.2. Benefits consist of three categories: multimodal travel benefits, externality effects, and wider economic (productivity) benefits. They are discussed in greater detail in sections 4.4.2-4.4.4. The value of user (traveler) benefit factors – travel time, cost, reliability and safety – is normally summed over all modes to provide a generalized cost savings metric.

5) Discount the future cost and benefit streams to represent the present value. Discounting of future costs and benefits adjusts for the time value of money, which expresses the principle that costs and benefits that occur in the more distant future are less valued than those occurring sooner. To make a direct comparison of costs and benefits accrued in different years, FRA (2016a) suggests using the discounting rate of 7% per year, which is the discount rate net of inflation rate, and also conducting an alternative analysis using a 3% discount rate for sensitivity analysis. The present value of the costs made during the t^{th} year in the analysis period can be calculated as (the same follows for present value of benefits):

$$PVC_t = \frac{C_t}{(1+r)^t}$$

where PVC_t is the present value of the costs C_t expended in t^{th} year (for present value of benefits, PVB_t, it can be calculated by replacing C_t with B_t). The total present value costs and benefits is the sum of all such PVC_ts and PVB_ts (i.e., $PVB = \sum_{t=0}^{T} PVB_t$; $PVC = \sum_{t=0}^{T} PVC_t$, where T is the length of the analysis period).

6) Calculate the output metrics. Three commonly used metrics are: Net Present Value (NPV), Benefit Cost Ratio (BCR), and Economic Rate of Return (ERR):

- NPV is the difference between the present value of benefits (PVB) and the present value of costs (PVC). A project with a positive NPV is considered "economically feasible".
- BCR is the ratio of PVB to PVC. A BCR value greater than 1 is required to guarantee the economic feasibility of a project. BCR is particularly useful for ranking a set of alternatives: the greater the BCR value, the better the alternative. Thus the BCR values allow for comparing different alternatives of a HS&IPR project, and HS&IPR projects in different regions.
- ERR is the discount rate with which PVB equates PVC, i.e., the NPV of the project is zero and the BCR is one. As a rate quantity, ERR can be used as an indicator for project efficiency: the greater the ERR, the more desirable the associated project. Similar to BCR, ERR enables comparison between alternatives of a HS&IPR project, as well as between different projects. The ERR is calculated by solving the equation $\sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t} = 0$.

4.2.1 Monetizing Multimodal Travel Benefits

Among the three categories of benefits included in BCA, the first one is multimodal travel benefits, which encompass the benefits from an HS&IPR project that accrue to multiple modes including rail, highway, bus, and air. Specific benefits cover savings in travel time and travel expenses, reduction of congestion and reliability, savings in energy resources used, and changes in revenues and expenses of service operators and facility owners. The methodologies for quantifying and monetizing these benefits are discussed in section 4.3.

If there is forecast growth in total travel (trips or mileage), then the valuation of additional demand is set by the "rule of one-half" which assumes a linear demand curve illustrated (Figure 4.1) below (Small and Verhoef, 2007).

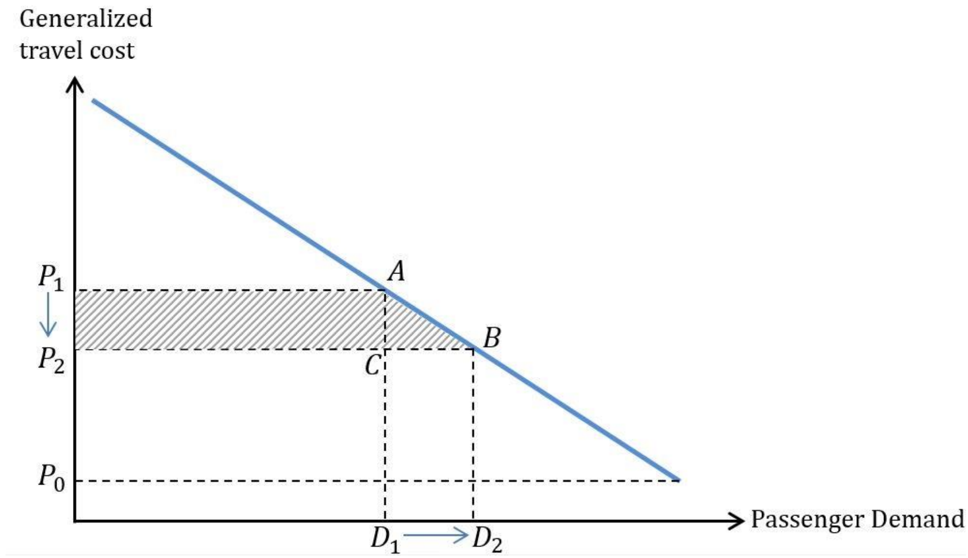

Figure 4.1: Illustration of a linear relationship between HS&IPR demand and the generalized travel cost

If the demand function is specified as a discrete choice logit model, then a "logsum" measure will be used to quantify the generalized cost savings. This is essentially a measure of the generalized travel cost for a representative traveler, under the assumption that the traveler has non-zero probability to choose any available mode. The exact form of the logsum term depends on specification of the discrete choice model. For further details, readers may refer to Train (2009) and Ma et al. (2015).

4.2.2 Monetizing Externality Effects

The second category of benefits is externality effects. The externality effects of an HS&IPR project include improvement in safety of users and operators of all modes, reduction in noise and emissions, and land development impacts. It is important to note that the impacts of land development and noise pollution usually get washed out in BCA as the positive impacts in one geographic area often occurs at the expense of the negative impacts in another geographic area. Again, detailed about the quantification and monetization methodologies for the externality effects are provided in section 4.3.

4.2.3 Monetizing Wider Economic (Productivity) Effects

The introduction of an HS&IPR project also results in wider economic effect, specifically gains in productivity due to improved accessibility and agglomeration economies. The discussions on quantifying and monetizing the productivity effects are given in much detail in section 4.3. It should be noted that the accessibility benefits are also often counted in EIA models.

4.2.4 Presentation of Output Results

The results of BCA can be tables of present value total benefits and costs by category, as shown in Tables 4.1 below. Since multiple years are involved, the results may also be presented in the undiscounted dollars (see Appendix). Besides these more detailed results, one or multiple of the aggregate output measures such as NPV, BCR, and ERR are typically presented which provide an overall indication of the attractiveness of the HS&IPR project under study.

Table 4.1: A Prototypical Presentation for Present Value of Benefits

Present Value of Benefits	Rail	Hwy	Air	NET TOTAL
1. Multimodal Travel Benefits				
Traveler Savings in Vehicle Operating Cost (VOC)				
Traveler Savings in In-Vehicle Travel Time (IVTT)				
Traveler Savings from Improved Time Reliability				
Consumer Surplus from Induced New Travel				
Costs for service operators and facility owners				
Revenues for service operators and facility owners				
2. Externality Effects				
Traveler Safety Improvement				
Carbon (Greenhouse Gas) Emission Reduction				
Emissions Reduction for Other Pollutants				
Noise Reduction				
3. Wider Economic (Productivity) Effects				
Improved Market Access and Agglomeration				
TOTAL BENEFITS				

4.3 Economic Impact Analysis

Methodology Objective and Approach. “Economic impact analysis” (EIA) refers to the measurement of impacts on the economy of a given area at a given point or period in time. The economic impact of a HS&IPR project is calculated by estimating how the economy of the area would be different in a scenario with the project completed, compared to what would be the case in a scenario of baseline (no build) conditions.

To calculate economic impacts, a statistical coefficient model or else a structural economic simulation model is used to forecast effects on growth and change in the economy over time, for each scenario and for the difference between the scenarios. These outcomes are provided in terms of jobs, wages paid, value added or Gross Domestic Project, and business output. In the case of simulation models, there are also estimates of changes in investment, unemployment, wage rates, and effects among various industries and occupations.

EIA is not a substitute for BCA. Rather, it is a complement to it. Effects on economic development, including job generation and income levels, are commonly seen as strategic goals of public policy, alongside environmental and social goals. Effects on addressing these goals or issues is often considered as part of long range plans, project prioritization and environmental impact processes. However, EIA does not compare impacts or benefits to costs. In fact, EIA shows how both expenditures on project costs and as well as productivity and cost savings effects affect the economy of an area. Multi-regional economic impact models can also show how economic impacts are distributed among multiple study areas.

4.3.1 Economic Impact Models: Analysis Steps

There are seven steps required for economic impact analysis:

1) Establish baseline economic conditions and forecasts for the study area (or areas). This includes economic measures (employment, wages, value added or gross domestic product, and output). For the regional simulation models such as REMI and TREDIS, the baseline will also include demographic measures (households, population, school age children, prime workforce-eligible age group, retirees/others).

2) Define project scenario(s). They must include specification of the project locations, and budgets for facility construction, equipment acquisition, operations and maintenance, along with an allocation of that spending over time.

3) Define study area and time horizon for analysis. The study area is typically the area of jurisdiction for the sponsoring public agency, which may be a city, metropolitan planning organization or state. Private business organizations may also be the study sponsor; they too normally have a local, regional or statewide focus of interest. The time horizon for assessing economic impacts of project completion normally goes 30 – 40 years into the future, including at least 20 years beyond the time of project completion. This is advisable since is large rail projects can often take ten years for completion, and economic development impacts often grow over a decade or two after completion of the project.

4) Calculate direct transportation system changes associated with both the baseline scenario (in which there is traffic growth and system performance changes over time) and project scenarios (in which there are changes in supply and demand patterns among modes, routes and transportation services over time. They lead directly to transportation system performance changes which can be expressed in terms of travel volumes, origin destination patterns, travel times, travel cost and volume/capacity ratios (affecting reliability) for various modes, classes of trip purpose and travel corridors. These transportation system changes are forecast for future years using either travel demand models (including trip generation, mode split, trip origin-destination distribution and network route assignment) or "sketch planning" spreadsheet-based engineering estimates.

5) Transform direct transportation changes into economic model inputs. Only some of the benefits and costs of changes in travel have direct bearing on the economy. These must be separated out to provide the input basis for economic impact calculations.

   - For instance, traveler costs savings must be split by trip purpose. The reason is that cost savings for businesses represents a reduction in the cost of doing business, and increases productivity. However, cost savings for households leads to a reallocation of discretionary spending to other types of purchases; there is no productivity gain.
   - Traveler time savings effects must also be split by trip purpose. Time savings for business worker travel and product delivery also represents a savings in the cost of doing business. However, time savings for personal trips does not affect the flow of money in the economy, even though it has a value to people.
   - Additional effects include changes in volume/capacity ratios (affecting travel time reliability) and inter-zonal or inter-city travel times (affecting the breadth of business access to worker and customer markets). These additional effects are sometimes also important to document as they can lead to wider business productivity gains.

6) Apply economic impact models. An economic model translates the forecast of transportation impacts into impacts on growth and change in the economy. The inputs, in all cases, are measures of the number of affected trips, the cost savings value for households and businesses, and other changes in accessibility and reliability for intercity travel. There are two types of economic models that can be used.

   - The simplest models are statistical elasticity models that apply coefficients or (elasticity factors) to directly translate the transportation system changes into GDP effects for the applicable study areas. (The Economic Rent model used in the Midwest study is an example of this approach.)
   - The more complex models are regional economic simulation and forecasting systems. These systems transform the transportation system changes into cost impacts for various elements of the economy (industry sectors), and then calculate broader implications for inter-regional productivity, competitiveness and investment patterns among industries – which ultimately also lead to changes in regional economic growth over time. (The TREDIS model used in the California study is an example of this approach).

7) Report on economic impact results. The outcome of economic impact models is typically a series of changes forecast to occur over time in terms of jobs, worker income, total value added or GDP, and total business output for the study area(s). Depending on the model, there may also be impacts shown in terms of population, government tax and fee revenues, and shifts in growth and change among industry sectors and job occupation classes.

Note: EIA results are normally reported for a specific study area and a specific future planning year, although they can also be shown on a year-by-year basis, if desired. Results are shown in constant (inflation adjusted) dollars but are not discounted as in BCA. The reason is that EIA is intended to show how future economic development will differ under alternative investment scenarios – which is often cited as a strategic policy goal by various local, regional or national agencies. EIA results can show the consequences of both short-term construction impacts and long-term travel efficiency impacts, it can show impacts of spatial shifts in future economic growth patterns, but it cannot show any impacts from non-money benefits nor can it show the relative efficiency of investments. For these reasons, EIA results should be reported as a complement but not a replacement for the efficiency measures in BCA.

4.3.2 Short-term Construction and Operations Spending Impacts

The construction of HS&IPR projects and the operation of services on built systems both require capital expenditure and operating budgets. The spending of these budgets initiates economic activities throughout the area of construction and operation, as well as beyond those areas. The total economic impacts resulting from the expenses of short-term construction and operations can be classified into the following categories:

- Direct impact, which refers to the immediate impact from spending, including the job creation for construction workers, train operators, maintenance workers and administrative staff. Direct impact typically has a small geographic coverage, in the vicinity of the project area.
- Indirect impact, which results from purchase of equipment and facilities such as construction materials, rolling stocks, tracks, station facilities, maintenance equipment, feeder services and power generation equipment. The purchase indirectly supports job in other industrial sectors and also circulate money through trade. The indirect impacts have effect on a wider geographic area as materials can be purchased from other states and foreign countries.
- Induced impact, which arises from spending and re-spending of the wages earned by individuals as the result of the direct and indirect impacts. Examples of induced impact include spending for food, clothing, shelter, and recreational and personal activities. The induced impact covers wide geographical areas.

These impacts are outcomes of spending and have no lingering impact on the economy. They normally last only as long as the spending occurs, and the impacts are normally proportional to that spending. A regional, static input-output accounting model (such as RIMS or IMPLAN) may be applied to calculate the extent to which the various direct, indirect and induced jobs and income are generated and occur within the designated study area within any single specific year. The more sophisticated transportation economic impact forecasting models (TREDIS and REMI TranSight) also incorporate these same input-output tables and automatically show how they take place over time. These models can also show impacts in terms of the associated mix of industries and occupations, and their allocation among multiple regions.

4.3.3 Long-term Cost Savings and Productivity Impacts

The long term economic impact of HS&IPR projects comes as a consequence of the lasting impact on business activity and productivity within some or all of its service area. The total long-term economic impacts can be classified into the following five categories:

(1) Effects of activity shifts – By shifting some transportation ridership among modes, terminal facilities and travel corridors, there will be corresponding spatial location shifts in the pattern of transportation service operations workers and rider-supported retail sales activities. Areas immediately at and surrounding HS&IPR terminals are likely to see growth in retail and service business while other areas may have less see activity growth. These shifts may appear to be significant if the economic impact is assessed for a relatively small (local) study area. They may be imperceptible (and skipped entirely) if the economic impact is assessed for a large (state or multi-state) study area.

(2) Effects of travel cost savings – By saving worker travel time and/or cost, businesses can effectively reduce their cost of doing business. This effect can come as a result of in-vehicle travel time and cost savings, or out-of-vehicle wait time savings that comes from more frequent and more reliable service. Section 4.3 provides further information regarding how to calculate and value travel time, travel cost, congestion and reliability impacts. Since productivity is defined as the ratio of [business output] / [business cost], a reduction in any of these aspects of business operating cost will effectively add to economic productivity. All of the economic models, including both elasticity coefficient models and regional simulation models, can calculate how these productivity gains lead to enhance GDP and job growth. The simulation models can also show effects of shifts in household spending among elements of the economy.

(3) Wider effects of market access enhancement – By linking businesses within the study area to wider customer markets or business-to-business markets, further productivity enhancement can result. There are two types of impact that have been shown by research to produce these additional productivity effects.

    - One is the expansion in the sheer scale or sized of business worker and customer markets, which can produce better worker skill matching and customer service scale economies.
    - The other is the enhancement of travel (lower cost, more frequent and reliable service) between specific city pairs that represent complementary skills and centers of excellence.

    Research in the US, Europe and Asia has shown that these mega-regions can develop as complementary city pairs are better linked, bringing together R&D and education centers, finance and investment centers, and advanced manufacturing centers. Both the elasticity coefficient model approach and the regional simulation model approach can be used to cover market access scale effects. Some of the regional economic simulation models have further capability to address effects of better linking various industries and city pairs.

(4) Broader impacts on economic geography – The preceding three categories of direct impact can lead to further changes in inter-regional spatial patterns of investment flows and industry economic growth. In most cases, there is no actual losses for any region, rather it is that future patterns of growth are shifted among areas as part of a phenomenon known as "economic geography." In some cases, as when HS&IPR projects support mega-region development, the

effects can be deemed important not only for regional economic growth, but also supportive of national economic competitiveness in global economic markets.

(5) Broader tax revenue impacts – The impact of enhanced property values (from #1 activity shifts) and enhanced economic growth (from #2-3-4 cost, productivity and economic geography effects) all lead to greater personal and business income generation. These economic impacts lead to further tax revenue collections for local and state economies. A fiscal impact model can be used to estimate details concerning expected changes in local or state government revenues and costs. The regional economic impact simulation models also incorporate summary calculations of tax revenue impacts.

It should be noted that all of these long term effects of cost savings and productivity gains can provide a lingering impact on the economy of affected regions, since they provide competitive advantages for businesses that continue year after year. The nature of these longer term impacts can only be forecast via a regional economic impact simulation and forecasting model.

4.3.4 Regional vs. Multi-Regional Impacts

A multi-regional economic model portrays the buy-sell pattern of industries trading among multiple regions. It can thus forecast how changes in specific industries in in any one region will lead to further changes in purchases and sales for industries in other regions. The transportation economic impact simulation models that are commonly used in the US also support multi-regional versions that enable this type of impact to be estimated and shown. In some cases, they can show that HS&IPR projects lead to broader economic gains for regions and states that are not even served by the new or improved rail services. This information can be useful to help show the broader benefits of passenger rail investment. On the other hand, care must be exercised in applying and communicating multi-regional impacts, since their results can also be construed to indicate that some regions will gain more than others from any given investment.

4.3.5 Presentation of Output Results

The most common form of economic impact results is a table of impact by year, or for a given future planning year, for the following metrics: jobs, worker wage income (or average personal income), value added or GDP (includes both worker income and corporate net profit income) and business output (total revenues or sales volume). It is important to note that each of the dollar denominated impacts represents a different perspective for viewing the very same economic growth effect. These effects can therefore never be added together. Essentially, value added or GDP represents that sum of worker income and business net profit income. That figure may also be defined as total business output minus he cost of non-labor inputs. Most economists consider GDP to be the most accurate measure of the economic activity occurring in a region’s economy.

4.4 Social Impact Analysis

Methodology Objective and Approach. "Social impact analysis" (SIA) refers to the measurement of environmental and social impacts that are of public policy interest as desired outcomes from public policies or public investments. While it is fundamentally derived from social welfare concepts embodied in benefit-cost analysis, it differs in important ways from the classic BCA calculation method currently practiced by economists., Unlike classic BCA, social impact analysis may include desirable distributional impacts (e.g., helping disadvantaged populations and economically distressed communities), very long term impacts (e.g., enhancing land use and the environment for future generations), and quality of life impacts (e.g., making more livable cities with greater mobility and lifestyle options). Note: BCA studies do not normally assign a benefit value for distributional impacts or inter-generational impacts, and also typically do not assign a benefit valuation for quality of life impacts that may be valued by some but not all stakeholder groups. Thus, social impact analyses provide a means of assessing how a project affects the achievement of long term public planning or policy objectives that are outside of the efficiency accountability perspective of classic BCA.

Since desirable social outcomes sometimes benefit specific sets of stakeholders at the expense of others, these benefits must be represented in one of two formats:

a) in the form of a *"multiple account evaluation" (MAE)* which explicitly lays out many different types of impacts benefitting many different types of stakeholders, without attempting to sum them up, or
b) in the form of a *"social return on investment" (SROI)* analysis, which explicitly focuses on a specific set of stakeholders and then sums up the benefits for them.

The MAE format is typically applied when the benefit analysis covers a range of local, statewide and national level benefits. The SROI format is typically applied when the benefit analysis is focused just on community level benefits – in which case it becomes a clearer and more straightforward process to calculate a sum total benefit.

4.4.1 Social Impact Analysis Steps

There are six steps required for SIA analysis:

1) <u>Define project and baseline scenarios</u>, in terms of the project locations, project construction and completion times, and project costs involved.

2) <u>Identify key stakeholders and scope of study</u>: in terms of who will be affected by the project and the types of impacts to be considered. The stakeholders may be residents living or working in specific locations (e.g., neighborhoods or communities), and/or specific socio-demographic groups (e.g., elderly, low income or minority groups). The types of impacts to be considered may include environmental (air and noise) impacts, quality of life impacts (mobility, accessibility, livability and land use factors), and/or economic (job and income) outcomes.

3) <u>Select the boundaries of analysis</u>: in terms of a specific stakeholder perspective, an applicable spatial area and a time period for data collection and observation of impacts. If there are multiple

stakeholder groups who will be differentially affected, then the appropriate stakeholder perspective will have to be specified to enable a focus on impacts of interest without having them unduly diluted or obscured by mixing them with additional perspectives. The boundaries should be selected to facilitate observation of project affecting the environment, land use, mobility and/or economic conditions at a future point in time. Note that multiple stakeholder perspectives, areas and points in time may be studied, but the associated impacts must be measured separately for each of them.

4) <u>Assess relevant outcomes</u> that will affect applicable stakeholders in a specified area at a specified point in time. This step normally requires a process of "mapping stakeholder outcomes" based on a theory of change that ties the project characteristics and/or its direct transportation impacts to broader effects on environmental quality, land development patterns, access, mobility and economic opportunities for specific stakeholder populations. Outcomes should be estimated based on qualitative assessment and quantitative analysis methods, when possible. The qualitative assessment relies on local expert and stakeholder interviews and observations. The quantitative analysis relies on available simulation models and/or statistical studies that help to predict environmental (air and noise) impacts, land use and land value patterns, and economic (job and income) impacts for a designated area and time.

5) <u>Translate the outcomes into economic valuations</u>, by applying unit valuation factors. These are typically the same valuation factors used in BCA, such the valuation of safety and environmental changes (which reflect medical costs and a value of life) and land valuation factors (which reflect access, noise, and income generating characteristics of locations).

6) <u>Sum and classify the valuation of all relevant outcomes and costs</u>. The value of outcomes should reflect the applicable stakeholder perspectives, areas and times, and the difference between project and baseline scenarios. For Multiple Account Evaluation, the valuation of outcomes may be described in terms of multiple forms of benefit for different parties and locations (perspectives), typically for a given future year. In that case, the benefits are not summed, since they apply to different parties and perspectives. For Social ROI presentation, the benefits may be summed as long as there is a consistent perspective being used (e.g., local community). That total may be compared to the accumulated cost as of the selected time.

Note: SIA is intended to enable a comparison of alternative scenarios in terms of their future outcomes for stakeholder groups. This is different from the efficiency metric in BCA, which combines effects over all areas, groups and times. Accordingly, SROI does not involve any discounting of cost or benefit streams for a net present value calculation. By presenting SROI results in this way, it can be used as a complement to BCA, representing an alternative view in which project proposals are evaluated in terms of investment results (social value) for communities and individuals.

4.4.2 Localized Mobility and Accessibility Effects

HS&IPR projects can make a substantial difference in the availability and characteristics of transportation available to residents of some local communities or areas, and thus also affect their access to health, education, employment and recreational opportunities. Both mobility and accessibility may be affected.

Mobility refers to the availability and cost of transportation options for travel to required destinations, such as medical or education providers. HS&IPR projects may bring pronounced mobility enhancement outcomes particularly pronounced for isolated, rural areas and smaller towns that do not currently have any bus or rail service for access to larger cities. Those residents who do not own cars may have limited options for getting to the larger cities, and the cost of taxi or other services may be prohibitive. For areas that do currently have bus or rail service, the current options for their residents may have severely limited service frequency and long travel times compared to the service provided by HS&IPR. In some cases, the new rail service may also offer faster speed and cost advantages even compared to driving, particularly if a current road route involves slow windy roads, congested routes with bottlenecks, and/or tolls.

The most common method for valuation of mobility impacts of HS&IPR is to calculate the average value of travel time and travel cost savings compared to the next best available option for access from these isolated areas to a major urban activity center that has hospital, four-year College and cultural venues. This value is then to the applicable number of affected parties. For some population and stakeholder groups, the next best option will be driving themselves. For others, the next best option may be a bus or taxi. The method for valuing travel time, expense and congestion/reliability differences is provided in Appendix B.

In some rare cases, there may be no transportation options, or individuals may decide to forego medical care, educational advancement or employment without the project. Those situations are more common for local transit impact studies than for intercity rail impact studies. However, if applicable for certain stakeholder groups, the valuation can be made based on the cost of additional illness due to foregone medical visits, and/or loss of income associated with foregone education and employment, based on the health and safety valuation factors also provided in Appendix B

Accessibility refers to the breadth of available opportunities. Even if residents of various small communities already have car, bus, rail and/or air access to larger cities, HS&IPR projects may expand the set of health, education, employment or recreation opportunities that they can realistically reach for a day trip.

From the perspective of households and individuals, access is viewed in terms of the breadth of shopping, personal business and job opportunities that are accessible within a given threshold of reasonable travel time and cost. From the perspective of businesses, access is viewed in terms of the scale (number) of suppliers and customer markets that can be reached within a given threshold of reasonable travel time and cost. (Access may be alternatively be calculated as a composite index in which there is no single threshold for counting opportunities but instead a formula that measures market opportunities with a "gravity model" exponent to gradually reduce the importance of more distant opportunities.)

The most common method for valuation of accessibility is the estimation of effects on productivity in the economy. There are both statistical equation models and reginal economic simulation models that translate employment accessibility and shopping/personal business accessibility changes into effects on the Gross Domestic Product (GDP) for an affected community or region. (GDP is a measure of worker and business income that is generated in a given area.) Tools to make these calculations are described in Appendix B.

4.4.3 Localized Livability Effects (health, environment, neighborhood activity)

HS&IPR projects can make a substantial difference in factor that residents consider to be elements of local livability. The concept of livability encompasses health and amenity effects associated with a local area's air quality, noise, traffic safety and activity mix. These various effects are discussed below. The general application of livability effects in SIA is to add together the various aspects of benefit. However, care must be taken to avoid double counting since elements of noise, environment and activity mix are derived from "hedonic price" models that derive valuation on the basis of statistical studies that relate them to differences or changes in property values. For that reason, care should be taken to avoid adding property value enhancement impacts with the valuation of noise, environment, and activity mix impacts.

Environment (air quality). HS&IPR can bring changes in modes of travel that affect the mix of transportation equipment technologies used, as well as their fuel mix, vehicle occupancy and vehicle miles of travel. All of these changes have effects on emissions of local pollutants and greenhouse gases. The pollutants (NOx, Sox, VOC and PM) can have regional scale irritant and health impacts that have accepted USDOT accepted annual "per ton" valuations. These greenhouse gas impacts have global rather than regional scale effects, but they also have accepted annual "per ton" valuations. Methods for calculating emission impacts and assigning their valuation are also discussed in Appendix B. The major difference in treatment of environmental impacts in SIA (compared to BCA) is that SIA documents the more severe nature of scenario outcomes in a future time period, rather than showing a net present value in which long term futures are heavily discounted relative to current effects.

Noise. HS&IPR project impacts on noise tend to be highly localized. There may be added noise adjacent to some tracks and rail stations, as well as slightly reduced noise adjacent to some highways and airports. In all cases, noise impacts (in terms of decibels) are estimated on the basis of the volume of vehicles passing by, the vehicle propulsion technology used, and the distance from homes or business locations to the tracks or stations. There are widely accepted methods for calculating noise impacts an applying valuation factors to them, as described in Appendix B. The major difference in treatment of safety impacts in SIA is that it typically focuses on highly localized impacts in a specific affected area, which elevates the potential importance of this effect. (Most BCA studies assess effects for broader regions, in which case noise impacts are most often treated as relatively small and usually ignored.)

Safety. HS&IPR project impacts on safety include both traveler impacts and local resident impacts. The rider impacts are directly related to changes in modes, vehicle volumes and miles of travel -- for applicable rail, car, truck, bus and airplane travel. The local resident impacts are determined by the extent of road rail crossings and pedestrian/car activity on specific routes. There are accepted collision, injury and death rate averages for specific classes of roads and road/rail crossings. There are also accepted valuations for vehicle damage, injury and death outcomes. These factors and calculation methods are described in Appendix B.

Neighborhood activity mix. The concept of livability is also affected by the visual look and 0resident activity characteristics an area and the extent to which residents can access nearby activities including recreation, culture, shopping and/or recreation destinations. These factors are not independent; thriving neighborhoods that feature significant resident activity opportunities are also likely to be deemed as more attractive for residents and have less crime and visual blight. In the context of HS&IPR projects, these type of livability factors tend to be affected insofar as the projects affect the pattern of development surrounding stations or alongside other facilities. The most common effect is for a HS&IPR project to support a higher density and mix of activities surrounding rail station stations. That can be in the form of transit oriented development or other mixed use development. Methods for assessing impact on adjacent land use and development are described in Appendix B.

4.4.4 Localized Prosperity Effects

HS&IPR projects can make a substantial difference in the prosperity of local communities as a consequence of attracting more local businesses and residents to communities that enjoy improved accessibility and savings in travel costs.

Job and Income Effects. Effects on growing jobs, reducing unemployment and increasing local income levels can be calculated for specific local areas and specific future times by use of an economic impact simulation model that is tailored for a study area defined as the local community. The application of these models is discussed further in Chapter 5.

Wealth Effects. It is also possible to calculate impacts on property values for local landowners. In general, this is considered an effect on asset wealth rather than increased income or prosperity. There are two reasons for this. First, homeowners who live on their property do not gain any income from higher property values, and in fact they may pay higher property taxes as a consequence. Landowners who rent out their land and buildings do receive higher net income from enhanced property values, but that money comes from their tenants who pay more rent and hence end up with less net spendable income. So it may be a net zero effect for local residents, or even worse if not all landlords are locally based. In some cases, higher property tax receipts may help to support more local investment in education, parks and other urban amenities. However, those outcomes must be supported by further evidence before being claimed. Most often, property value impacts are ignored as overall benefits, though property value studies are commonly used to help justify the valuation of various livability factors.

4.4.5 Long Term Sustainability and Resilience Effects

SIA analysis can have another use besides documenting local community benefits, and that is to support broader sustainability and resilience benefits for wider populations. HS&IPR projects can affect these outcomes in the following ways:

- HS&IPR projects provide mode and route alternatives (options) that can be used in the event of a short-term or long-term road closure that is caused by unexpected weather events, traffic collision incidents, special event emergencies or infrastructure facility failures. That increases resilience of the transportation system. The added flexibility of options for travelers can also reduce the adverse consequences of making necessary repairs to specific infrastructure elements.

- HS&IPR projects can redistribute demand across a broader set of facilities, thus lengthening the effective lifespan of other road, aviation and rail infrastructures by reducing demand levels placed on them. That can make transportation infrastructure more economically and physically sustainable over a long time period.
- HS&IPR projects involving electrification of rail service can also help lead to more use of diverse solar, wind, biomass and hydropower sources to power transport. This can also support greater energy security for the US.
- HS&IPR projects can support higher density development of the urban areas that it links and serves, which can potentially help to reduce sprawl and preserve more natural habitats.

4.4.6 Presentation of Output Results

SIA results should be presented with explicit disclosure of the stakeholder perspective, boundaries of analysis and mapping of impacts to consequences. The analysis should be presented as providing useful information regarding the social value of investment results for local communities. It should normally be seen as a complement to – and not replacement for – economic impact analysis (EIA) and benefit cost analysis.

5 Recommended Framework for Social Return on Investment

The various costs, benefits, and impact elements have been exhaustively catalogued in this report along with a comprehensive look at the different strands of benefits estimation (BCA, EIA, and SIA). There are distinct differences between the three approaches and each of them brings a different and unique dimension to capturing the nuances of return on investment. This chapter takes a comprehensive look at all these approaches and recommends a framework for establishing a business case Return on Investment (ROI). The business case ROI is an amalgamation of the various approaches discussed with certain boundary conditions as well as a segmentation by audience type. It includes all of the monetizable benefits over the life of the project. The next section discusses the various objectives and perspectives that need to be kept in mind along with the guidelines for selecting the appropriate analysis methods for estimating specific impact elements.

5.1 Guidance on Using the Framework

5.1.1 Clarifying Objectives and Perspectives

To understand the reasons why multiple forms of economic analysis can be useful, it is useful to first consider the range of relevant impacts that HS&IPR projects can potentially provide. The impacts span:

a) A wide set of *spatial scales* (study area effects) – ranging from national productivity effects and megaregion economic development to local city growth and localized station area development.

b) A wide set of *temporal scales* (time periods) – ranging from short-term construction impacts to medium-term traveler cost savings to multi-generational, strategic policy effects on the evolution of economies, land development patterns and the environment.

c) A wide set of *distributional shifts* that are deemed socially desirable – ranging from effects on investment and income growth in inner cities and/or distressed rural areas, to effects on spurring high tech business clusters to make affected cities more competitive in global markets.

There is also wide range of *perspectives* from which these effects can be viewed and measured – including the perspective of travelers, the perspective of public agencies, the perspective of investors, and the perspective of "all of society."

No single measurement method can encompass all of these dimensions of analysis and perspectives. In general, all three methods can be considered to be different ways of viewing project effects or benefits. For instance, the specific methodology that is formally defined by economists as BCA is set up to provide a measure of the investment efficiency. As such, it provides a net present value of benefits, in which long-term effects are discounted and multi-generational benefits are ignored. BCA also adopts an "all of society" perspective, in which effects that shift investment and development patterns are considered to be zero sum distributions among parties, even if they are strategic public policy goals.

EIA and SIA, on the other hand, do not discount future effects, but rather, examine outcomes for a designated future year and measure them in "constant dollars" that allow comparison with today. Both of these methods also adopt specific stakeholder and study area definitions intended to align with various public policy perspectives. EIA represents effects on future economic development (job and income) outcomes for a designated area, which may be a small local area, an entire state or even a multi-state region. SIA can represent a broader set of social and environmental outcomes achieved from the viewpoint of specific stakeholder groups, which can be local neighborhood or city residents.

It is important to note that these three methods are NOT substitutes. Each one addresses a very different set of issues. The selection of analysis method must be determined based on the questions being asked. In many cases, EIA and SIA are viewed as supplements to BCA. Used together, they enable more informed decision-making that can consider both (a) the efficiency of alternative investments and (b) the achievement of strategic public policy goals that are also part of the business case for public investments.

5.1.2 Selecting among available analysis methods

Treatment of various impact elements. A common set of direct impact factors drive BCA, EIA and SIA studies. However, these direct impacts are treated differently by the various methods. To illustrate this point, consider the chart below, which covers most impacts associated with HS&IPR

projects. This is illustrated in Figure 5.1, and bulleted notes which follow (drawn from Weisbrod and Duncan 2016).

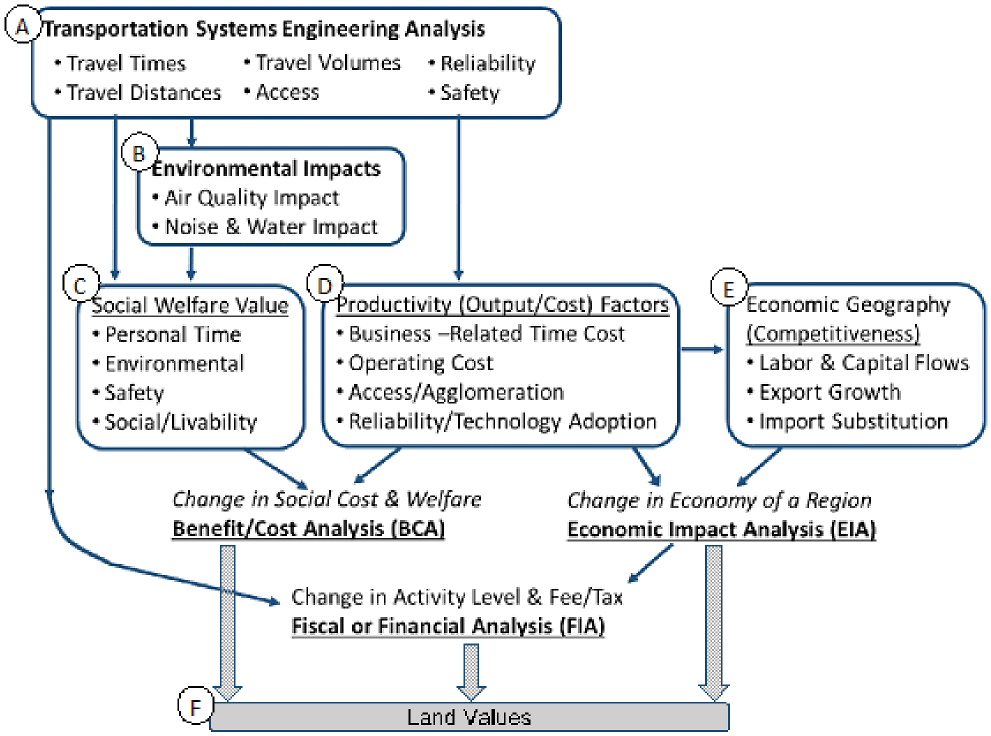

Figure 5.1. Illustration of HS&IPR Impacts

The chart shows several key relationships:

- Both economic impact measures and societal (social welfare) benefit measures are fundamentally driven by the same set of transportation system changes (Box A in Figure 5.1).
- While transportation system cost and access changes directly affect users (Box A), they can also drive a variety of non-user impacts – including effects on the environment (Box B), on productivity in the economy (Box D) and on social welfare (community livability) benefits for residents that do not directly affect the economy (Box C).
- Transportation changes may benefit some elements of the economy or some areas more than others. Shifts in productivity and competitiveness can lead to "economic geography effects – i.e., spatial shifts in economic growth patterns (Box E), which may be deemed beneficial or non-beneficial.
- Benefit-Cost Analysis (BCA) and Economic Impact Analysis (EIA) capture different elements of these various impacts. BCA captures social welfare benefits (boxes C and D), while EIA captures economic impacts (Boxes D and E).
- Any of the various facets of societal benefits and/or economic impacts can also lead to localized effects on land development and land values (Box F). Changes in land value are viewed as

representing the "capitalized value" of current and expected future societal benefits and economic income effects on a specific area.

- Social Impact Analysis (SIA) can capture any of the elements applicable for BCA and EIA, as well as impacts on land values and developments; however, it requires that a specific stakeholder and temporal perspective be selected to view these broader community outcomes.

A key point to note, though, is that all of the social, productivity and economic geography impacts are consequences of project investments and their direct effects on transportation systems and travel patterns. For that reason, it is critical that the analysis stage is set by correctly defining transportation impact scenarios.

Treatment of cost factors. Each scenario will also have an associated level of public and private sector spending on project development, construction, and ongoing (post-construction) expenditures for operations and maintenance of facilities and services. The additional rail-related costs for HS&IPR projects are obviously an important element of the alternative scenarios. However, in some cases there may also be differences in future aviation and/or road system costs, particularly if the rail projects either (a) require rebuilding or reconstruction of some airport or road facilities, or (b) save operating costs for other modal facilities due to diversion of some users away from those other modes.

The cost factors will be applied differently in the application of each analysis method. BCA requires the development of a total cost stream for all future years under each scenario, and then it calculates the discounted present value of the cost stream. This cost is compared against the present value of a social welfare benefit stream, to measure investment efficiency. SIA, on the other hand, may compare each scenario's social, economic and environmental outcomes in a defined future year against the cumulative cost incurred as of that year, to allow for comparison of the future outcomes for alternative scenarios. EIA provides yet another view of cost, as it measures how project development, construction and completion all lead to effects on jobs and income that vary depending on the future year being considered.

5.1.3 Setting the Stage: Correctly Defining Scenarios and Mode Split Categories

The elements of a scenario. All three methods applicable for assessing proposed HS&IPR projects require a comparison of project outcomes against a realistic alternative referred to as the "baseline." (Figure 5.2 which follows, illustrates the comparison between a project and a baseline impact on the economy.)

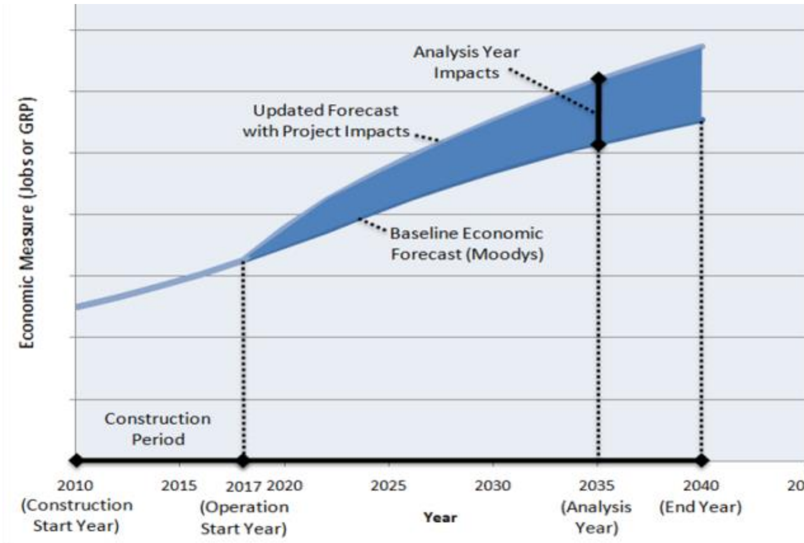

Figure 5.2. Comparison between Project and Baseline Impact on Economy

In actual studies, there may be multiple project scenarios but normally they will all be compared to the same baseline. Each scenario requires, at a minimum, the designation of costs to be incurred and transportation impacts to be achieved under alternative scenarios. The transportation impacts under both project and baseline scenarios must be forecast using either formal travel demand models or engineering-based "sketch planning" impact models. Either way, these models calculate effects on traveler mode and route choices, their time and cost consequences for travelers, the volume of travelers affected, and expected changes in travel behavior outcomes for all relevant scenarios.

Defining the spatial and temporal scale of analysis. Normally, project cost and transportation impact metrics cover a specific period of time into the future and a specific area of study. Either way, the travel model will explicitly encompass some spatial (state or multistate) transportation network, and will forecast expected impacts on travel for some period of time into the future. Both the area of study and the time period should be large enough to encompass most relevant costs and impacts, but not so overly broad as to dilute the measurement of impact.

Defining a baseline scenario. The baseline scenario must be clearly defined, and represent how the way the world would look without the project. Normally a "no-build alternative", in which the existing infrastructures are maintained to keep the current service quality, is often considered as a realistic baseline. The baseline scenario is also expected to consider future changes such as the economic growth, increased traffic volumes, growing population, and projected passenger traffic and freight shipping flows. The baseline scenario is further expected to assume reasonable and sound management practices.

A "do nothing" alternative, in which current infrastructures are allowed to decay, is not acceptable. US DOT guidelines make it clear that a baseline scenario in which the operator (e.g., a railroad or highway agency) does not perform infrastructure maintenance may not be considered as it will affect the outcomes of the economic/public appraisal of a project. Although guidance from both FRA USDOT suggest the "no-built alternative" as the baseline for assessing rail projects, any other capacity expansion alternative (e.g., increasing train service frequencies, expanding the capacity of a competing highway or an airport) could also be considered as a baseline scenario (FRA 2016a and USDOT 2016a).

Defining modal impacts. For all scenarios, the transportation impacts must be estimated for all relevant transportation modes, particularly since HS&IPR projects nearly always involve the attraction riders from other modes of travel, which may include cars, buses, aircraft or other rail services. The calculation of changes in travel times and travel costs for travelers must then be compared under both baseline and project scenarios for all applicable mode-scenario combinations.

For example, if calculating travel time savings for rail riders, there should be comparison of travel time with the new or improved rail service against the travel times that they would experience if still relying on their previously used car, air or rail travel options. If calculating travel time savings for remaining auto travelers, then travel time for auto travelers would be compared under "no build" conditions in which roads might be congested, against faster travel times that may apply if roads became less clogged due to some travelers switching from cars to trains.

Note that in some situations, there may be relatively few riders forecast to switch from existing air, bus or rail services, or some of those other options may not actually exist. In that case, the analysis may focus just on primary modal options such as car travel.

Treatment of Supplier responses and induced demand effects. Four additional methodological points are worth noting in travel demand modeling:

- *Modal competition*. In many intercity travel markets, rail faces competition from commercial aviation, driving, and intercity bus services. Modal competition affects travel demand split between rail and non-rail modes. For example, airlines will adjust fare and service frequency to maximize profit in response to the introduction/improvement of HS&IPR services. A complete modeling framework for travel demand should account for the supplier responses of rail and non-rail modes as part of a continuing modal competition.

- *Induced demand for HS&IPR*. After a new HS&IPR service is in place, some travelers who would not travel may will be encouraged to use the new HS&IPR service. Others who use the new service may be induced to travel more frequently. Induced demand benefits accrue to travelers new to the intercity market and supports increased economic activity (for both business and leisure travel). However, it also adds to the overall system congestion.

- *Induced demand for air, bus, and auto travel*. As some air and highway travelers shift to rail, congestion on the highways and at airports may be reduced which leads to improved service quality of the two modes. However, the effect may be reduced or offset if more travelers are induced to use air, bus, and auto modes.

- *Assumption of feeder services.* New and expanded intercity train services can call for, or support, additions and changes in local transit feeder services. Most travel demand models do not make any assumptions about the presence of feeder services. The number of trips made will, however, depend on the presence/absence of the feeder services that connect to the HS&IPR. In some cases, additional costs may be incurred to support local feeder services. In other cases, local transit services may merely be redirected or restructured to better support local transit feeder routes to support intercity rail services.

5.2 Framework for Overall ROI Calculation and Presentation

The calculation of impact results reflects varying spatial areas and impact times, and is measured in terms of both time streams and a future outcome year, reflecting the perspectives of BCA, EIA and SIA as discussed in Chapter 4.

Application Framework. *Note to reviewers: As we completed the illustrative examples (Appendix C), the study team realized the need to enhance the discussion of reporting methods. Additional text on reporting methods is shown below.*

A key aspect of the overall benefit reporting examples is to show how different perspectives can be recognized through a multiple-account system that recognizes different constituencies and frames the measurement of benefits as seen by them. This is important because different benefit elements dominate public policy over different spatial scales. This is demonstrated by Table 5.1.

Table 5.1. Various Perspectives of HS&IPR Evaluations

Perspective	Constituency	Public Policy Talking Points (dominant benefit issues)
National Benefit	US (taxpayers, residents and business)	HS&IPR saves time, expense and improves safety for travelers. It also enhances national productivity and hence GDP. In some cases, it can alleviate or delay upgrade investment needs for aviation and highway systems. It can also reduce greenhouse gas emissions and increase independence from imported fuels.
Regional Benefit	State (tax-payers, residents and business)	HS&IPR enhances efficiency of the state's highway, rail and aviation facilities. It also effectively enlarges labor and business markets (which create agglomeration benefits), leading to more economic activity and tax base growth over time.
Local Benefit	Station area, city or metro (taxpayers, residents, business)	HS&IPR supports growth (of jobs, income & investment) in areas around HSR stations, particularly downtown business districts. Visitors may also dwell longer and spend more money in the city if entering downtown rather than at an outlying airport
Owner/ Operator	Public and Private Owner & Operators	HS&IPR generates revenues and expenses for rail facility owners and operators. Fares reduce the net expense. Services operators who use and/or maintain air and road facilities may also see changes in use affecting their operating net revenues and costs.

A key takeaway point from Table 1 is that some localized economic and community development impacts that would be dismissed as "distributional effects" in a strict national benefit-cost view may indeed be recognized as benefits for residents. In some cases, those local benefits may also be socially desirable from the viewpoint of state or national public policy. In addition, owner/operator impacts can matter, particularly as they affect net public sector spending requirements and the viability of privately provided services.

Table 5.2 below lists the various benefit and impact elements covered in Chapter 4, and shows how they relate to the spatial scales defined in Table 1. For each element, the spatial scale at which it tends to be largest and most widely recognized is denoted by "XX." Other spatial scales at which it is commonly recognized but tends to be seen of lesser value is denoted by "X." For instance, travel time savings is greatest at when viewed at a national scale representing all travelers, and tends to be of lesser magnitude when viewed only from the perspective of one state or region's residents. On the other hand, station area development benefits tend to be greatest when viewed from a local perspective, with diminished value when seen from a state or national perspective. While these exact patterns do not always apply to all studies in all cases, the basic point is that the same elements may be seen to have different value at different spatial scales.

Table 5.2. Significance of Benefit Categories to Different Evaluation Perspectives

1. Travel Benefits	**National**	**Regional**	**Local**	**Owner/ Operator**
A. Travel Time	**XX**	X	X	
B. Travel Cost	**XX**	X	X	
C. Reliability	**XX**	X	X	
D. Consumer Surplus from Induced New Travel	**XX**			
2. Broader Societal Benefits	**National**	**Regional**	**Local**	**Owner/ Operator**
A. Safety Impact	**XX**	X	X	X
B. Noise impact	X	X	**XX**	
C1. Reduction in Greenhouse Gas (CO_2)	**XX**			
C2. Emissions Reduction for Other Pollutants	**XX**	**XX**	**XX**	
D. Energy Resources: Oil Import Reduction	**XX**			
E. Accessibility Benefits (agglomeration economies)		**XX**	X	
3. **Other (Local, Government, Operator) Impacts**	**National**	**Regional**	**Local**	**Owner/ Operator**
A. Station Area Land Development			**XX**	
B. Regional Economic Development			**XX**	
C. Government Revenues from Taxes		X	**XX**	**XX**
C1. Service Operator and Facility Owner Costs				**XX**
C2. Service Operator and Facility Owner Revenues				**XX**

Note: XX = largest effect seen; X = lesser effect seen

Another important aspect of the various perspectives shown earlier in Table 1 is the matter of timing. These benefits or impacts may be classified into two groups, as defined below and shown in Table 5.3:

- Recurring effects (measured by the "present value" of time streams). These effects occur immediately and continue every year, though they may gradually grow or diminish over time due to gradual demand growth or supply performance degradation. Most notably, they include effects on time savings and cost savings for travelers, and associated revenues and expenses for owners and operators of transportation facilities and services. These benefits may be effectively viewed from the accounting perspective of BCA, which calculates a discounted "present value" of annual recurring benefit and cost streams.

- Cumulative effects (measured by a future year "outcome"). These effects develop over time, as the cumulative consequence of all prior year effects. Most notably, they include effects on the evolution of the environment, land use and economy of an area. These effects are non-symmetric over time; i.e., once they are degraded, it can be harder to reverse losses than to avoid them in the first place. For that reason, these benefits are commonly viewed from the accounting perspective of EIA and SIA, which typically portrays the expected cumulative outcome in a selected future year (without any discounted present value adjustment).

Table 5.3. Significance of Benefit Categories to Different Measurement Approaches

1. Travel Benefits	**PV (Stream)**	**Outcome (Year)**	
	BCA	**EIA**	**SIA**
E. Travel Time	**XX**	**XX**	X
F. Travel Cost	**XX**	**XX**	X
G. Reliability	**X**	**XX**	X
H. Consumer Surplus from Induced New Travel	**XX**		
2. Broader Societal Benefits	**BCA**	**EIA**	**SIA**
C. Safety Impact	**XX**	X	X
D. Noise impact	X		**XX**
C1. Reduction in Greenhouse Gas (CO_2)	X		**XX**
C2. Emissions Reduction for Other Pollutants	X		**XX**
F. Energy Resources: Oil Import Reduction			**XX**
G. Accessibility Benefits (agglomeration economies)	X	**XX**	**XX**
3. **Other (Local, Government, Operator) Impacts**	**BCA**	**EIA**	**SIA**
D. Station Area Land Development		**XX***(a)*	**XX***(a)*
E. Regional Economic Development		**XX**	
F. Government Revenues from Taxes		**XX***(b)*	
C1. Service Operator and Facility Owner Costs	**XX**	**XX***(b)*	
C2. Service Operator and Facility Owner Revenues		**XX***(b)*	

Note: XX = widely included in this form of analysis; X = less frequently included; (a) = used primarily in local impact studies; (b) = included in fiscal impact extensions of EIA studies

5.3 Social ROI (targeted for specific audiences)

Proof of Concept. The two illustrative cases: California High Speed Rail, and the Midwest Regional Rail (Appendix C) demonstrate how different impacts of HS&IPR – which occur at different spatial scales, at different points in time, and for different stakeholders -- can in fact be identified and measured. They also demonstrate how the various impact elements can be represented in quantitative terms, expressed as monetary values, and interpreted as benefits when viewed from various spatial or stakeholder perspectives. A reasonable case can be made that much of our public policy tends to recognize benefits across spatial scales, such as the national government interest in supporting the growth of communities and regions (particularly when they are not already thriving and already overwhelmed with too much economic growth).

Opportunities for Improvement. To varying degrees, these illustrative cases also show that there is room for improvement in future studies by further expanding their breadth of coverage and completeness (beyond that already done by some past studies). The areas for improvement fall into five categories where existing studies tackle these issues but in a less complete way than could be done in the future:

1) *Modes and Study Areas*: inclusion of all relevant modal alternatives and spatial scales in the benefit calculations, treated in an internally consistent manner for valuation of benefits;
2) *Access Benefits:* calculation of regional access benefits to include not only the scale of same day markets (agglomeration effect), but also benefits associated with improving connectivity between cities, connectivity to airports, and expanded tourism markets;
3) *Community and Economic Development:* clarification to distinguish local and regional benefits of attracting more inward investment and business activity (especially into areas where it is most needed);
4) *Productivity Benefits:* measurement of the business value of increased travel time reliability that enables more effective business processes; and
5) *Local Land Development:* benefits of achieving greater clustering of development around station areas, and more vibrant downtown areas.

Implications for Recommended Practice. This Section demonstrates that a wide variety of HS&IPR benefits can be measured and valued from different viewpoints. It also demonstrates that it can be both possible and informative to adopt two fundamentally different ways of viewing benefits: (a) from the viewpoint of today's "net present value" -- for consideration of recurring benefit and cost streams, and (b) from the viewpoint of desired future "outcomes" – for consideration of cumulative effects that will affect the future of our society and subsequent generations. Both are important. The illustrative calculation examples provided in Appendix C, demonstrate that both views can be calculated, though the two cannot be simply added together in one overall benefit calculation.

As shown in Appendix C, the individual benefit elements that are calculated, can support at least three different types of BCA calculations:

- The classic BCA framework, as reflected by FRA guidance, provides a consistent measurement of the efficiency of investments that is generally corresponds with that of other transportation administrations (FHWA, FAA and MARAD). It adopts a "society wide" view that treats government and private sectors equally. Thus, fare collection is a transfer among parties that can be ignored. It also ignores distributional equity as well as cumulative and inter-generational impacts, though there is no real disagreement that these other factors are still relevant for relevant public policy. For that reason, the classic BCA is commonly used as one part of a larger decision framework that also considers these other effects.

- An alternative BCA framework adopted in the UK and Australia recognizes government as an interested party representing public interest. Accordingly, it adds business productivity gains and associated tax revenues as benefits, and considers public tolls and fares collected by government as reductions in required public funding for a project (as well as a factor reducing cost savings for travelers).
- A third perspective that adopts the view of local or regional residents. From this perspective, effects on generating more livable and attractive communities is also seen as a benefit, particularly insofar as it attracts investment to create more jobs and income. With this perspective, the value of income or GDP associated with development of transit oriented development clusters at station areas, as well as other economic growth in surrounding areas, is a local benefit. From a national policy perspective, this result may also be a desirable outcome, particularly if no other party is "harmed." [1]

The recommended presentation format lays out a distinction between the following four categories:

1) Transportation system effects, which may include net time, cost, reliability and productivity benefits for all business and personal travelers using HSR and all other modes. These are annual benefits that grow over time as population and economic activity grow.
2) Societal benefits of national scale importance, which may include benefits affecting non-users as well as travelers. They include safety, greenhouse gas reduction and energy security (reduced reliance on oil imports from abroad).
3) Regional benefits of potential state or national significance, which may include both regional market access and intermodal connectivity effects, as well as pollution emissions that affect regional air quality.
4) Local area benefits of potential local, state or national interest, which may include noise reduction impacts, as well as desired station area development and broader economic growth impacts (that reflect impacts on improving the livability and economic competitiveness of cities and metro areas).

This four-part categorization makes it possible for analysts to select the desired spatial and stakeholder perspective, and then add those elements of the above four lists that are deemed to be socially relevant for that perspective. In effect, it allows for inclusion of desired local and regional

[1] In the classic BCA framework, any attraction of investment into an area is a shift from elsewhere, and hence a zero-sum outcome. However, in normative economics, which considers public values, it is not necessarily a zero-sum outcome. For instance, if a project brings economic activity to an area that has heretofore received less than its "fair share" of economic growth (relative to outcomes occurring elsewhere), then most people would consider the added income to be a benefit that has not necessarily harmed others. This is particularly true if areas not receiving this benefit experience no actual loss of income, but just a smaller rate of future growth than would have happened if their formerly disproportionately high share of growth had continued.

transfer effects to be counted as publicly desired benefits, as part of a more inclusive Return on Investment (ROI) calculation.

Appendix A: Literature Review

Development of high-speed rail (HSR) and other forms of intercity passenger rail (IPR) services benefits the society in numerous ways. The literature has seen a number of studies looking into various benefits generated by HSR&IPR development. These studies include, but are not limited to those that attribute benefits such as:

- provide passengers with a convenient, comfortable, and reliable mode of travel;
- increase productivity for business travelers;
- catalog huge safety benefits as it eliminates numerous fatalities of car accidents;
- is affordable and safe for a large group of consumers;
- reduce highway congestion, with highway users enjoying greater degrees of comfort and mobility;
- release rail capacity to freight transport and shorter distance passenger services;
- create diverse jobs nationwide required for building and maintaining new rail infrastructure and manufacturing train equipment;
- is less dependent on oil and thus reduces the risks from possible oil price increases;
- reduce trade deficit each year, as the result of reduced oil import;
- contribute to mitigating climate change as it helps reduce fossil fuel consumption and resulting emissions, etc.

This section reviews these studies to understand the specific benefits and impacts covered in the various economic analysis of high-speed(HS)&IPR service development, and the ways that different types of impacts are categorized and modeled. Specifically, three types of studies are considered: benefit-cost analysis (BCA), economic impact analysis (EIA), and social impact analysis (SIA). This section will particularly help to accomplish Task 4, i.e., methodology development, as it gives insights on selecting appropriate impacts and benefits for each study type. In addition, this section sheds light on how each impact/benefit is modeled in the literature. For each study type (BCA, EIA, and SIA), we identify the following issues:

a- The range of study objectives and target audiences;
b- The range of different types of benefits and impacts covered;
c- The breadth of the scope of study in terms of covering different modes (HSR, other forms of intercity rail, and other non-rail modes);
d- The breadth of the study in covering geography, both in the US and abroad;
e- How broad a study is in covering perspectives (ex ante vs ex post research);
f- The range of different estimation or measurement methods used

Benefit-cost analysis of rail services

In this subsection, we review the literature on benefit-cost analysis (BCA) of IPR and HS&IPR services. BCA is a technique for combining both money savings and non-money benefits and portraying them in terms of an overall net present value. It can span benefits to HSR users, travelers using other modes and non-travelers (externality impacts). The first step in conducting a BCA is to quantify each type of impact, translate it into monetary units, and then portray it as a stream of benefits and costs over time. Finally, a discount rate is used to roll up future costs and benefit streams into a "net present value" (Banister and Berechman, 2003).

While BCA has a well-determined procedure, there exist very few guidelines for incorporating different benefits and impacts of rail services into BCA. According to FRA (1997), only a benefit/impact which has all of the following criteria could be considered in BCA:

- **Immediately quantifiable in practical terms:** data for the impact must be available at an appropriate detail and well-accepted methodologies for quantifying the impacts in practical terms must exist.
- **Monetizable:** the impact/benefit must be expressible in dollar terms in a straightforward manner. FRA considers noise pollution, impacts on water quality, community disruption, effects on endangered species habitat, and impacts on wetlands as non-quantifiable and non-monetizable impacts.
- **Not duplicative:** no impact could duplicate other benefits and impacts. For instance, congestion-driven airport delay costs to airlines and travelers and the value of deferred airport expansions are actually two ways of assessing the same effect; therefore, incorporating both of them would be double counting. FRA further recognizes highway investment deferrals and energy savings as other examples of double counting.
- **Not a transfer effect:** an impact representing "a reallocation of infrastructure investments and economic benefits from one geographic area or type of project to another" cannot be incorporated into BCA. Economic multiplier effects of HS&IRP construction, operations, and station area development are typical examples of transfers, according to FRA (1997).

In this report, we review the studies presented in

Table . This table further documents the ridership forecasts for each study. In some cases, ridership may be substantially overestimated (GAO, 2013; Reason Foundation, 2013). Considering the fact that the total benefit of a rail project is directly a function of the forecasted ridership, overestimation of the riders could lead to a highly inflated benefit cost ratio (BCR).

Table A.1: The list of the reviewed BCA studies

Abbreviation	Description	Annual ridership		Reference
		Ref. year	Passengers in million	
California	California High-Speed Rail	2060	42.5	PB (2014)
Midwest 1	Midwest Regional Rail Initiative	2025	14.8	TEMS (2004)
Chicago-Iowa	Chicago to Iowa City High-Speed Intercity Passenger Rail	Average annual	0.33	HDR (2010)
Florida 1*	Florida High-Speed Ground Transportation	2036	7.87	Lynch (2002)
Texas 1	Fort Worth to Austin High-Speed Rail Project	2035	3.1	TxDOT (2014)
Mountain 1 **	Rocky Mountain High-Speed Rail	2045	49.17	TEMS (2010)
Spain	High-Speed Rail in Spain	1996	1.44	De Rus and Inglada (1997)
Norway	High-Speed Rail in Norway	2043	3.66	Atkins (2012)
UK	High-Speed Line in the UK	2031	52.56	WS Atkins (2001)
China 1	High-Speed Rail in China	NA	NA	Wu (2013)
DC-Richmond	Washington – Richmond High-Speed Rail	2035	0.74	Hamilton et al. (2010)

Abbreviation	Description	Annual ridership		Reference
		Ref. year	Passengers in million	
China 2	High-Speed Rail Link between Hong Kong and China	2016	36.14	Tao et al. (2011)
Northeast 1	High-Speed Rail in the Northeast Corridor	2040	17.7	Amtrak (2010)
Cal-SNCF	HSR in California: proposal of French National Railways	2030	54.6	SNCF (2009b)
Florida-SNCF	HSR in Florida: proposal of French National Railways	2040	20.71	SNCF (2009c)
Texas-SNCF	Fort Worth/Dallas – San Antonio HSR: proposal of French National Railways	2040	15.13	SNCF (2009a)
Midwest-SNCF	HSR in Midwest: proposal of French National Railways	2040	43.93	SNCF (2009d)
Richmond-Raleigh***	High-Speed Rail in the Southeast Corridor (Richmond, VA to Raleigh, NC)	2020	36.5	FRA (1997)
Cle-Cinti#	Cleveland-Cincinnati HSR	2035	1.68	TEMS (2001)
Minnesota##	Twin Cities-Rochester HSR	2039	4.3	TEMS (2003)
Atl-Char###	Atlanta to Charlotte Rail corridor	2050	6.30	GDOT (2015)
Minnesota	Twin Cities to Duluth HSR	NA	NA	MDOT (2016)

* Ridership forecast pertains to the 250 mph scenario on the Tampa-Orlando corridor
** Ridership forecast pertains to the 300-mph maglev scenario
*** Ridership forecast pertains to the New maglev scenario
\# Ridership forecast pertains to the scenario with 10 roundtrips
\## Ridership forecast pertains to the 250 mph scenario
\### Ridership forecast pertains to the Greenfield option (220 mph)
NA: Not Available

Table documents the range of differences in study types and audiences. The majority of the reviewed studies are prepared for transportation authorities to help them decide if implementing a project would be beneficial to society. The remainder of the studies are developed by the academic community.

Table A.2: The range of differences in study types and audiences of in

The BCA of rail projects in literature

Study	Study type	Audience
California	Business plan	California High-Speed Rail Authority
Midwest 1	Economic impact study	Amtrak and multiple state DOTs
Chicago-Iowa	Service development plan	Iowa Department of Transportation
Florida 1	Economic impact study	Florida Transportation Association
Texas 1	Investment plan grant application	US Department of Transportation
Mountain 1	Business plan	Rocky Mountain Rail Authority
Spain	Academic research	Scientific community
Norway	Assessment study	Norwegian National Rail Administration
UK	Feasibility study	UK Strategic Rail Authority
China 1	Academic research	Scientific community
DC-Richmond	Academic research	Amtrak & Scientific community
China 2	Academic research	Scientific community
Northeast 1	Feasibility study	Amtrak
Cal-SNCF	Service development plan	Federal Railroad Administration
Florida-SNCF	Service development plan	Federal Railroad Administration

Study	Study type	Audience
Texas-SNCF	Service development plan	Federal Railroad Administration
Midwest-SNCF	Service development plan	Federal Railroad Administration
Richmond-Raleigh	Commercial feasibility study	US Department of Transportation
Cle-Cinti	Feasibility study	Ohio Rail Development Commission
Minnesota	Feasibility Study	Minnesota Department of Transportation
Atl-Char	Alternatives development report	Federal Railroad Administration
Minnesota	Economic impact study	Minnesota Department of Transportation

Table illustrate the differences among the reviewed studies in covering the benefits and impacts of passenger rail service in BCA. In total, 13 impacts are recognized:

- **Travel cost saving:** by introduction of HSR, travelers who realize lower generalized travel costs shift from road and air to HSR. As a result, passengers remaining on the highway system or air transportation system will incur lower congestion delays which is known as travel cost saving.
- **Benefits from induced demand:** improvement of travel environment generates additional demand. The benefits of induced demand are in the forms of consumer surplus.
- **Safety benefits:** modal shifts from road to rail transportation result in total VMT reduction which in turn reduces total car crashes. Safety benefits are estimated by monetizing crash reduction (an often controversial factor).
- **Energy and environmental benefits:** total VMT reduction further results in less energy consumption, pollutants, and noise which can be monetized as environmental and energy benefits of the new or improved rail services.
- **In-vehicle productivity benefits:** unlike car drivers, rail travelers can use their laptops and cellphone or read books while they are traveling, which is recognized as productivity benefits.
- **Reliability benefits:** compared to rail travelers, road travelers expect less reliability in arriving on time. Yet the comparison of reliability between air and rail is less clear, although flight delays and cancellations are very common phenomenon at large airports in the US (such as those along the Northeast corridor). Travelers who shift from road and air transportation, therefore, may benefit from higher reliability.
- **Capital, operating and maintenance cost reductions in other passenger transportation systems:** when road travelers shift to rail transportation, they will incur lower non-fuel operating costs, e.g. the cost of operations and maintenance of vehicles, the cost of tires, and vehicle depreciation. Introduction of HS&IPR services further reduces the need for parking infrastructure due to highway travelers shifting to HSR. In a similar way, modal shift from air to rail lowers congestion at the region's airports. As a result, commercial airlines will incur lower operating cost and more slots will become available at airports.
- **Improvement in freight distribution systems:** lower congestion on the highway network helps freight distributers reduce their travel time. With a new rail HSR service that uses dedicated right-of-way, passenger trains running on shared-use corridors can be eliminated. This releases some capacity to freight trains which will be translated as benefits to the freight distribution system, although this may depend on how remaining non-HSR services (short-distance intercity and commuter rail) are structured.
- **Improvement in intermodal network connectivity:** improvement of rail service also promotes intermodal connectivity between rail, air and ground networks.
- **Economic productivity benefits:** improvement of travel environment may lead to shifts in employment patterns and make job markets more accessible. This could elevate productivity in the labor market of the region.
- **Impact on land use:** a new rail service requires land acquisition. Economic loss will be realized if agricultural lands are acquired. Changes in the quantity of wetlands also imposes

environment cost to the society. On the other hand, land utilization in urban areas could be increased attributable to HS&IPR development.

- **Oil import saving:** the wider impact of auto fuel consumption is oil import. Lower oil import can reduce the country's dependence to oil and the impacts of oil import on the economy of the country.

Almost all of the reviewed studies cover travel time savings and environmental benefits. Only two studies do not account for environmental benefits. However, the study of HSR in the US (WS Atkins, 2001)) includes a separate analysis for environmental impacts. The analysis of HSR in China considers energy savings rather than emission/noise reduction. Most of the studies further include safety and induced demand benefits, as well as capital, operating and maintenance cost reductions in other systems. Improvement in intermodal network connectivity is not covered in any of the studies, probably due to difficulties in monetizing this impact. In-vehicle productivity benefits, reliability benefits, economic productivity benefits, and improvement in freight distribution systems are the impacts which are taken into consideration only in a few of the studies. We find no study that addresses all the benefits presented in
Table and

Table .

Table A.3: The range of benefits and impacts covered in the BCA of rail projects

Study	Travel cost savings	Benefits from induced demand	Safety benefits	In-vehicle productivity benefits	Reliability benefits	Improvement in freight distribution systems	Improvement in intermodal network connectivity	Economic productivity benefits	Impact on land use
California	✓	✓	✓	✓	✓				✓
Midwest 1	✓	✓							
Chicago-Iowa	✓	✓	✓						
Florida 1	✓	✓	✓					✓	
Texas 1	✓		✓					✓	
Mountain 1	✓	✓	✓						
Spain	✓	✓	✓						
Norway	✓	✓	✓			✓			
UK	✓	✓	✓		✓	✓			
China 1	✓	✓	✓			✓			
DC-Richmond	✓	✓	✓						
China 2	✓	✓	✓		✓				
Northeast 1	✓	✓	✓		✓			✓	
Cal-SNCF	✓	✓	✓						
Florida-SNCF	✓	✓	✓						
Texas-SNCF	✓	✓	✓						
Midwest-SNCF	✓	✓	✓						
Richmond-Raleigh	✓	✓			✓				
Cle-Cinti	✓	✓							
Minnesota	✓	✓							
Atl-Char	✓	✓	✓						
Minnesota	✓	✓	✓	✓					✓

Table A.4: Further investigation of the range of benefits and impacts covered in the BCA of rail projects

Study	Environmental benefits		Capital, operating and maintenance cost reductions in other systems				Oil import saving	Energy benefits (fuel efficiency)
	Emissions	Noise	Highway maintenance	Parking infrastructure	Air-carrier operating cost	Auto operating costs (non-fuel)		
California	✓	✓	✓	✓	✓	✓	✓	✓
Midwest 1	✓				✓			
Chicago-Iowa	✓	✓	✓			✓		
Florida 1	✓		✓			✓		✓
Texas 1	✓							
Mountain 1	✓					✓		
Spain	✓	✓	✓		✓	✓		
Norway	✓	✓						
UK						✓		
China 1								✓
DC-Richmond	✓					✓		
China 2	✓							
Northeast 1	✓				✓	✓		✓
Cal-SNCF	✓							
Florida-SNCF	✓							
Texas-SNCF	✓							
Midwest-SNCF	✓							
Richmond-Raleigh	✓							
Cle-Cinti	✓				✓			
Minnesota	✓				✓			
Atl-Char	✓							
Minnesota	✓		✓			✓		

Table and Table indicate that there is a consensus on incorporating travel cost savings, benefits from induced demand, safety benefits, and impacts on emissions. Other impacts and benefits are infrequently considered in BCA, which might be due to two reasons. First, the impact or benefit may not exist in the area of study or may be very insignificant. For instance, introduction of a new rail service may not result in lower air carrier operating cost if the corridor is too short or no air service exists for the corridor. An example of this could be the relatively short, 155-mile corridor connecting Duluth to Twin cities, where introduction of high-speed rail services may not impact airports in the region. Second, an impact may not be considered if it violates the four rules described by FRA, i.e., immediately quantifiable in practical terms, monetizable, not duplicative, not a transfer effect. In-vehicle productivity, economic productivity benefits, and oil import saving seem to be examples of transferred effects.

We follow FRA's approach to identify impacts and benefits which could be considered in BCA, as documented in Table 8. Compared to FRA's study, however, we consider a more comprehensive list of impacts/benefits. Focusing on Table , only impacts and benefit which have all four features can be incorporated in BCA. There exist seven impacts which have all four criteria: travel cost saving, benefits from induced demand, safety benefits, emission benefits, highway maintenance cost, air-carrier operating cost, and auto operating costs (non-fuel). Note that travel cost saving includes both savings to rail travelers and travelers who remain on the highway and air transportations systems. No well-accepted methodology exists for quantifying and monetizing improvement in freight distribution systems, improvement in intermodal network connectivity, impacts on land use (e.g., wetlands), and noise impacts. However, these impacts could be considered in BCA if a reasonable methodology is developed. Reliability benefit overlaps congestion saving (travel time saving) and may not be considered. Energy and oil import saving cannot be considered as operating expenses of IPR&HSR accounts for both of them (FRA, 1997).

Table A.5: Identifying impacts and benefits which could be included in BCA following FRA guidelines

Benefit/impact		Quantifiable	Monetizable	Duplicative	Not transfer
Travel cost savings		✓	✓	✓	✓
Benefits from induced demand		✓	✓	✓	✓
Safety benefits		✓	✓	✓	✓
In-vehicle productivity benefits		✓	✓	✓	
Reliability benefits					✓
Improvement in freight distribution systems				✓	✓
Improvement in intermodal network connectivity				✓	✓
Economic productivity benefits		✓	✓	✓	
Impact on land use				✓	✓
Environmental benefits	Emissions	✓	✓	✓	✓
	Noise			✓	✓
Capital, operating and maintenance cost reductions in other systems	Highway maintenance	✓	✓	✓	✓
	Parking infrastructure				✓
	Air-carrier operating cost	✓	✓	✓	✓
	Auto operating Costs (non-fuel)	✓	✓	✓	✓
Oil import saving		✓	✓		✓
Energy benefits (Fuel efficiency)		✓	✓		✓

Table shows the range differences in covering geography, modes, and perspectives in BCAs in the literature. In this study, we consider a set of unconnected corridors as *multiple corridors*, whereas a network is defined as set of cities connected to each other by rail lines. The table shows that most studies are ex ante; very few have analyzed the benefits and costs of rail services based on actual results (i.e., observed behaviors subsequent to construction). The majority cover HSR, while nearly half of them consider other forms of intercity passenger rail services (e.g., higher speed rail or conventional rail). Half of the reviewed studies evaluate more than one rail corridor.

Table A.6: The range of differences in covering geography, perspectives, and modes in the BCA of rail projects in literature

Study	Geography			Modes		Perspective	
	Single corridor	Multiple corridors	Network	HSR	Other forms of IPR*	Ex ante	Ex post
California	✓			✓		✓	
Midwest 1			✓		✓	✓	
Chicago-Iowa	✓			✓		✓	
Florida 1			✓	✓	✓	✓	
Texas 1	✓			✓		✓	
Mountain 1			✓	✓	✓	✓	
Spain	✓			✓			✓
Norway			✓	✓	✓	✓	
UK			✓	✓		✓	
China 1		✓		✓			✓
DC-Richmond	✓			✓		✓	
China 2	✓			✓		✓	
Northeast 1	✓			✓		✓	
Cal-SNCF	✓			✓		✓	
Florida-SNCF	✓			✓		✓	
Texas-SNCF	✓			✓		✓	
Midwest-SNCF			✓	✓	✓	✓	
Richmond-Raleigh	✓				✓	✓	
Cle-Cinti	✓				✓	✓	
Minnesota	✓			✓	✓	✓	
Atl-Char	✓			✓	✓	✓	
Minnesota	✓				✓	✓	

* IPR: Intercity Passenger Rail

There is a consensus on estimations of most of the benefits presented in
Table and Table . VMT reduction is multiplied by the relevant cost (or benefit) factor. To estimate safety impacts, for example, VMT reduction due to introduction of new rail services is first multiplied by crash rates for casualties and property damage only (PDO) crashes for each area under study. This gives total casualty and PDO crash reduction in each area. We then multiply total casualty and PDO crash reduction by the monetary value of fatalities and crashes to obtain safety benefits. The key methodological differences among the reviewed BCAs depend upon the methods that they use to account for ridership forecast, reliability benefits, improvement in freight distribution system, and economic productivity benefits, as shown in Table . Most of the reviewed studies use a travel demand model to obtain future ridership. Four studies (California, UK, China 2, Northeast 1) that take into consideration reliability benefits approach this issue in different ways. The California study considers a buffer time for auto travel and computes the saving due to modal shifts from auto to HSR. The study in the UK considers a series of crowding costs associated with differing congestion levels and calculates the benefits of reduced congestion. The China 2 study simply considers 13.7% of travel time saving as reliability benefits. To model improvement in the freight distribution system, the study in Norway uses a macro freight demand model at a national-level; whereas studies for the UK and China 1 consider the benefits of release of rail capacity to the freight system. Regarding economic productivity benefits, the Florida 1 study monetizes the benefits of the generated permanent jobs

while the Texas 1 study phases in 0.25 percent increase in the combined gross regional products (GRPs) of the Austin and Fort Worth regions over 25 years.

Table A.7: The range of estimations and measurements used in the BCA of rail projects in literature

Study	Ridership forecast	Reliability benefits	Improvement in freight distribution system	Economic productivity benefits
California	Travel demand model	Planning time index		
Midwest 1	Travel demand model			
Chicago-Iowa	Growth rates			
Florida 1	Travel demand model			Generated permanent jobs
Texas 1	Travel demand model			A percentage of gross regional products
Mountain 1	Travel demand model			
Spain	Actual ridership			
Norway	Travel demand model		National-level freight demand model	
UK	Travel demand model	Congestion relief	Rail capacity release	
China 1	Actual ridership		Rail capacity release	
DC-Richmond	Travel demand model			
China 2	Not available	A percentage of travel time saving		
Northeast 1	Travel demand model	Delay reduction for air and highway travelers		Value of added jobs
Cal-SNCF	Travel demand model			
Florida-SNCF	Travel demand model			
Texas-SNCF	Travel demand model			
Midwest-SNCF	Travel demand model			
Richmond-Raleigh	Travel demand model			
Cle-Cinti	Travel demand model			
Minnesota	Travel demand model			
Atl-Char	Travel demand model			
Minnesota	Not available			

Economic impact analysis of rail services

This subsection reviews the literature on economic impact analysis (EIA) of IPR and HSR services. The objective of EIA is to analyze expected future impacts on the economy of a defined project impact area. In general, EIA focuses more narrowly on changes in the flow of dollars and associated effects on income and jobs; whereas BCA seeks to assess the net value of benefits to society. From an alternative methodological perspective, EIA is also broader than BCA, in that it counts impacts on regional growth occurring as a consequence of changes in productivity, economic competitiveness and attraction of business investment into a region. The next difference arises from the fact that BCA quantifies and monetizes all impacts; whereas EIA does not necessarily quantify all impacts nor monetize them. Public leaders and decision-makers rely on EIA to translate impacts into tangible job growth and wage terms that can be considered in the context of broader policy goals. In this section we review the studies presented in Table A.8

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Table A.8: The list of the reviewed EIA studies

Study	Description	Reference
Cal 1	California High-Speed Rail	PB (2012)
Chi-Stl	Chicago to St. Louis 220 mph High-Speed Rail	TranSystems (2010)
Midwest 1	Midwest Regional Rail System	EDR Group and AECOM (2011)
Midwest 2	Midwest Regional Rail System	TEMS (2004)
Texas	Huston-Dallas High-Speed Rail	TCP (2015)
Chi-Iowa	Chicago to Iowa City High-Speed Intercity Passenger Rail	HDR (2010)
Florida	Florida High-Speed Ground Transportation	Lynch (2002)
Conf of Mayors	HSR in Los Angeles, Chicago, Orlando, and Albany Metropolitan Areas	EDR Group (2010)
APTA	High performance passenger rail in California, Chicago, Northeast Corridor, and Pacific Northwest	APTA (2012)
China 1	High-Speed Rail in China	World Bank (2014)
China 2	High-Speed Rail in China	Chen et al. (2015)
UK	High-Speed Rail network in UK	DfT (2011)
Cal 2	California High-Speed Rail	Kantor (2008)
Calg-Edmtn	Calgary Edmonton High-Speed Rail	The Van Horne Institute (2004)
Europe	High-Speed Rail in Europe	de Rus et al. (2009)
Japan 1	Shinkansen High-Speed Railway	Sasaki et al. (1997)
Korea	High-Speed Rail in Korea	Shin (2005)
Cal 3	California High-Speed Rail	Cambridge Systematics (2007)
Japan 2	Shinkansen High-Speed Railway	Sands (1993)
Northeast 1	High-Speed Rail Northeast Corridor	NEC Master Plan Working Group (2010)
Cal 4	California High-Speed Rail	FRA and California High-Speed Rail Authority (2008)
Cal SNCF	HSR in California: proposal of French National Railways	SNCF (2009b)
Florida SNCF	HSR in Florida: proposal of French National Railways	SNCF (2009c)
Texas SNCF	Fort Worth/Dallas – San Antonio HSR: proposal of French National Railways	SNCF (2009a)
Midwest SNCF	HSR in Midwest: proposal of French National Railways	SNCF (2009d)
Rich-Raleigh	Richmond to Raleigh High-Speed Rail	NCDOT and DRPT (2015)
Northeast 2	Next generation of HSR in Northeast Corridor	Amtrak (2010)
Minnesota	Twin Cities to Duluth HSR	MDOT (2016)

Table shows how different the reviewed EIAs are in the audience and type of the study. The majority of the reviewed studies are economic impact studies that are prepared for governmental bodies. The remainder of the studies are addressed to the scientific community.

Table A.9: The range of differences in study types and audiences of in the EIA of rail projects in literature

Study	Study type	Audience
Cal 1	Economic impact study	California High-Speed Rail Authority
Chi-Stl	Feasibility study	Midwest High-Speed Rail Association
Midwest 1	Economic impact study	Midwest High-Speed Rail Association
Midwest 2	Economic impact study	Amtrak and state DOTs
Texas	Economic impact study	Texas Department of Transportation
Chi-Iowa	Service development plan	Iowa Department of Transportation
Florida	Economic impact study	Florida Transportation Association
Conf of Mayors	Economic impact study	The US Conference of Mayors
APTA	Economic impact study	American Public Transportation Association
China 1	Economic impact study	World Bank and China Railway Corporations
China 2	Academic research	Scientific community
UK	Economic impact study	UK Department for Transport
Cal 2	Academic research	Scientific community
Calg-Edmtn	Prefeasibility study	Alberta Government
Europe	Academic research	Scientific community
Japan 1	Academic research	Scientific community
Korea	Academic research	Scientific community
Cal 3	Economic/environmental impact study	California High-Speed Rail Authority
Japan 2	Academic research	Scientific community, California DOT
Northeast 1	Infrastructure master plan	Northeast state DOTs, District DOT
Cal 4	Economic/environmental impact study	California High-Speed Rail Authority
Cal SNCF	Service development plan	Federal Railroad Administration
Florida SNCF	Service development plan	Federal Railroad Administration
Texas SNCF	Service development plan	Federal Railroad Administration
Midwest SNCF	Service development plan	Federal Railroad Administration
Rich-Raleigh	Economic/environmental impact study	Federal Railroad Administration
Northeast 2	Economic/environmental impact study	Amtrak
Minnesota	Economic impact study	Minnesota Department of Transportation

Table shows the differences in the reviewed studies in incorporating different impacts and benefits of passenger rail services into EIA. In particular, we investigate the following aspects:

- **Short-term construction and long-term operation & maintenance impacts:** Construction, operations, and maintenance of HS&IPR lines generates a stream of spending on labor and materials. The impacts of construction on employment and wage impacts is analyzed based on the specific mix of workers, equipment, materials, and services required for rail line construction, acquisition of rail system equipment, and ongoing operations and maintenance. These impacts have geographic associations, and can be investigated at both national and regional levels.
- **Long-term productivity gains due to improved travel environment:** Reduction of travel time and cost and increase in reliability of the rail travel system make the region more accessible and thus directly affect dollar flows. For instance, travel time and cost savings for business travel are both counted as business cost savings and lead to productivity gains in the economy. On the other hand, time savings for personal trips has no direct effect on dollar flows, and expense savings for personal travel often affects the economy through shifts in local discretionary spending.
- **Productivity gain due to wider economic benefits:** Improvements in intercity rail service can also enable wider (non-traveler) productivity gains at both regional and national levels. There are two relationships: (1) enhanced connectivity among rail, air and ground travel services can lead to denser and ultimately more productive travel networks, and (2) agglomeration economies as attributable to shorter travel times between cities enable more inter-city commerce (i.e., business-to-business linkages of R&D, service and sales centers), as well as greater labor market sharing and mega region efficiencies (Banister and Berechman, 2003).
- **Tax revenues:** All of the major economic impact models calculate impacts on household and business revenues, and they use that information to directly calculate longer-term effects on income, tax revenues at both state and federal levels. Tax revenues may include: (1) Income taxes on earnings, (2) Sales taxes on earnings, (3) Sales taxes on construction goods which include construction purchases in-state and out-of-state purchases, and (4) Property taxes which is local property taxes on the increased value of property due to the property premium effect.
- **Overall impacts on jobs and wages:** Short-term spending and long term productivity changes lead to larger changes in the economy at a regional and national levels which are (a) direct effects on construction and operations activities; (b) indirect effects on business orders for American suppliers of equipment, parts and materials; (c) induced effects on consumer spending associated with re-spending of worker wages; and (d) dynamic effects over time as increased business productivity expands economic competiveness. These can include "generative" effects on the national growth and "distributive" effects on the location of activity. Economic impact models calculate these impacts based on details of the project and the area's economic context, and portray them for future years.
- **Station area development:** Development of HS&IPR services have important land use and urban development impacts. In particular, development of a rail station may substantially change land use and land value of the surrounding areas. It should be noted that existing

studies that look at this type of effect typically take into account generative rather than allocative effects of station area development.

The impacts on jobs and wages have been the focus of almost all reviewed studies but the impacts are usually studied at an aggregate level (state or country). Impact on station areas is ranked the second most frequent issue investigated in the reviewed studies. Productivity gains due to wider economic benefits have also been studied in several studies. However, the gains due to enhanced connectivity are usually discussed qualitatively. Tax impacts are studied in a few studies. In particular, Texas HSR study focuses on two tax elements: (i) direct tax revenue which includes property, sales and hotel occupancy taxes, and (ii) indirect tax revenues which are generated as a result of first tier employment and other taxable spending. The Richmond-Raleigh study computes state income, corporate income, state sales, property, franchise, and employment security taxes. The three other studies which studied tax impacts also look at similar tax benefit elements. Economic impacts of construction, operations, and maintenance are also studied in a few studies. We find no study that covers all aspects of EIA.

Table A.10: The range of benefits and impacts covered in the EIA of rail projects in literature

Study	Construction, operations, and maintenance		Productivity gain due to wider economic benefits		Impacts on jobs and wages		Tax impacts	Impacts on station area	Benefits due to reduced travel cost and time
	National /state	Regional level	Enhanced connectivity	Agglomeration economies	National /state	Regional			
Cal 1					✓	✓			
Chi-Stl			✓		✓	✓			✓
Midwest 1				✓		✓			✓
Midwest 2				✓	✓			✓	✓
Texas	✓			✓	✓		✓		
Chi-Iowa		✓			✓				
Florida	✓				✓	✓			
Conf of Mayors	✓			✓	✓	✓		✓	✓
APTA				✓			✓		✓
China 1	✓			✓	✓	✓		✓	✓
China 2				✓				✓	✓
UK			✓	✓					✓
Cal 2	✓		✓			✓	✓	✓	✓
Calg-Edmtn			✓	✓	✓			✓	✓
Europe			✓						✓
Japan 1				✓					
Korea				✓				✓	
Cal 3				✓	✓	✓		✓	✓
Japan 2				✓	✓			✓	✓
Northeast 1					✓				✓
Cal 4				✓	✓	✓		✓	✓
Cal SNCF					✓			✓	
Florida SNCF					✓			✓	
Texas SNCF					✓			✓	
Midwest SNCF					✓			✓	
Rich-Raleigh	✓				✓		✓	✓	
Northeast 2					✓				
Minnesota						✓	✓		

Table shows the range of differences in covering geography, perspectives, and modes in the EIA of rail projects in literature. Only a few studies investigate other forms of intercity passenger rail services. Ex-post economic analysis of HSR/IPR services can only be found for the services in Europe, China, and Japan. Most of the reviewed studies consider more than one high-speed rail corridor.

Table A.11: The range of differences in covering geography, perspectives, and modes in the EIA of rail projects in literature

Study	Geography			Modes		Perspective	
	Single corridor	Multiple corridors	Network	HSR	Other forms of IPR*	Ex ante	Ex post
Cal 1	✓			✓		✓	
Chi-Stl	✓			✓		✓	
Midwest 1			✓	✓		✓	
Midwest 2			✓		✓	✓	
Texas	✓			✓		✓	
Chi-Iowa	✓			✓		✓	
Florida			✓	✓		✓	
Conf of Mayors		✓	✓	✓	✓	✓	
APTA		✓	✓	✓	✓	✓	
China 1			✓	✓	✓		✓
China 2			✓	✓	✓		✓
UK			✓	✓		✓	
Cal 2	✓			✓		✓	
Calg-Edmtn	✓			✓		✓	
Europe			✓	✓			✓
Japan 1			✓	✓			✓
Korea			✓	✓			✓
Cal 3			✓	✓		✓	
Japan 2			✓	✓			✓
Northeast 1			✓	✓		✓	
Cal 4			✓	✓		✓	
Cal SNCF	✓			✓		✓	
Florida SNCF	✓			✓		✓	
Texas SNCF	✓			✓		✓	
Midwest SNCF			✓	✓	✓	✓	
Rich-Raleigh	✓			✓		✓	
Northeast 2	✓			✓		✓	
Minnesota	✓				✓	✓	

* IRP: Intercity Passenger Rail

Social impact analysis of rail services

This subsection reviews the literature on social impact analysis (SIA) of IPR and HSR services. Social performance measures cover factors that are important to people, yet are not easy to express in monetary terms and hence are not covered at all (or well) by typical benefit-cost and economic impact analyses. Many types of factors can fall into this category, and not all categories can be directly translatable into monetary terms due to perhaps data limitations. As a result, some of the social impacts are only acknowledged and discussed in a qualitative way rather than quantitatively. The social impact factor is an adjunct to BCA and EIA metrics that can be considered in broader (multi-criteria) decision frameworks. In this section we review the studies presented in Table .

Table A.12: The list of the reviewed SIA studies

Study	Description	Reference
Cal 1	California High-Speed Rail	Kantor (2008)
Australia	High-Speed Rail in Australia	Edwards (2011)
Spain	High-Speed Rail in Spain	Lopez et al. (2008)
Europe	High-Speed rail in Europe	de Rus et al. (2009)
Europe & Asia	High-Speed rail in Europe and Asia	Feigenbaum (2013)
Cal 2	California High-Speed Rail	Cambridge Systematics (2007)
Missouri	Missouri State Rail Plan	HTNB (2012)
UK	Quantification of the non-transport benefits resulting from rail investment	Banister and Goodwin (2011)
SE England	Economic and Social Impact of High-Speed Train	Preston and Wall (2008)
Taiwan	High-Speed rail effect on residential property prices	Andersson et al. (2010)

Table shows how different the reviewed SIAs are in the audience and type of the study.

Table A.13: The range of differences in study types and audiences of in the SIA of rail projects in literature

Study	Study type	Audience
Cal 1	Academic Research	Scientific community
Australia	Benefits of High-Speed rail	Australia government
Spain	Academic Research	Transport Planners
Europe	Economic Impact analysis	European government
Europe & Asia	Lessons from existing HSR projects	American government
Cal 2	Economic and Environmental Impact	California High-Speed Rail Authority
Missouri	State Rail Plan	Missouri Department of Transportation
UK	Academic Research	Scientific Community
SE England	Academic Research	Scientific Community
Taiwan	Academic Research	Scientific Community

The literature on SIA is relatively scarce compared to those on BCA and EIA. The 10 studies we considered represent the exhaustive literature search in this area. In the reviewed studies, we investigate the coverage of the following factors:

- **Accessibility to jobs, healthcare, education and other services:** The implementation of HS&IPR would result in greater personal and community utility due to improved accessibility to jobs, healthcare, education and other services. Note that the primary type of change relates to intercity accessibility.
- **Personal mobility**: Mitigation of highway and airport congestion due to investments in a rail project is expected to enhance personal mobility. Personal mobility can be assessed based on the changes in the distribution and mode split patterns of existing trips, and in the associated travel time and cost, as well as increase in the number of travelers (induced demand) in the multimodal transportation system due to the introduction of HS&IPR.
- **Public health and environmental quality:** Air pollutants are known to be the main factors causing deterioration in the environment and in public health (Baron, 2009). The benefits in public health can be derived from increased physical activity attributed to walking and bicycling around HSR stations. Similarly, the decrease in air pollution due to reduced vehicle and airplane usage accounts for the environmental quality benefits.

- **Improvement and new development of livable urban communities:** HS&IPR stations promote compact, transit-oriented development in the immediate surrounding areas. Therefore, it is expected that businesses who seek better commuting conditions for their employees concentrate near rail services. In addition, HS&IPR creates new opportunities for the development of more livable, walkable urban communities, boosting real estate values, and ultimately making the business district stronger.
- **Property value change and affordable housing:** Fast and convenient rail services can connect relatively remote, affordable housing to major business districts (United States GAO, 2010). On the other hand, development of HS&IPR services, analogous to that of transit, elevates nearby land and housing values and makes them less affordable to workers. In order to ensure affordable housing, municipal interventions, similar to Transit Oriented Development (TOD) policies, need to be in place around HS&IPR station areas.
- **Unique impact on public institutions**: Unique benefits can be accrued to public institutions due to potential patronage of the HS&IPR services due to the connection made between the institution locations and major cities.
- **Accident reduction:** Another benefit of HS&IPR is reduced road accident and increased road safety.

Most of the issues mentioned above pertain to local level analysis. The impact is limited to a small group of people or a neighborhood. Some national level social impacts of HS&IPR could be environmental impact and climate change issues. However, to our knowledge, no study has covered such broad level impact of HS&IPR. Further, quantifying these local and broader benefits in monetary terms are often not intuitive. Most existing studies present the benefits in qualitative terms rather than quantitatively. In Table below, we present the different areas covered by the reviewed literature.

Table A.14: The range of benefits and impacts covered in the SIA of rail projects in literature

Study	Accessibility to jobs, healthcare, education and other services	Personal mobility	Public health and environmental quality	Improvement and new development of livable urban communities	Property value change and affordable housing	Unique impact on public institutions	Accidents reduction
Cal 1	✓	✓	✓		✓		
Australia		✓	✓	✓			✓
Spain	✓						
Europe	✓	✓					✓
Europe & Asia		✓	✓		✓		✓
Cal 2	✓	✓	✓				✓
Missouri		✓	✓	✓	✓		
UK				✓	✓		
SE England	✓				✓		
Taiwan					✓		

Changes in personal mobility and property values have been considered by most of the studies reviewed for SIA. In contrast, none of the studies consider the impact on public institutions. Personal mobility covers the factors like mitigated congestion on road and spillover of benefit on the overall mobility. Agglomeration effects are related to two categories: accessibility to jobs, healthcare, education and other services; and improvement and new development of livable urban communities. A few academic studies look into the changes in property values in proximity to rail infrastructure. Table below presents the geography, mode and perspective of the reviewed literature.

Table A.15: The range of differences in covering geography, perspectives, and modes in the SIA of rail projects in literature

Study	Geography			Modes		Perspective	
	Single corridor	Multiple corridors	Network	HSR	Other forms of IPR*	Ex ante	Ex post
Cal 1	✓			✓		✓	
Australia			✓	✓		✓	
Spain			✓	✓		✓	
Europe			✓	✓		✓	
Europe & Asia			✓	✓			✓
Cal 2			✓	✓		✓	
Missouri			✓		✓	✓	
UK		✓		✓	✓		✓
SE England			✓	✓		✓	✓
Taiwan			✓	✓			✓

* IRP: Intercity Passenger Rail

As it can be seen in Table , most of the studies are focused on the network and HSR mode. Similar to BCA and EIA, the majority of SIA studies are ex-ante. The ex-post perspective is mainly the subject of HSR studies in Europe and Asia (probably because there is no true HSR service in the US) and for the academic study looking into the property value change due to presence of rail facility.

Table below provides the range of estimation methodologies used in most of the studies reviewed. Adhering to our earlier discussion, not all studies have specific methodologies to quantify the impacts. Qualitative discussions of the impacts are provided in such studies where detailed methodologies and information are not available.

Table A.16: The range of estimations and measurements used in the SIA of rail projects in literature

Study	Accessibility	Personal mobility	Public health and environmental quality	Improvement and new development of livable urban communities	Property value change and affordable housing	Unique impact on public institutions	Accidents reduction
Cal 1	Reports value from Study 6	Reports value from Study 6	Reports value from Study 6		No specific methodology used		
Australia		Estimate based on travel demand forecast	Estimate based on travel demand forecast	No methodologies described			Estimate based on travel demand forecast
Spain	Calculates using GIS accessibility toolbox						
Europe	Measured using activity function and impedance function	Estimation based on marginal cost of congestion					Estimation based on marginal cost of external costs of accidents
Europe & Asia		Reports value from several other studies	Reports value from several other studies		Reports value from several other studies		Reports value from several other studies
Cal 2	Measured as the number of people and jobs that were accessible within certain time bands	Based on HSRA's intercity travel demand model	Estimation based on forecasted value and marginal cost of pollution				Estimation based on forecasted value and marginal cost of accident
Missouri		No methodology described	Based on Travel demand forecast	No methodology described	No methodology described		
UK				Benefit Cost analysis	Geographically weighted regression		
SE England	Hansen Index				Regression Analysis		
Taiwan					Hedonic price regression		

Conclusion

This section reviewed a number of studies analyzing social and economic impacts and benefits of high-speed rail and intercity passenger tail services. The studies are categorized into three groups: benefit cost analysis (BCA), economic impact analysis (EIA), and social impact analysis (SIA). The scale of each study primarily depends on its audience. The audience for BCAs are mostly state departments of transportation (DOTs); thus, BCAs usually investigate impacts at an aggregate level (e.g., state or regional level). On the other hand, city DOTs and planning and economic development departments may also be interested in more localized impacts as in EIA and SIA. In that case, EIA and SIA analyze impacts and benefits at a more disaggregate level (e.g., regional, city, or station level).

While BCA quantifies and then monetizes all impacts and benefits, EIA and SIA frequently rely on qualitative or non-monetized analysis of the impacts. Compared to BCA, EIA and SIA are broader in the sense that they count impacts on regional growth occurring as a consequence of changes in productivity, economic competitiveness, and quality of life. Despite differences, BCA, EIA, and SIA have some overlap with each other, as shown in Figure A.1. We observe that several impacts/benefits are covered in more than one study type. For instance, travel time and cost savings for business travel lead to productivity gains in the economy. Therefore, it is the travel time saving that lies in the intersection of EIA and SIA. Another example is economic productivity which is also investigated in BCA (e.g., Texas HSR). Recall from Table 3.1, safety benefits is investigated in SIA. Given that almost all reviewed BCAs have considered safety benefit, this benefit is considered in the intersection of BCA and SIA. Similar rational is used for placing various impact/benefits of IPR&HSR service in different areas of the Venn diagram shown in Figure A.1. We find that no benefit is covered in all three study types.

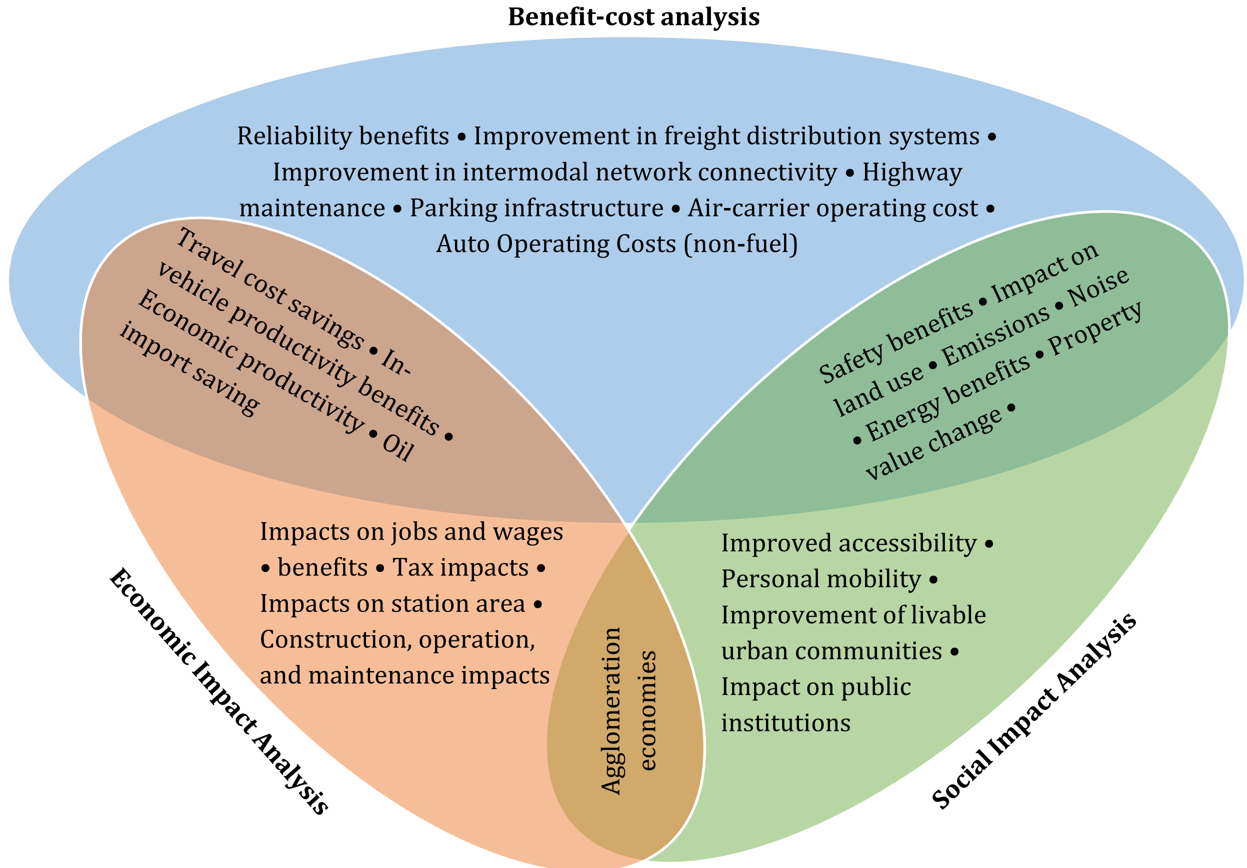

Figure A.1: Coverage of different impacts of IPR&HSR services in BCA, EIA, and SIA studies

Review of BCA studies indicated that there is a consensus on incorporating travel cost savings, benefits from induced demand, safety benefits, and impacts on emissions. However, other impacts and benefits are infrequently considered in BCA. Following FRA (1997), we recognize that a benefit or an impact can be incorporated into BCA only if it is immediately quantifiable in practical terms, monetizable, not duplicative, and not a transfer effect. Compared to FRA's study, however, we consider a more comprehensive set of potential impacts/benefits and recognize seven benefits/impacts that could be considered in BCA as travel cost saving, benefits from induced demand, safety benefits, emission benefits, highway maintenance cost, air carrier operating cost, and auto operating costs (non-fuel). Improvement in freight distribution systems, improvement in intermodal network connectivity, impacts on land use (e.g., wetlands), and noise impacts can also be incorporated into BCA if strong and well-accepted methodologies for monetizing these impacts are developed. Compared to BCA, EIA and SIA are broader than BCA; thus, we do not recognize any criteria for considering an effect or a benefit in EIA or SIA.

Despite the rich literature on the benefit-cost analysis, economic impact analysis, and social impact analysis on HS&IPR services, some gaps and issues remain. First is the issue of double counting and ways to avoid double counting, which is considered not an omission or error but a professional disagreement among different researchers/practitioners. For example, inclusion of land value impact could be double counting if travel time saving is already considered. In fact, as pointed out by De Rus and Inglada (1997), land value change is a consequence of accessibility improvement, which is already accounted for in the reduction of travel time. Discussions on double counting issue in EIA can be found in World Bank (2014). Transportation analysts are advised to pay special attention to the double counting issue given that there is no unique answer nor guidelines to avoid this issue.

Second, several benefits have not received sufficient attention in the past studies. A notable example is the intermodal connectivity benefits. As discussed in section 0, improvement of rail services enhances intermodal connectivity between rail, air and ground transportation networks. However, none of the studies reviewed in

Table account for monetizing improvement in intermodal network connectivity and incorporating it into BCA (we are only aware of some qualitative analysis of this impact in EDR Group (2013)). In addition, impact on land use is only studied in the BCA of California HSR (PB, 2014). The impacts of rail services on freight distribution systems, highway maintenance cost, noise impacts, and air carrier operating cost are also only investigated to a limited degree. In EIA, tax impacts and productivity gains due to improved connectivity have not been sufficiently examined. In SIA, improvement of livable urban communities and the impact on public institutions are neglected by several studies. Clearly, these impacts/benefits deserve more in-depth investigation in the future.

Third, the literature lacks a sophisticated approach for comprehensive stakeholder analysis. As is made clear by the literature, intercity passenger rail services result in various benefits which are to be received by different stakeholders. This gives rise to the distributional effect. Inadequate sharing of benefits and allocation of cost among stakeholders or stakeholder coalitions could create barriers toward successful development of the HS&IPR services. Further analysis is needed towards fair and efficient distribution of benefits and costs among different stakeholders so that all parties are incentivized to advocate for the advancement of the HS&IPR programs.

Fourth, as rail ridership forecast is a fundamental root for BCA, EIA, and SIA, and consequently policy judgments on HS&IPR development, decisions could be biased and suboptimal if rail ridership is overestimated. Thus, development of rigorous travel demand models that provide credible forecast of multimodal traffic is critical and essential to ensure the credibility of estimated benefits from future HS&IPR development.

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Appendix B: Compiling existing estimates of HS&IPR economic and public benefits

This section assembles studies and reports that are related to the estimation of economic and public benefits for specific HS&IPR projects. This includes studies prepared for HS&IPR projects under development in California, the Midwest, and the Southeast, among other regions. In addition, two case studies corresponding to California and the Midwest presented, with focus on the impact elements included and the methodologies/approaches used to estimate the impact elements. Below a general description of the HS&IPR projects studied in the three regions is provided first.

California HSR is a high-speed rail system that will provide fast and convenient passenger rail services between mega-regions of the State of California including Los Angeles, San Francisco, San Jose, San Diego, and Sacramento. The first phase of the project, which is currently under construction and is expected to initiate the service by 2029, is a 520-mile corridor connecting between San Francisco, Los Angeles, and Anaheim with trains running at a maximum speed of 220 mph. When construction of Phase 1 is completed, a trip from San Francisco to the Los Angeles basin will be under three hours. The second phase of the project, which is 280 miles long, will expand the service from Merced to Sacramento and from Los Angeles to Riverside and San Diego. The complete system (Phase 1 and Phase 2) will have 24 stations in total.

The Midwest high-speed rail network is a hub-and-spoke rail system in which Chicago serves at the hub, with spokes that connect Twin Cities, Milwaukee-Green Bay, Detroit/Pontiac, Grand Rapids/Holland, Port Huron, Cleveland, Cincinnati, St. Louis, Kansas City, Quincy, and Quad Cities-Des-Moines-Omaha. The system encompasses approximately 3,000 route miles with trains running at a maximum speed of 110 mph. For several corridors, including Chicago to St. Louis, Twin Cities, Cincinnati, Detroit, and Cleveland, 220 mph trains are also proposed. Currently the segment Porter Indiana-Kalamazoo of the Chicago-Detroit corridor is operating at 110 mph. Projects under construction include the Kalamazoo-Dearborn segment and segments between St. Louis to Kansas City.

Several HS&IPR projects are proposed in the Southeast region including projects in Florida, Georgia, North Carolina, and Virginia. In Florida, a 363-mile high-speed rail is proposed to connect Miami to Orlando, and further to Tampa. Multiple maximum speeds (168 mph, 186 mph, and 220 mph) are proposed and trains will run alongside the state's highway network. An HS&IPR service to connect Atlanta and Charlotte, which is approximately 280 miles long, is also proposed. Three routes and four train speeds (79 mph, 110 mph, 125 mph, and 220 mph) are proposed for this corridor. Another HS&IPR project is the Washington DC-Richmond-Raleigh corridor which will be an extension of the Northeast Corridor (NEC). It will be a shared-use corridor in which 110 mph passenger trains use tracks owned and maintained by CSX.

The compilation of existing estimates on the economic and public benefits of HS&IPR projects will help us better understand whether, and if so, to what extent different studies consider benefits from HS&IPR services. It should be noted that the comparisons are not intended for any judgment on the economic feasibility and profitability of the existing or proposed HS&IPR projects in the US. ***The***

existing studies are dictated by any differences in the ridership forecast methodologies employed, the types of benefits covered, the methodologies used to quantify the benefits, the scale of the study and the potential issue of double counting (as discussed in Chapter 4). These can significantly affect the outcomes and the range of estimates in the reviewed studies that are included later in this task.

Estimates for benefit-cost analysis

The list of BCA studies reviewed in this section is presented in Table . Table compiles the range of BCA estimates of intercity rail services in California, the Midwest, and the Southeast. ***It should be reiterated that the estimates presented here are in no way meant to comparing different projects.*** To make the inventory of benefits estimates comprehensive, the numbers presented come from a wider range of sources than the studies reviewed in Appendix A. For example, in addition to the 2014 Business Plan of California HSR (CAHSR), the 2012, 2008, and 2000 Business Plans are presented in Table . In the following discussions, general insights obtained from Table are summarized first. A closer look is then taken at HS&IPR projects for each region.

There are a few important factors that result in different benefit estimates. First, discount rates in the reviewed studies fall in the range of 3 to 7 percent. Note that, in its High Speed Ground Transportation (HSGT) study for California, FRA (1997) uses two discount rates to compute net present values of alternatives: a 10% rate is used to discount revenues, operating expenses, and continuing investments; whereas initial investments (including vehicles and infrastructure) are discounted at a rate of 7%. Most of the reviewed studies examine B/C ratio for multiple discount rates. Second, as shown in Table B.2, the analysis periods of HS&IPR projects, which cover construction and operation, also vary between 25 and 70 years. Third, a wide range of train speeds (90 mph to 300 mph) are considered in the reviewed studies, which directly impact HS&IPR cost and ridership. Lastly, different types of benefits are considered in the reviewed studies (readers may refer back to Appendix A), leading to different total estimated benefits even for the same project.

Table B.1: list of studies reviewed in this section

Region	Source/System		Speed (max)	Corridor length	Sponsor
California	2000 Business Plan		220 mph	700 miles	CAHSRA
	2008 Business Plan		220 mph	800 miles	CAHSRA
	2012 Business Plan	IOS	220 mph	300 miles	CAHSRA
		Bay to Basin		410 miles	
		Phase 1 Blended		520 miles	
	2014 Business Plan	IOS	220 mph	300 miles	CAHSRA
		Bay to Basin		410 miles	
		Phase 1 Blended		520 miles	
	SNCF's proposal		220 mph	800 miles	
	FRA's HSTG feasibility study		New HSR: 220 mph	545 miles	FRA
			Maglev: 300 mph	527 miles	
Mi d w	Midwest High Speed Rail Network		110 mph	3000 miles	Nine state consortium and Amtrak

	SNCF’s proposal		220 mph	3000 miles	
	Twin Cities-Rochester HSR		Flyer: 150 mph TGV: 180 mph Maglev: 300 mph	85 miles	Minnesota DOT
	Chicago-Iowa HSR		110 mph	220 miles	Iowa and Illinois DOTs
	Cleveland-Cincinnati HSR		110 mph	258 miles	Ohio Rail Development Commission
Southeast	Florida HSR: Tampa-Orlando		150 mph 180 mph 250 mph	Not presented	Florida High Speed Rail Authority
	Florida-SNCF (Tampa-Orlando-Miami)		220 mph	363 miles	
	DC-Richmond-Raleigh		110 mph	477 miles	FRA
	Atlanta to Charlotte Rail corridor	Alt. 1A	79 mph	268 miles	Georgia DOT
		Alt. 1B	110 mph	268 miles	
		Alt. 2A	125 mph	255 miles	
		Alt. 2B	220 mph	255 miles	
		Alt. 3A	125 mph	274 miles	
		Alt. 3B	220 mph	274 miles	

Table B.2: Compilation of BCAs of HS&IPR in California, Midwest, and Southeast

Region	Source/System		Dollar value	Evaluation period	Discount rate (%)	Benefits to rail travelers in million $	Social benefits in million $[1]	Total benefits in million $	Total costs in million $	B/C ratio	ROR[3] (%)	Ridership in million passengers: Ref. year	Ridership in million passengers: value	Reference
California HSR	2000 Business Plan - 220 mph		1999$	2001-2050	4	8,836	883	44,149	21,458	2.06	8.8	2020	32	CAHSRA (2000)
	2008 Business Plan - 220 mph		2008$	2010-2050	4	56,752	13,882	150,478	53,058	2.84	8.8	2030	55	CAHSRA (2008)
	2012 Business Plan - 220 mph	IOS	2011$	2013-2080	7	26,270	4,137	43,245	20,259	2.13	12.89	2060	13.6	PB (2012)
		Bay to Basin				37,972	6,130	62,738	27,854	2.25	13.49	2060	23.0	
		Phase 1 Blended				42,432	6,787	70,190	33,261	2.11	12.91	2060	32.9	
	2014 Business Plan - 220 mph	IOS	2013$	2013-2071	7	29,989	3,599	46,548	20,832	2.23	12.17	2060	19.4	PB (2014)
		Bay to Basin				43,132	5,176	66,595	28,371	2.35	12.60	2060	29.4	
		Phase 1 Blended				52,523	6,081	80,542	34,639	2.33	12.54	2060	42.5	
	SNCF's proposal - 220 mph		2009$	2011-2050	4	27,700	7,100	86,600	38,700	2.23	10.8	2030	54.6	SNCF (2009a)
	FRA's HSTG feasibility study	New HSR - 220 mph	1993$	2000-2040	7 and 10[2]	7,688	656	23,181	19,511	1.19	NA	2020	15.6	FRA (1997)
		Maglev – 300 mph				10,324	736	30,429	27,007	1.13	NA	2020	18.6	
Midwest	Midwest High speed Rail Network 110 mph	2004 Analysis	1998$	2004-2030	5	13,200	300	15900	9,300	1.7	NA	2025	14.8	TEMS (2004)
		2006 Analysis	2002$	2008-2040	3.9	17,200	600	23,100	1,2900	1.8	NA	NA	NA	TEMS (2006)
					7	9,700	400	13,200	9,100	1.46	NA	NA	NA	
	SNCF's proposal - 220 mph		2009$	2011-2050	4	30,000	4,600	93,000	63,500	1.46	6.9	2040	43.93	SNCF (2009c)
	Twin Cities-Rochester HSR	Flyer 150 mph	2000$	2001-2039	4	657	35.4	2,125	1,569	1.35	NA	2039	2.4	TEMS (2003)
		TGV 180 mph				801	11.6	2,519	1,823	1.38	NA	2039	2.8	
		Maglev 300 mph				1,328	16.5	3,854	6,927	0.56	NA	2039	4.3	
	Chicago-Iowa HSR - 110 mph		2011$	2011-2045	3	1,107	42.6	1,269	537	2.37	14.28	Average annual	0.33	HDR (2010)
					7	570	19.7	657	386	1.70	14.28			
	Cleveland-Cincinnati HSR - 110 mph		1998$	2005-2035	7	473	180	1,274	807	1.42	NA	2035	1.7	TEMS (2001)
Southeast	Florida HSR: Tampa-Orlando	150 mph	2000$	2005-2036	5	NA	NA	2,009	1,577	1.27	NA	2036	6.5	HNTB Corporation (2002)
		180 mph				NA	NA	2,285	1,985	1.15	NA	2036	7.0	
		250 mph				NA	NA	2,839	5,563	0.51	NA	2036	7.9	
	Florida-SNCF (Tampa-Orlando-Miami)- 220 mph		2009$	2011-2050	4	13,600	1,537	28,200	16,600	1.7	8.1	2040	20.7	SNCF (2009b)
	Washington DC-Richmond-Raleigh (110 mph)		1993$	2000-2040	7 & 10**	2,550	22	6,519	2,567	2.54	NA	2020	5.7	FRA (1997)

Table B.2: Compilation of BCAs of HS&IPR in California, Midwest, and Southeast (Cont'd)

Region	Service		Dollar value	Evaluation period	Discount rate (%)	Benefits to rail travelers in million $	Social benefits in million $[1]	Total benefits in million $	Total costs in million $	B/C ratio	ROR[3] (%)	Ridership in million passengers		Reference
												Ref. year	value	
Southeast	Atlanta to Charlotte Rail corridor	Alt. 1A 79 mph	2012$	2014-2050	3	502	194	1,351	2,154	0.63	NA	2050	0.94	GDOT (2015)
		Alt. 1A 79 mph			7	207	80	558	1,271	0.44	NA	2050	0.94	
		Alt. 1B 110 mph			3	645	248	1,756	2,356	0.74	NA	2050	1.18	
		Alt. 1B 110 mph			7	267	102	725	1405	0.52	NA	2050	1.18	
		Alt. 2A 125 mph			3	4,162	933	11,094	12,065	0.92	NA	2050	5.50	
		Alt. 2A 125 mph			7	1,718	387	4,577	7,623	0.60	NA	2050	5.50	
		Alt. 2B 220 mph			3	4,679	1044	12,408	13,605	0.91	NA	2050	5.62	
		Alt. 2B 220 mph			7	1,933	433	5,122	8,688	0.59	NA	2050	5.62	
		Alt. 3A 125 mph			3	4,348	1,047	11,753	6,794	1.73	NA	2050	5.38	
		Alt. 3A 125 mph			7	1,794	433	4,847	3,989	1.22	NA	2050	5.38	
		Alt. 3B 220 mph			3	5,737	1,393	15,383	8,886	1.73	NA	2050	6.30	
		Alt. 3B 220 mph			7	2,370	576	6,349	5,316	1.19	NA	2050	6.30	

1 Social benefits include highway accident cost reduction, and highway, freight, and commercial aviation emission cost reduction.

2 FRA's study uses two discount rates. Revenues, operating expenses, and continuing investments are discounted at a 10% rate. Initial investments are discounted at a 7% rate.

3 ROR: (Economic) Rate of Return.

NA: not available.

Readers are advised not to make any direct comparison between the result of the studies presented.

Estimates for economic impact analysis

This section presents estimates for economic impact analysis of HS&IPR projects, based on the studies reviewed in Appendix A. These include studies in California, the Midwest, and the Southeast, but also in Texas. For the convenience of readers, the list of studies reviewed in this section is presented in Table . Table documents economic impacts of short-term construction and long-term operation & maintenance. As mentioned in Appendix A, implementing HS&IPR projects generate a stream of spending on labor and materials, which can be disaggregated into direct, indirect, and induced impacts. However, only the Chi-Iowa study has separate estimates for all three components; whereas the others report only total estimates*. **Keep in mind that the estimates compiled here should in no way serve as a basis for comparison between different projects or studies.***

Table B.3: List of the reviewed EIA studies

		Max. speed (mph)	Corridor length (miles)	Sponsor
Cal 2		220	520	CHSRA
Cal 3		220	800	
Cal 4		220	NA	CHSRA
Cal 5		220	800	CHSRA and FRA
Cal-SNCF		220	800	
Chi-Iowa		110	220	Iowa DOT and Illinois DOT
Conf of Mayors	California	220	800	Siemens
	Midwest	110 & 220	3000	
	Florida	168 & 220	363	
Florida		220	363	Florida Transportation Association
Florida-SNCF		220	363	
Midwest 2		110	3000	Nine state consortium and Amtrak
Midwest-SNCF		220	3000	
Rich-Raleigh 2		110	477	FRA
Texas 2		NA	NA	Texas DOT
Texas-SNCF		220	271	

NA: Not Available

Table B.4: Compilation of estimates for short-term construction and long-term operation & maintenance impacts

Study	Unit	Economic impacts (million$)				Note
		Direct	Indirect	Induced	Total	
Texas 2	2015$				36,330	Cumulative economic impact of HSR construction and operation in 2015-2040
Chi-Iowa	2010$	216.2	58.0	66.9	341.0	Business output during construction
		89.2	29.9	36.8	155.8	Value-added during construction
		15.9	5.3	3.9	25.0	Business output during operation
		7.2	2.6	2.1	11.9	Value-added during operation
Florida	2002$	6,826			6,826	Project implementation
		2,583			2,583	Operation and maintenance
		3,225			3,225	Construction at station sites
Cal 3	NA	6,000 12,000			6,000 12,000	Direct construction benefits accruing to the Central Valley
Rich-Raleigh 2	2014$				792	Total impact includes economic and fiscal benefits of construction

Note: an empty cell indicates that the study does not offer the estimate for the corresponding economic impact
NA: Not available

There are also exist explicit estimates of productivity gains, as documented in Table . These estimates fall under two categories: productivity gains due to 1) enhanced connectivity and 2) agglomeration economies. The first category is only discussed qualitatively in two studies (Cal 2 and Cal 4). More estimates are reported for the second category.

Table B.5: Compilation of estimates for productivity gains due to wider economic benefits

Study	Productivity gains due to enhanced connectivity	Productivity gains due to agglomeration economies	
		Estimate (million $)	Note
Cal 2		Qualitative analysis	
Midwest 2		16,934	Impacts on business output
Conf of Mayors		7,600	Total economic impact as of 2035 for California HSR
		2,600	Total economic impact as of 2035 for Midwest system
		2,100	Total economic impact as of 2035 for Florida system
Cal 3		Qualitative analysis	
Cal 4	Qualitative analysis	Qualitative analysis	
Cal 5		Qualitative analysis	

Note: an empty cell denotes that the study does not discuss the corresponding benefit/impact

The economic impact is also reflected in job creation and increase in tax revenues. In general, an HS&IPR can generate direct and indirect construction jobs, permanent jobs related to operating and maintenance of the services, direct and indirect supplier industry jobs, and jobs generated from tourism (Table B.6). The estimates suggest that implementation of an HS&IPR project will result in a large number of temporary and permanent jobs.

Table documents the estimated tax impacts. Tax impacts include state income tax, corporate income tax, sales/use tax, property tax, franchise tax, and employment tax. Only the Rich-Raleigh 2 study which covers all the six tax components. For studies within table B.1, the overall estimates of generated taxes are reported. The tax revenue estimates range from $355 million to $40,950 million per project. Again, as different tax components are considered in these studies, this may explain the wide variety in the estimates.

Table B.6: Compilation of estimates for impacts on jobs

Study	Estimate	Note
Cal 2	98,000	Job-years for the first phase of constructing IOS
	406,000	Job-years for IOS
	276,000	Job-years for Bay to Basin
	217,000	Job-years for Phase 1 Blended
	249,000	Job-years for Phase 1 Full
	997,000	Total job-years for Phase 1 Blended
	1,246,000	Total job-years for Phase 1 Full Build
Midwest 2	58,260	Combined short term construction and long term indirect jobs
Texas 2	49,758	Direct jobs due to construction and operations
	4,283	Indirect jobs pertaining to HSR operations
Chi-Iowa	1,305	Cumulative direct jobs during construction

Study	Estimate	Note
	1,074	Cumulative indirect jobs during construction
Florida	41,267	Total permanent jobs due to project implementation, O&M and construction of stations for the Tampa-Orlando-Miami corridor
	5,000–8,000	Indirect jobs for the Tamp-Orlando corridor
Conf of Mayors	54,056	Total jobs in 2035 for California HSR
	18,374	Total jobs in 2035 for the Midwest system – 110 mph
	42,200	Total jobs in 2035 for the Midwest system – 220 mph
	19,935	Total jobs in 2035 for the Florida system – 168 mph
	27,453	Total jobs in 2035 for the Florida system – 220 mph
Cal 3	160,000	Jobs created to plan, design, and build the system
Cal 4	2,337	Job growth (thousands of jobs) for the Pacheco high-speed train alternative
	2,343	Job growth (thousands of jobs) for the Altamont high-speed train alternative
Cal-SNCF	154,000	Jobs in construction over the planning and construction phase
	300,000	Jobs in operations and maintenance over the 30-year operation phase
Florida-SNCF	102,000	Jobs in construction over the planning and construction phase
	220,000	Jobs in operations and maintenance over the 30-year operation phase
Texas-SNCF	68,000	Jobs in construction over the planning and construction phase
	145,000	Jobs in operations and maintenance over the 30-year operation phase
Midwest-SNCF	316,000	Jobs in construction over the planning and construction phase
	677,000	Jobs in operations and maintenance over the 30-year operation phase
Rich-Raleigh 2	32,600	New one-year construction jobs in North Carolina
	800	Permanent new railroad operation jobs in North Carolina
	19,000	Permanent jobs from businesses which choose to locate or expand in North Carolina because of the rail service
	22,100	Permanent jobs due to the expansion of Amtrak's operations

Table B.7: Compilation of estimates for tax impacts

Study	Tax impacts (Million $)							Note
	State income	Corporate income	Sales and use	Property	Franchise	Employment Security	Total	
Texas 2							3,108	Total direct and indirect tax revenue (over a 25-year analysis period)
Cal 3	2,200		46				2,246	Annual tax revenue in Central Valley
Rich-Raleigh 2	500	95	309	68	3	109	1,083	Annual tax revenue

Note: an empty cell denotes that the study does not discuss the corresponding benefit/impact

As mentioned in Appendix A, rail stations play an important role in the economic development of the surrounding areas. A rail station acts as the "front door" or "gateway" to the passenger rail network. Rail stations attract service industries which lead to commercial and residential development. Consequently, property values in the vicinity of a rail station will rise. Table compiles the estimates for the economic impacts on station areas. Cal 3, Cal 4, Cal-SNCF, Florida-SNCF, Texas-SNCF, Midwest-SNCF, and Rich-Raleigh 2 only provide qualitative discussions, and thus are not presented in this table. Quantitative estimates are offered in two studies, one for property value increase (Midwest 2) and the other for new spending in downtown areas (Conf of Mayors).

Table B.8: Compilation of on the economic impacts of HS&IPR projects related to rail station areas

Study	Estimate (million $)	Note
Midwest 2	4,970	Total property value increase
Conf of Mayors	360	Annual new spending in downtown areas for California HSR
	700	Annual new spending in downtown areas for Midwest system
	225	Annual new spending in downtown areas for Florida system

Estimates for social impacts

The list of studies for social impact analysis is presented in Table B.9. Because social impacts estimates are limited in the US (only Cal 3, Cal 4, and Missouri), estimates of international HS&IPR projects where SIA discussions are available are also presented in the table. Table compiles estimates of HS&IPR social impacts in the reviewed studies. A mix of qualitative and quantitative discussions exist in these studies. In addition, the types of social impacts included in each study vary significantly. This suggests the lack of standard methodologies for assessing the benefits.

We note that some of the social impact benefits overlap with those in BCA and SIA. For example, personal mobility benefit refers to the benefits from mode shift which is already considered in BCA and EIA. Similarly; benefits for public health and environment quality involve pollution reduction which may also be considered in BCA. For a complete picture of potential overlapping, the readers may refer back to Figure A.1 (in Appendix A).

Some studies compute indexes as a way to quantify social benefits if a type of benefits cannot be quantified in monetary terms. For example, the Spain 2 and Europe studies compute accessibility indexes using impedance functions. SE England study chooses the Hansen index (Hansen, 1959) to characterize accessibility. For property value changes (note that some studies consider this as part of the social impacts), regression analysis such as hedonic price regression and geographically weighted regression techniques are used. Apart from these, most of the studies provide qualitative judgements on the social impacts brought by the implementation of HS&IPR.

Table B.9: List of the reviewed EIA studies

	Max. speed (mph)	Corridor length (miles)	Sponsor
Cal 3	220	800	
Australia	NA	NA	Australia Greens
Spain 2	135-185	NA	
Europe	125-185	NA	
Europe & Asia	110-186	NA	
Cal 4	220	NA	CHSRA

	Max. speed (mph)	Corridor length (miles)	Sponsor
Missouri	90-220	4000	Missouri DOT
UK 3	NA	NA	
SE England	NA	NA	
Taiwan	155-185	215	

NA: Not Available

Table B.10: Compilation of social impacts estimates from existing studies

Study	Evaluation metric used	Accessibility	Personal mobility	Public health and environmental quality	Improvement and new development of livable urban communities	Property value change and affordable housing	Impact on public institutions
Cal 3	2005$	Qualitative discussion	$780 M from mode shift	$48 M		Qualitative discussion	
Australia	2010$		$66 M per annum	$64 M per annum from reduced pollution	Qualitative discussion		
Spain 2	Index value	3 different types of indexes for 10 scenarios					
Europe	Index value	0-180	0-3 hours				
Europe & Asia	--		Qualitative discussion	Qualitative discussion		Qualitative discussion	
Cal 4	2005$	Qualitative discussion	$780 M from mode-shift	$48 M			
Missouri	--		Qualitative discussion	Qualitative discussion	Qualitative discussion	Qualitative discussion	
UK 3	BCR improvement				BCR increased from 1.8:1 to 2.6:1 by including this factor	BCR increased from 0.95:1 to 1.75:1 by including this factor	
SE England	Percentage change after the HSR project	-30.3% to 95.3% for different HSR lines				140%-325% increment for different HSR lines	
Taiwan	Regression coefficients					Coefficients for several variables	

Note: The empty cells denote that the study does not discuss about those factors

Case studies

Earlier in this Appendix a wide range of studies which differ significantly in their scales, geographical areas, and benefits were presented and considered. The difference in the benefits estimated occurs mainly due to the difference in the scale of the studies considered. Since not every detail can be readily inferred from the previous subsections, this subsection presents two specific case studies conducted for the state of California and the Midwest region. The case studies investigate the scale of the study and the benefits considered, and explain methodologies used for the estimation of those benefits. This subsection concludes with the strengths and limitations of the current approaches and provides guidelines for formulating a fresher and holistic method of assessing all types of HS&IPR project benefits.

Case Study 1: 2014 California High-Speed Rail Speed Rail Benefit-Cost Analysis, PB (2014)

About: This study was prepared for the California High-Speed Rail Authority by Parsons Brinkerhoff (PB). It provides benefit-cost analysis (BCA) for the 2014 Business Plan of the California High-Speed Rail, for three scenarios (IOS, Bay to Basin, and Phase 1 blended). The study primarily focuses on state-wide benefits. Different from previous studies conducted for the state of California, unique HSR benefits are captured such as in-vehicle productivity benefits, reliability benefits, impact on land use, and oil import savings. The study further accounts for the fact that fuel efficiency of competing modes is expected to improve over time.

Impact Elements: The set of benefits included in the study are: (1) Travel time saving, (2) Travel reliability improvement, (3) Safety benefit, (4) Noise pollution reduction, (5) Environmental benefits (emissions, wetland loss, loss of agricultural land), (6) Energy resource use (reduction in vehicle operating costs and oil import costs), (7) Service owner and facility owner impacts (reduction in parking infrastructure needs, airline operator savings, propagated air delay costs, airline fuel savings, airline passenger delay savings) and (8) Productivity benefits.

Methodology/Approach used: The methodology/approach used for each of the impact elements are discussed below:

(1) Travel time saving: As is made clear in Appendix A, the premise for the estimating benefits including travel time saving is the travel demand forecasting. The study makes use of a previously estimated travel demand model by Cambridge Systematics (2013) which also provides an assessment of the impact of CAHSR project on existing highway travelers, as well as users switching from auto and air to HSR. Cambridge Systematics (2013) further uses the travel demand model to estimate the savings in Vehicle Miles Travelled (VMT) and Vehicle Hours Travelled (VHT) due to the introduction of HSR. The savings in travelers' time cost is obtained by multiplying the saved Vehicle Hours Travelled (VHT) by the average number of people in a vehicle and further by the value of time recommended by the USDOT (2013).

(2) Travel reliability improvement: The reliability benefit is calculated as the reduction in the extra buffer time for a trip. It is assumed that on average 30% extra time is added as buffer time to a highway trip (Texas Transportation Institute, 2010). Part of the buffer time will be eliminated for passengers switching from highways to HSR given the higher frequency and on-time performance of the HSR, resulting in the travel time reliability savings.

(3) Safety improvement: Safety improvement is measured as the number of reduced crashes as VMT decreases. The categorized crash rates – from fatal crash to minor property damage – draw from the California Highway Patrol (2011). The crash reduction in each category is then monetized using the values of crashes recommended by the USDOT (2013).

(4) Noise reduction: Noise pollution is monetized by multiplying the per mile cost for noise (0.13 cents per mile for cars and 2.04 cents per mile for trucks (FHA, 2005)) and the VMT reduced for cars and trucks. The introduction of HSR will reduce the noise generated from highway vehicles. However, at the same time there will also be new noise generated by the HSR trains. The monetizing value of HSR noise is assumed to be \$0.33 per mile (Maibach, et al., 2008). Therefore, the noise benefit would be the net of reduced highway noise and increased HSR train noise.

(5) Environmental benefits: The study considers two types of benefits that are related to the environmental benefits. The first environmental benefit is the reduction in emissions of C02 and non-CO2 pollutant. The emissions are proportional to the reduction in the VMT. The CO2 emission factor per VMT for auto vehicles are calculated in accordance with CEQA (California Environmental Quality Act) and NEPA (National Environmental Policy Act) guidance. The monetizing factor for CO2 emissions is borrowed from USEPA (2010) and USDOT (2014). The factor of non-CO2 emissions per VMT and the monetizing factor are derived from the NHTSA (2010). The second environmental benefit is the cost (or disbenefit) due to the loss of agricultural lands and wetlands. The total agricultural land and wetlands lost to HSR project is multiplied by the per acre value of agricultural lands (USDA, 2011) and wetlands (Jenkins et al., 2010).

(6) Energy resource use: Reduction in VMT will reduce the dependency on imported oil as vehicles using oil are replaced by high-speed rail which uses electricity as the energy source. This will reduce the cost of importing crude and refined oil. The saving is estimated as the product of reduced oil requirement due to reduced VMT and per gallon cost of oil imports which can be derived from NHSTA (2009).

(7) Service owner and facility owner impacts: Benefits under this category include reduction in parking infrastructure needs, airline operating costs, propagated air delay costs, and fuel and non-fuel operating cost for other modes. The introduction of HSR reduces the need for parking infrastructures. Basically, every 365 vehicles taken off the road is associated with one less parking space requirement (this value comes from the assumption that one parking can serve one car for one day for 365 days a year), or a saving of \$300/year for surface parking and \$1000/year for structured parking. The two types of parking space are assumed to have an equal share. Saving in the airline operating cost is obtained by multiplying the airline unit cost factor (ATA, 2011), the estimate of the reduction of average delay per flight and the number of flights reduced due to the introduction of HSR. The average delay per flight and the number of flights reduced (due demand shifted from air to rail) are estimated based on the BTS (2010) data which gives an average of 99.6 passengers per flight and 10.7 minutes of delay per flight. Further, to account for the propagated delay factor (which is a phenomenon by which the delay occurring at a flight gets transferred to other flights) the airline unit cost factor from ATA (2011) is multiplied by 1.5 which is the delay propagation multiplier obtained from MITRE (2011). HSR will also lead to reduced operating cost for passenger cars, buses, and trucks due to reduced fuel consumption. Additional savings also come from non-fuel related cost savings

such as repair and depreciation of vehicles. The cost factor ($/VMT) for monetizing the fuel and non-fuel related costs come EIA (2012a, 2012b) and Minnesota DOT (2003) respectively.

(8) Productivity: The productivity benefit is calculated based on the rationale that the HSR travelers can utilize the travel time more productively than if driving or flying. Specifically, the study assumes that 50% of HSR travelers are productive in transit as compared to 0% and 33% for auto and air travelers.

Findings: The B/C ratio of the study ranges from 2.23 to 2.35 depending on the scenario considered (see Table B.2). Note that for some benefits included in the study, they are suitable only for the micro or local level analysis and usually get washed when scaled to the macro or state level. One such example is the noise impact. With the HSR service, some communities will benefit from reduced highway noise; whereas other communities will suffer from increased noise generated by trains moving at a high speed, thereby netting out the total noise reduction benefits. Also note that energy resource use, which is considered in this study, is usually not considered in BCA as the associated cost is reflected in measures such as service owner and facility owner impacts. Furthermore, economic and social impacts are not considered in this study.

Case Study 2: Midwest Regional Rail Initiative Project Notebook, TEMS (2004)

About: TEMS (2004) studies the Midwest passenger rail network with more than 3000 route-miles serving nine states and a combined population of 60 million. The study is sponsored by seven state departments of transportation, one state department of roads, one state rail development commission, and Amtrak. It presents a detailed estimation of a variety of economic benefits and costs using the criteria and structure in the USDOT/FRA (1997) study: High-Speed Ground Transportation for America. The study is conducted from a multi-state level perspective, which means that the benefits are beyond a single state.

Impact Elements: The study basically groups benefits considered for BCA into three main categories: Rail user benefits, Benefits to users of other modes and Resource benefits. Each category contains the following impact elements.

- Rail user benefits: travel expenses

- Benefits to users of other modes: travel time, congestion and reliability

- Resource benefits: service operator and facility owner impacts (air carrier operating costs), environmental benefits

In addition to these benefits considered for BCA analysis, the study also presents the estimation of other community benefits such as an increase in property values, incomes and jobs, station area development, and multi-modal connectivity.

Methodology/Approach used: The methodology/approach used for each of the categories are described below:

User benefits include the sum of consumer surplus and system revenue. Consumer surplus is defined as the additional benefit consumers (service users) receive from the purchase of service (travel), above the price actually paid for that service. Revenues are included in the measure of consumer surplus as a proxy measure for the consumer surplus forgone because the price of rail service is not zero. The consumer surplus, given the demand curves (the curve representing the number of trips as a function of the generalized cost of travel), can be determined by using the rule of one-half, as discussed later in Chapter 4. The demand curve is estimated using stated preference surveys and the "COMPASS" multimodal demand model developed by TEMS for ridership and revenue forecast.

The second benefit category includes the benefit to users of other modes such as air and highway travelers. The HSR will attract users from air and highway modes, therefore mitigating airport and highway congestion. The "COMPASS" model and "air-connect model" are used to calculate the number of users that will divert from highway and air respectively to HSR. The numbers of users diverting from the aviation to HSR (1.35 million) and highway to HSR (4.4 million) are comparable to those in USDOT/FRA (1997). The number of diverted users is multiplied by benefits of diversion per traveler value in USDOT/FRA (1997) to yield the total user benefits in this category.

The third category of the benefits considered is resource benefits which include the air carrier operating cost savings and emissions reduction. Air carriers benefit from lower operating cost due to reduced congestion at airports. The cost savings are calculated as the product of the projected reduction in the number of aircraft hours of delay and the average cost to airlines for each hour of delay. The estimation in the reduction of aircraft hour delay and the average cost to airlines for each hour of delay follow USDOT/FRA (1997) methodology. For emissions, the savings are assumed to be proportional to the number of auto vehicle miles diverted. The auto vehicle miles diverted are obtained by multiplying the number of diverted auto trips and the average trip length divided by an average vehicle occupancy rate. The auto vehicle miles diverted are multiplied by the emission benefit factor of $0.02 per vehicle mile from USDOT/FRA (1997) to yield the total emissions reduction benefits.

Other community benefits such as an increase in property values, incomes, and jobs are measured by evaluating the relationship between the improved accessibility due to the proposed rail project and the performance of the economy in terms of its overall size. An "Economic RENT" model is developed that estimates the socioeconomic measures (employment, income, and property value) as the function of the weighted generalized cost of travel (which represents the accessibility). The study also provides a brief analysis of the associated station area development and the multimodal connectivity. The developed economic rent model is used for assessing the station area development benefits while the experiences from other similar projects are used to analyze the multimodal connectivity benefits.

Findings: The B/C ratio of the study is equal to 1.7 (see Table B.2). The benefits considered are consistent with the scale of the study. Compared to case study 1, more benefits could be included, such as safety and productivity benefit due to improved accessibility.

Conclusion

This chapter presents a comprehensive compilation of HS&IPR economic and public benefits from existing studies. Consistent with Appendix A, the benefits are categorized under BCA, EIA, and SIA. The results of the review suggest that substantial differences exist in the benefit estimation, which is attributable to at least three factors: 1) the difference in the information used, in particular the ridership forecasts; 2) the difference in the methodologies employed; and 3) the scale of the study. The last difference is critical as it determines the type of benefits/impacts to be considered.

For BCA, selecting the right discount rate is crucial and an inappropriate value could lead to biased policy judgments. A common approach is to conduct the analysis with multiple discount rates. Regarding EIA, none of the reviewed studies investigates all aspects. The estimates for the economic impacts of construction, operation, and maintenance are mostly presented in aggregate. Separate estimates of direct, indirect, and induced impacts are rare. In terms of wider economic gains, the impact of enhanced connectivity has so far been studied only qualitatively. In contrast, productivity gains due to agglomeration economies are more widely reported. Only a few studies present separate values for direct, indirect, and induced job generations during the construction and operations periods. Similarly, tax benefits are estimated mostly at an aggregate level. Only one study (Rich-Raleigh 2) provides separate estimates for state income tax, corporate income tax, sales and use, and property and franchise taxes. An important aspect of EIA is the station area impact which is usually studied at the city- or station area-level. However, discussions about this impact are mostly qualitative. Another local impact of train stations is new spending in downtown areas, of which quantitative assessment is also rare. To conclude, the nature that EIA covers a broad range of benefits makes it difficult for EIA to be compared among different studies.

Limited studies exist on SIA in the US. In addition, most of the social impacts cannot be expressed in monetary terms. Only three out of the reviewed studies (Table B.10) report monetary values for benefits from improvement in 1) personal mobility and 2) public health and environmental quality. Some other studies make use of index values or simply offer qualitative discussions. There does not seem to be a consensus on the estimation methodologies in the literature which prevents a consistent comparison of the estimates across different studies.

To further understand the differences in benefits estimation, two case studies are conducted. The two cases represent different scale and geographical area coverage of HS&IPR projects. The first one looks at the state-level BCA analysis for the state of California. The second one presents the BCA and economic impact analysis at the multi-state level for the Midwest. The choice of the impact elements are found to depend on the scale of a study. More specifically, the following points are worth highlighting.

First, micro-level impacts should not be mixed with macro-level impacts, as benefits at the two levels may not be additive. This is because localized benefits may get washed out if the analysis is done to cover a wider geographical area. Thus the study scope is key to determining what and how benefits should be included and counted. Examples include noise effect and land development effects. **Second, the data and model used for a study should be consistent with the study scale**. As an example, a corridor level travel demand model might not be suitable for the state level impact study.

Third, the methodology choice is largely governed by the type of model used. A notable example is that the rule of one-half is used to estimate consumer surplus when the demand function is or can be approximated to be linear. On the other hand, a different measure will be used if demand is characterized by a discrete choice model. Keeping these takeaways in mind, a fresher approach needs to be prescribed to preserve the uniformity in such studies. Chapter 4 aims to develop such an approach.

Appendix C: Illustrative Cases

Overview. This chapter illustrates how the UIC-EDRG methodology (that was laid out in chapter 4) can be applied to portray the broad benefits and impacts of high speed and intercity passenger rail (HS&IPR), as viewed from multiple perspectives. It relies on "real world" data to show examples of how the various benefit and impact elements can be calculated and valued. It extends the examples to also show how these elements can be combined, using the accounting frameworks of benefit-cost analysis (BCA), economic impact analysis (EIA) and societal benefit analysis (SIA) as described in Chapter 4. Finally, the examples are extended to show how these various forms of analysis can be used together, to portray local, regional and national level benefits.

The data assembly and calculation examples shown in this chapter will provide a basis for recommendations, to be laid out in Chapter 6, regarding how to demonstrate and portray broader benefits of HS&IPR to audiences representing a variety of different constituencies with different perspectives. Thus, the information in this chapter should be viewed as primarily a "proof of concept" rather than as a model or guide to producing and packaging economic impact or benefit studies.

Chapter Organization. This chapter features two examples of benefit and impact calculations, each one drawing data from past economic analysis reports conducted for planned high speed rail systems. They are: California high speed rail and Midwest (Chicago hub) high speed rail. These two are organized identically, covering the elements discussed in Chapter 5 of the report and shown next:

1. Cost Elements:
    - A. Preliminary costs
    - B. Capital investment costs
    - C. Operating and maintenance costs
    - D. Asset replacement cost and the value of assets' remaining life
2. "User" (Traveler) Benefit Elements
    - A. Travel Time
    - B. Travel Cost
    - C. Congestion and Reliability
3. Broader Societal Impact Elements
    - A. Safety
    - B. Noise
    - C. Emissions
    - D. Energy Resource Use
    - E. Accessibility and Intermodal Connectivity
4. Local (Area and Stakeholder) Impact Elements
    - A. Service Operator and Facility Owner Revenue Impacts
    - B. Land Value and Development Impacts
    - C. Other Economic Impacts
    - D. Government Revenue Changes
5. Benefit Measurement and Reporting Perspectives
    - A. Outcome Results for a Future Year (EIA and SIA)
    - B. Present Value of Benefit and Expense Streams over Time (BCA)

Warning on Interpretation. It is important to stress that the calculation examples in this Section are illustrations to demonstrate how the prior Chapter 4 methods can be applied. While these illustrative calculations draw data from past studies conducted for California and the Midwest, they are only intended to illustrate calculation methods. They are not intended to second guess or re-state findings from any of the past studies. It should be stressed that numbers are drawn from studies done at different times for different system design and operation scenarios, sometimes for different study areas and different purposes (e.g., environmental impact studies, benefit-cost studies and economic impact studies). They are meant only to show how measurement methods can be applied, and not to draw any conclusions about the ultimate value of any specific proposed policies or plans.

California High Speed Rail

The planned California High Speed Rail line will focus on connecting San Francisco and Los Angeles, with possible future links connecting north to Sacramento and south to San Diego. Case study data is drawn from reports for the California High Speed Rail Authority by PB (2014) and CS (2007 and 2008), and from the US Conference of Mayors (2010).

Cost Elements

Project costs are the sum of the economic resources required to bring about the expected outcomes of a high speed and intercity passenger rail (HS&IPR) project. Consistent with the description in Chapter 4, there are four cost elements that are calculated for applicable years:

A. Preliminary costs,
B. Capital investment costs,
C. Operating and maintenance costs, and
D. Asset replacement cost and the value of assets' remaining life.

Up-Front (Preliminary + Capital Investment) Costs

Description: Preliminary costs include the expenses to conduct engineering design and environment review processes, and studies for the feasibility of the projects. Many preliminary costs take place before detailed cost calculations are made and used in benefit-cost analysis (BCA), economic impact analysis (EIA), or social impact analysis (SIA). Capital investment costs represent the sum of the monetary resources needed to build a project and acquire relevant assets.

Example of Methodology: Existing studies for California HSR have emphasized past planning expenses and as of the 2014 Business Plan many of the preliminary costs have been completed as construction begins. These studies have focused on the future cost of capital investments. Capital investment costs are estimated based on engineering design and standard unit cost factors. Construction cost estimates also include a percentage increase for professional service ranging from 10 to 20 percent. FRA (2016a) provides the standard categories of the capital investment costs which are also discussed in Chapter 4. PB (2014S) provides an example of best practice in line with Chapter 4, by considering detailed costs by project phase and segment.

Example Results: Estimates of capital investment costs from the 2014 business plan (PB, 2014) are summarized as below.

Table C.1. California HSR Capital Costs

2013-2028 Constant Dollars	**2013-2028 YOE[2] Dollars**	**2013-2028 Present Value[3]**
$54.9 billion	$67.6 billion	$29.4 billion

Operating and maintenance costs

Description: Operating and maintenance (O&M) costs are recurring expenses that start to apply after completion of construction and opening of service. They pertain to a wide array of costs that are necessary on a continuous basis to support HS&IPR functions to provide a given level of service. The O&M costs of an HS&IPR project throughout the entire analysis period should be evaluated. FRA (2016a) also recommends the standard categories for O&M costs which are discussed earlier in Chapter 4.

Example of Methodology: O&M cost estimation is based on the expected lifetime of facilities and equipment, and typical costs to maintain them. It also includes detailed service development planning and the costs of operating trains, facilities, and ancillary services. An example of O&M cost methodology is shown by PB (2014a). The O&M costs are reported from 2022 (after the completion of Initial Operation Segment) to 2071 in terms of constant 2013$ value.

*Example Results: Supporting documentation (PB 2014b) shows how annual estimates have been made under several potential scenarios. PB's work for the 2014 business plan provides an example of best practice adding a risk analysis component that exceeds the methodology for cost estimation included in Chapter 4. The reported costs are summarized in Table 4**C.2**.*

Table 4. California HSR Operating and Maintenance Costs

O&M Scenario	**2040 O&M Cost[4]**	**2022-2071 Cumulative[5]**	**2022-2071 Present Value[6]**
High	$982 million	$49.9 billion	$5.4 billion
Medium	$872 million	$41.7 billion	$4.7 billion
Low	$788 million	$37.4 billion	$4.1 billion

[2] Year-of-Expenditure
[3] Constant 2013 dollars. Present value calculated using a 7 percent real discount rate.
[4] PB 2014 *High, Medium, Low Cash Flows,* the technical supporting document for Section 6 of the Business Plan. Constant 2013 dollars.
[5] Calculated from PB 2014 *High, Medium, Low Cash Flows.* 2051-2060 growth trend extrapolated to 2061-2071 O&M costs. Constant 2013 dollars.
[6] Calculated from PB 2014 *High, Medium, Low Cash Flows.* Constant 2013 dollars. Present value calculated using a 7 percent real discount rate. Adjusted so that medium case matches PB 2014 *Benefit Cost and Economic*

Asset replacement and remaining life values

Description: The railroad project consists of assets whose expected life may be shorter than the period of the BCA analysis. Such assets should be replaced and repurchased which incurs additional cost during the repurchase time. On the other hand, some railroad assets such as bridges and tunnels have expected life exceeding the analysis period. Any remaining life of the infrastructures must be discounted at the end of the analysis period.

Example of Methodology. Life cycle cost guidelines provide a means for (1) estimating periodic facility reconstruction and equipment replacement costs at scheduled times (related to the useful life of the various equipment and facilities), and (2) estimated "salvage value" of remaining equipment and other assets at the end of the study period.

Example Results: PB (2014) calculates the asset's replacement and a residual value cost reduction category. This detailed asset replacement cost modeling is consistent with the Chapter 4 methodology. The benefit cost analysis for the business plan only includes purchases of real estate for right of way in the residual value line item. This is inconsistent with the chapter 4 methodology which recommends estimating the remaining value of other capital assets at the end of the analysis period.

Table C.3. Asset Replacement and Remaining Life Valuation for California HSR

Type of Cost	2022-2071 Cumulative	2022-2071 Present Value
Asset replacement cost	$7,029 million[7]	$546 million[8]
Asset remaining life value	-$3,492 million[9]	-$69 million[10]

"User" (Traveler) Benefit Elements

Affected "users" of the transportation system may include travelers who travel on high speed trains or on roads, aircraft or conventional trains. Benefits may accrue to those who switch to high speed

Analysis value from Table . Actual calculating values, from high to low, are $6.1, $5.4, and $4.8 billion. Benefit cost results net out operating costs of existing Amtrak service that will be replaced by CAHSR.

[7] PB 2014 *Business Plan*, p37, Exhibit 3.6. Value based on medium scenario. Includes expenses for replacement beginning in 2022 and analyzed through 2060. No expenses estimated for 2061-2071. See also PB 2014 *High, Medium, Low Cash Flows,* the technical supporting document for Section 6 of the Business Plan.

[8] PB 2014 *Benefit Cost and Economic Analysis,* p30, Table . Constant 2013 dollars. Present value calculated using a 7 percent real discount rate. Includes expenses for replacement beginning in 2022 and analyzed through 2060. No expenses estimated for 2061-2071. Reconstructed using *High, Medium, Low Cash Flows.*

[9] All remaining life value accrues in the final analysis year. An undiscounted value can therefore be calculated based on the -$69 million present value. Because this item only includes real estate purchases, which are treated as having no depreciation, we can also reference Exhibit 3.4 of the *2014 Business Plan,* which shows purchase or lease of real estate as totaling $3,989 million, including leases of land for staging during construction.

[10] PB 2014 *Benefit Cost and Economic Analysis,* p30, Table . Constant 2013 dollars. Present value calculated using a 7 percent real discount rate.

rail from other modes, and to those who remain traveling on those other modes. For travelers (of any mode), the primary benefits of high speed rail are likely to be measured in terms of:

A. Travel Time
B. Travel Cost
C. Congestion and Reliability

Travel Time

Description: As mentioned in Chapter 4, travel time savings occur to the HSR users due to increased train speed, greater service frequency and more convenient access to/egress from train stations. Users of other modes including highway and air travel also experience the savings in travel time due to reduced congestion at those modes. When information is not available on the cost of prior alternatives (including non-rail modes), then a "consumer surplus' approach may be used which estimates the incremental benefit of switching alternatives (e.g., from air or bus to high speed rail) to be half of the savings per trip that applies for those already traveling by rail.

Example of Methodology: An example of the methodology for calculating the travel time savings can be found in PB (2014). The savings are calculated for the entire state of California using the methodology described in Chapter 4. Two key inputs required for the calculation, travel demand model results and a value of time factor, are derived from Cambridge Systematics (2013) and the USDOT (2013) respectively. They also include a productivity benefit for travelers that switch modes and can now use their time in transit more productively by conducting work or engaging in leisure activities.

Example Results: The results of the PB (2014) study are summarized in Table on the next page. Results include savings for remaining highway and air travelers based on reductions in congestion delay. The elements of time savings shown in this table follow the Chapter 4 guidelines except that they also add a second time-related benefit that is additional to the standard value of travel time savings. It is the added benefit of business travelers being able to do productive work "en route" (while riding a train), which could not be done if driving or riding in a car. While the Chapter 4 methodology does not distinguish the two forms of time benefit, it would be possible to incorporate this second type of benefit into the Chapter 4 methodology through a revised time value for high speed rail travel time.

Table C.4. Travel Time Savings from California HSR

Mode Affected	2040 Time Units (hours saved)	2040 Benefit Value	2022-2071 Present Value[11]
HSR (Reduced Travel Time)	101.8 million[12]	$7.6 billion[13]	$34.7 billion
HSR (Productivity En Route)[14]	Unavailable	$1.4 billion[15]	$7.2 billion
Highway	99.4 million[16]	$3.1 billion[17]	$15.4 billion
Air Delay	176.2 thousand[18]	$0.013 billion	$0.043billion

Travel Cost

Description: Travel cost include the direct cost of travel such as out-of-pocket expenses such as fares for line haul intercity rail, fares for access to/from intercity rail via taxi or public transit, and if accessing via car, then all associated costs of fuel, vehicle wear-and-tear, tolls and parking costs. For users of other modes, there are similarly fares for bus or airline travel and vehicle costs if traveling by car. Travelers who switch to HS&IPR have net travel cost changes calculated as the difference in expense between the old and new mode. Travelers of other modes may also see changes if the addition of HS&IPR services leads them to a change in fares or fees.

Example of Methodology: An example for the application of the methodology for calculating the Travel Cost saving can be found in PB (2014a). The methodology followed by PB (2014a) is like that stated in Chapter 4 for Travel Cost savings. The study includes the reduction in vehicle operating costs (fuel and non-fuel related) for the auto drivers but does not account for the fare of the HSR and other modes like air or bus. Chapter 4 recommends calculating total cost of travel changes for travelers, including fares, so that a traveler perspective can be communicated, even though fares are a transfer between travelers and operators from a broad societal perspective.

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[11] PB 2014 *Benefit Cost Analysis,* p30, Table . Reported in 2013 constant dollars. Benefit stream discounted to 2013 using a 7 percent real discount rate.

[12] Time travel savings for highway users switching to HSR identified in PB 2014, p4, Table 3. Assuming an occupancy rate of 1.5, passenger hours saved = 1.5 * 67,886,020. Time savings for travelers switching from air to HSR not documented.

[13] Value of time for HSR travelers identified in PB 2014, p6, Table 7, in 2013 constant dollars as $75.03.

[14] PB 2014 *Benefit Cost Analysis* assumed 0 percent productivity for auto travelers, 33 percent productivity for air travelers and 50 percent productivity for rail users.

[15] Estimated based on the observation that undiscounted 2040 benefits for travel time are roughly 20 percent of the present value over the 50-year period. It is not possible to reproduce an estimate of productivity because the total hours of productive in-transit time cannot be reconstructed from the documentation.

[16] Remaining Highway User VHT savings identified in PB 2014, p4, Table 2. 0.929 * 67,886,020 = 63,066,112 passenger vehicles, and 4,819,907 trucks. Assuming an occupancy rate of 1.5, passenger hours saved = 1.5 * 63,066,112.

[17] Value of time for highway users identified in PB 2014, p6, Table 7, in 2013 constant dollars as $30.66 for passengers and $41.83 for truck drivers. $2.900 billion of passenger time and $201.6 million of truck crew time.

[18] 327,808 delay minutes * (1.06 “non-disrupted” + 31.19 “disrupted” minutes of passenger delay per minute of flight delay).

Results: The result of the study is summarized in Table C.5. Highway users benefit to a slightly greater degree because they include trucks and freight that have higher costs per mile – an approach consistent with Chapter 4 methodology.

Table C.5. Operating Cost Savings from California HSR

Mode Affected	**2040 VMT Reduction**	**2040 Benefit Value**[19]	**2022-2071 Present Value**[20]
Switch to HSR	3,772,066,673[21]	$1.1 billion	$ 5.4 billion
Remain on Highway[22]	N/A	$0.1 billion	$ 0.3 billion

Congestion and Reliability

Description: Travel time variability increases as transportation systems become more congested due to travel volumes exceeding facility capacity. By providing an alternative mode HS&IPR can reduce congestion on other networks, therefore improving those system's reliability. Reliability can often be measured using a buffer time or planning time concept.

Example of Methodology: Based on the Planning Time Index reported by the Texas A&M Transportation Institute (TTI) for several regions along the corridor, the amount of buffer time saved by switching from unreliable highway modes to reliable high speed rail is estimated in the 2014 Benefit-Cost Analysis.[23] This use of a buffer time measure closely follows the Chapter 4 methodology.

Example Results: The reliability results from the example study are shown in Table C.6. They include only reliability benefits for travelers who switch modes. Chapter 4 discusses how analysis could also estimate the reliability benefit to travelers who remain on the roads but now face slightly reduced congestion due to vehicles being diverted.

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[19] $4.58 per gallon / 36.1 mpg = $0.12687 per light-vehicle-mile. $3.97 per gallon / 8.15 mpg = $0.487 per truck-mile. Fuel prices from PB 2014, pg. 8, Table . Fuel efficiency projects from PB 2014, pg. 9, Table . $0.153 per mile light-vehicle-mile and $0.214 per truck-mile. Operating costs from PB 2014, pg. 9, Table . All costs in constant 2013 dollars.

[20] PB 2014, p30, Table reports $5.7 billion in combined fuel and non-fuel O&M savings for highway users. Of this benefit, $5.4 is attributable to users switching to highspeed rail, with the remaining difference attributable to more efficient routing available for remaining automobiles and trucks on the road. All costs in constant 2013 dollars discounted at 7 percent.

[21] Avoided VMT for highway users switching to HSR identified in PB 2014, p4, Table 3.

[22] PB 2014, p4, Table 2. PB 2014 further identifies the truck share of traffic as 7.1 percent.

[23] PB 2014 "2014 California High-Speed Rail Benefit-Cost Analysis," *2014 Business Plan.*

Table C.6. Congestion and Reliability Benefits from California HSR

Mode Affected	2040 Buffer Hrs. Reduction	2040 Benefit	2022-2071 Present Value
Highway	20,365,806	$936.6 million[24]	$5,338.2 million[25]

Broader Societal Benefit Elements

The broader societal benefits are sometimes referred to as "non-user" benefits or impacts because they can affect everyone in each area – including non-users. They include:

A. Safety
B. Noise
C. Emissions
D. Energy Resource Use
E. Accessibility
F. Intermodal Connectivity.

Safety

Description: Safety includes the benefits of avoided vehicle and plane crashes, and dis-benefits of increased train crashes, ideally categorized by severity (e.g., fatalities, injuries, property damage). A multitude of cost savings occur when crashes are avoided, including reduced medical expenditures and health insurance premiums, and the reduced need for emergency response and litigation. Safety impacts are non-localized, meaning that benefits and dis-benefits are generally not confined to a specific geography.

Below is an illustration of an applied methodology drawn from a benefit-cost analysis prepared for the California High-Speed Rail Authority (PB 2014). The study's separate consideration of fatalities, injuries, and property damage is consistent with the Chapter 4 methodology. The study methodology diverges from that recommended in Chapter 4, however, by accounting for reduced vehicle crashes but not reduced plane crashes and increased train crashes. Without more detailed information on diverted plane-miles and increased train-miles, we are unable to estimate associated safety impacts.

Methodology: Safety values are estimated using crash rate assumptions, typically expressed per 1 million vehicle miles traveled, 1 million train miles traveled, and 1 million flight hours. The example methodology considers avoided vehicle crashes only, using 2010 crash statistics from the California Highway Patrol. Crash figures are statewide averages categorized by the authors using the Maximum

[24] Planning time = Planning Time Index * VHT = 1.3 * 67,886,020 = 88,251,826. Buffer time = Planning time – VHT = 20,365,806. Reliability benefit = Value of Time (VOT) * Buffer time saved * Occupancy rate. Assumes a 1.5 person per auto occupancy rate, since actual calculations used several occupancy rates, none of which are clearly documented in the Business Plans. VHT savings identified in PB 2014, p4, Table 3. VOT identified in PB 2014, p6, Table 7. All values in 2013 constant dollars.

[25] PB 2014 *Benefit Cost Analysis,* p30, Table . Cumulative result includes 3 project phase-in steps, travel growth over time, and value of time growth over time. Value in 2013 constant dollars, discounted at 7 percent.

Injury Abbreviated Scale (MAIS), and represent incidents on Interstates, state highways, county roads, and arterials.

After estimating avoided vehicle crashes under a build scenario for high-speed rail, the authors use values per crash category to monetize the safety benefit. Crashes involving injuries and fatalities are monetized using USDOT guidance. The value of property damage comes from the National Highway Traffic and Safety Administration (NHTSA).

Results: The safety benefit shown here is derived from PB (2014), which reports reduced vehicle fatalities valued at $2.9 billion and a benefit from reduced vehicle injuries which is also valued at $2.9 billion (in 2013 dollars). Based on VMT savings, a further effect on reduced property damage from vehicle crashes is valued at $1.1 million. All benefits are discounted by 7 percent over the 58-year period spanning from 2013 to 2071. These results are consistent with the Chapter 4 methodology except that they do not estimate the dis-benefit of train crashes, hence the net safety benefit equals the sum of all vehicle safety benefits: $5.8 billion.

Table C.7. Safety Benefit Results from California HSR

Mode	2040 VMT Reduction	2040 Benefit Value	2022-2071 Present Value[26]
Highway	7.5 billion[27]	$1.189 billion[28]	$5.8 billion

Noise

Description: Noise pollution is a localized impact that can be measured on a per-mile basis. Noise reduction resulting from diverted vehicle trips represents a benefit while added noise from high-speed rail represents a dis-benefit. Noise pollution represents an externality that can be valued using stated preference surveys or revealed preference techniques like hedonic pricing. Legally, noise is considered a nuisance that local governments can regulate using zoning laws.[29] Below is an illustration of an applied methodology drawn from the 2014 California Study.

Methodology: The example methodology relies on guidance provided by the Federal Highway Administration and repeated in Chapter 4 for per-VMT noise costs. The study uses a weighted average of urban and rural cost values using a 50-50 split. Offsetting noise increases from high-speed rail are valued using European Commission figures for passenger rail. Per-kilometer costs differ by setting and time-of-day, with rail imposing the highest costs in urban areas at night and the lowest costs in rural areas during the day.

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[26] PB 2014 *Benefit Cost Analysis,* p30, Table . Constant 2013 dollars. Present value calculated using a 7 percent discount rate.
[27] VMT saved by remaining highway users identified in PB 2014, p4, Table 2. VMT saved due to mode shift identified in PB 2014, p4, Table 3. Both quantities reduce accident incidents.
[28] Crash rates and values assigned for the Abbreviated Injury Scale, 0-6, in PB 2014 p15-16, Tables 14 & 15. Average of $157,612 in savings per mile of VMT reduction.
[29] John R. Nolon and Patricia E. Salkin, *Land Use in a Nutshell* (St. Paul, MN: Thomson/West, 2006).

Results: The net noise benefit after subtracting vehicles and adding trains is $41.1 million. See Table C.8 for details.

Table C.8. Noise Benefit Results from California HSR

Mode	2040 Distance Units	2040 Benefit Value	2022-2071 Present Value[30]
Highway	3,772,066,673 VMT[31]	$10.0 million[32]	$73.0 million
Rail	23,229,750 train-miles[33]	-$7.8 million[34]	-$31.9 million

Emissions

Description: Benefit-cost analyses can estimate the amount and value of high-speed rail emissions and avoided emissions from diverted automobile, truck, and plane trips. Criteria air pollutants regulated under the Clean Air Act are most important to consider, given their threat to human health.[35] Criteria pollutants represent a mobile source of pollution for vehicles and planes, and a stationary source of pollution for high-speed rail (the source being a remote power plant). Mobile pollution is localized while stationary pollution is localized only if the source is located within the study region.

Localized pollution sources can sometimes create "hotspots," or concentrated areas of poor air quality that represent an environmental justice issues if disproportionately burdening low-income or minority communities. Greenhouse gases (GHG) including carbon dioxide, methane, nitrous oxide, and hydrofluorocarbons are also regulated under the Clean Air Act per the 2007 Supreme Court decision in *Massachusetts v. EPA*.[36] Because GHG emissions enter the atmosphere and travel far distances from their point of origin, they represent a non-localized impact. Below is an illustration of the 2014 California study methodology.

Methodology: The example methodology relies on four inputs to estimate the change in air pollution and GHG emissions resulting from high-speed rail[37]: (1) vehicle miles traveled (VMT) diverted, (2) plane trips diverted, (3) energy used by high-speed rail electric traction power and facilities, and (3) the construction schedule and equipment used. This methodology is generally consistent with that recommended in Chapter 4, but differs in at least two ways that could affect the results: the authors

[30] PB 2014 *Benefit Cost Analysis,* p30, Table . Constant 2013 dollars. Present value calculated using a 7 percent discount rate.
[31] VMT saved by remaining highway users identified in PB 2014, p4, Table 2. PB 2014 further identifies the truck share of traffic as 7.1 percent.
[32] $0.0013 per light-vehicle-mile and $0.0204 per truck-mile. See PB 2014, p18.
[33] (84,019 single consist and 8,902 double consist daily miles) * 250 service days. See PB 2014, *Service Planning Methodology,* p19.
[34] $0.3348 per-train-mile. See PB 2014, p19.
[35] The six criteria pollutants are carbon monoxide (CO), nitrogen dioxide (NO_2), particulate matter (PM), sulfur dioxide (SO_2), lead (Pb), and ground-level ozone (O_3). Nitric oxides (NO_X) and volatile organic compounds (VOC) combine to form ozone. See https://www.epa.gov/criteria-air-pollutants for more information.
[36] Daniel A. Farber, *Environmental Law in a Nutshell*, 9th ed. (St. Paul, MN: West Academic, 2014).
[37] The study does not estimate air pollution from high-speed rail, instead considering it nonlocalized.

do not use emissions rates that differentiate between congested travel and congested travel, nor do they use emissions rates that differentiate between light truck VMT and heavy truck VMT. The study uses the following datasets to estimate emissions of nitric oxides, particulate matter, sulfur oxides, and volatile organic compounds:

- Emissions factors issued by the California Air Resources Board (CARB) that incorporate California-specific GHG reduction targets and low carbon fuel standards
- VMT and associated emissions reductions emanating from a travel demand model
- Electric power emissions inventory data from (CARB) incorporating future estimates
- Plane emissions from the Federal Aviation Administration (FAA) Emission and Dispersion Modeling System (EDMS) and CARB
- Construction emissions based on a CARB off-road emissions model

After estimating emissions, the authors use cost factors from the National Highway Traffic and Safety Administration's (NHTSA) MY2012-MY2016 CAFE Standards.[38] Emissions from construction are measured in tons per year of construction for the 2013-2023 period, and projected through 2028 using miles of track constructed. These emissions are valued using the same rates listed above.

Results: The net benefit from greenhouse gas reductions is $189 million with modal components shown in Table C.9. The net benefit from air pollution reductions is $38.8 million.

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[38] NHTSA 2020, *Corporate Average Fuel Economy for MY2012-MY2016 Passenger Cars and Light Trucks,* p403, Table VIII-8. http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/CAFE_2012-2016_FRIA_04012010.pdf

Table C.9. Greenhouse Gas and Criteria Pollution Benefit Results from California HSR

Mode	2040 Impact Value	2040 Benefit[39]	2022-2071 Present Value[40]
Construction	N/A	N/A	-$46.0 million
Air Non-CO2	2,040,458 diverted trips	$2.7 million	$13.4 million
Air CO2	2,040,458 diverted trips	$4.6 million	$36.8 million
Highway Non-CO2	3,772 million avoided VMT	$5.1 million	$25.4 million
Highway CO2	3,772 million avoided VMT	$21.1 million	$168.8 million
Rail CO2	Unavailable	-$2.1 million	-$16.6 million
Tree Program	Unavailable	$0.2 million	$1.9 million

Energy Resource Use

Description: Beyond reducing operational costs and emissions, fuel savings achieved through reduced vehicle and plane miles traveled may lessen the need for oil imports. Import dependency represents a non-localized impact that is global in scale, and when dependency on imports is high, the U.S. transportation system is vulnerable to price shocks caused by supply disruptions. Reduced fuel consumption can therefore lead to price stability and enhanced energy security.[41] Impacts on energy resource use are not typically included in benefit-cost analyses; instead, they are typically included in social return-on-investment (SROI) analyses as part of the natural resource element. The California example avoids double-counting energy resource benefits by including them in the benefit-cost analysis only.

Methodology: Consistent with the Chapter 4 methodology, the authors of the 2014 California study use a per-gallon cost of importing oil to estimate the value of reduced fuel consumption. The study uses NHTSA's cost of imports, which is $0.34 per-gallon in 2013 dollars after being adjusted for inflation by the authors.

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39 See PB 2014 *Benefit Cost Analysis*, p16-18 for details. Values were prepared using a variety of models developed federal and California agencies. Calculations consider many factors that are not efficiently documented outside the models. For illustrative purposes, 2040 values have been estimated as one-fifth of the present value for non-Co2 categories and one-eighth for CO2 based on the observation that phasing of travel benefits and factor value growth generally support this relationship and that CO2 is discounted at 3 percent rather than 7 percent.

40 PB 2014 *Benefit Cost Analysis,* p30, Table . Constant 2013 dollars. Present value of CO2 benefits is calculated using a 3 percent real discount rate, following USDOT guidance, rather than the 7 percent rate used for other benefit and cost categories.

41 National Highway Traffic Safety Administration, *Corporate Average Fuel Economy for MY 2011 Passenger Cars and Light Trucks* (Washington, D.C.: U.S. Department of Transportation, March 2009), II-2.

Results: Reduced vehicle fuel consumption generates an estimated oil import benefit of $394.6 million from 2013-2071 (in 2013 dollars). The authors use a discount rate of 7 percent in their benefit calculation.

Table C.10. Oil Imports Benefit Results from California HSR

Mode	**2040 Savings in Fuel Imported (gals)**	**2040 Benefit Value**	**2022-2071 Present Value**[42]
Highway	222.7 million	$75.7 million[43]	$394.6 million

Accessibility

Description: HS&IPR potentially increases the amount of population and economic activity which can be reached for a given amount of travel time and cost. Statistical and regional economic simulation models can estimate the value of increasing access to these people and businesses. Access improvement is typically measured in terms of the increase in scale of population or business markets (defined by either a travel time threshold or a gravity model decay function).

Example of Methodology: The CAHSR business plan notes the accessibility benefits described in Chapter 4. Economic growth impacts (from PB, 2014) are on a review of literature looking at how corridors which have high speed in Europe compare to corridors without HSR. Coefficients from this review are combined with regional economic data and travel model results to make estimates of jobs supported by accessibility improvements. The environmental impact report (Cambridge Systematics, 2008) used elasticities to an increase in the size of the market within a same day access threshold of 3.5 hours.

Example Results: The result of applying the accessibility factors or elasticities is like the effect of scaling the growth impacts found in a case study of Los Angeles to the entire corridor.[44] To more closely follow Chapter 4, future work could analyze the economic structure of the areas around the high-speed rail line to estimate more situation-specific accessibility impacts rather than applying coefficients from the literature to the entire corridor. USCM (2010) provides an example for LA that could be extended to other portions of the network.

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[42] PB 2014 *Benefit Cost Analysis,* constant 2013 dollars, discounted at 7 percent.
[43] See PB 2014 *Benefit Cost Analysis*, p9-10, which uses NHTSA's cost of imports: $0.34 per gallon. All values are in constant 2013 dollars.
[44] USCM 2010, *The Economic Impacts of High-Speed Rail on Cities and their Metropolitan Areas.*

Table C.11. Accessibility Benefit Results (Gross Regional Product) from California HSR

Source	Network-Wide	Metro (LA)
Productivity Effects	$6.1 billion[45]	$0.7 billion[46]
Business Attraction	$14.1 billion	$1.5 billion

Local (Area + Stakeholder) Impacts

"Local" impacts refer to effects that are specific to certain parties, either because of their location or their stakeholder role in financing or operating high speed trains or related services. They include:

A. Service Operator and Facility Owner Effects,
B. Land Development, and
C. Economic Impacts.

Service Operator and Facility Owner Revenues and Expenses (all modes)

Description: Road, rail and aviation modes involve facilities and services which may be owned and/or operated by public or private sector entities. In that context, HS&IPR may affect the revenues and expenses of rail and other modes, because of changes in use patterns. These net revenue or cost changes may be viewed as transfers between parties, as changes in user costs, and/or as changes in net government costs.

Example of Methodology: The chapter 4 methodology involves calculation of revenue and expenses based on simple multiplication of per traveler (or per vehicle) unit costs or fees, multiplied by the change in level of travel activity (rail or air travelers or cars).

Example Results: The PB (2014) study for California HSR applied the preceding methodology to estimate future changes in revenues for HSR operators and costs for operators of aviation, parking and road infrastructure (Table C.12).

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[45] Jobs reported in PB 2012 *Economic Impact Analysis Report*, p31, which was not updated for 2014, as ranging from 100,000-400,000 jobs. The upper range in the 2014 business plan is based on a GDP bonus coefficient for linked areas, while the 100,000 figure is based on an elasticity tied to access changes. For purposes of this example, we use a value of 200,000. It is reasonable to assume that 30 percent of these jobs are due to business productivity benefits of agglomeration and connectivity. Total access benefits estimated based on a GDP value of $101,000 per job.

[46] Constant 2009 dollars. USCM 2010 reports total impacts of $4.3 billion the Los Angeles region based on travel time savings, visitor spending and market access. About 50 percent of this impact is attributed to accessibility changes based on other case studies from USCM report.

Table C.12. Effects on Modal Operators or Owners from California HSR

Modal Effect	2040 Value	2040 Benefit	2022-2071 Present Value[47]
HSR Operator Revenue (and low-high range)	34,960,000 trips	$1,719 million ($1.288 – $2.207 million)	$10.0 billion ($7.4 – 13.0 billion)
Airline Operator Delay[48]	327,808 delay min.	$12.6 million	$60.9 million
Airline Operator Fuel[49]	806,554,533 seat-miles	$46.7 million	$293.7 million
Parking Infrastructure[50]	49,700 unneeded parking spaces	$42.5 million	$187.8 million
Pavement Damage	7.5 billion VMT	$12.7 million[51]	$62.3 million

Land Development

Description: HS&IPR increases the attractiveness of areas around the stations that it serves by making local business more accessible and giving residents more convenient access to other locations. This can spur construction of new buildings of greater density to take advantage of this accessibility benefit.

Example of Methodology: One example of the market assessment methodology described in Chapter 4 is provided the Economic Impact Analysis Report accompanying the 2012 Business Plan. A report selection looks at population and employment growth trends, ridership forecasts, intermodal connectivity and real estate absorption potential. However, this information is not used to make development assessments. The CAHSR environmental impact studies looked at land development from a different perspective based on the change in land consumption and urban density that might be caused by the rail service. Because of the scale of High Speed Rail projects, it is difficult to make detailed real estate development predictions within the scope of studies.

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[47] Constant 2013 dollars. Present value calculated based on a 7 percent real discount rate. See PB 2014 Benefit Cost Analysis, p30, Table .

[48] PB 2014 Benefit Cost Analysis, p11-12, p30, Delay & Propagated delay = 1.5 propagation ratio * 10.7 minutes of delay per flight * 2,040,458 passengers diverted from air / 99.6 passengers per plane = 327,808 delay minutes * $38.56 Cost of Delay Per Minute = $12,640,276. All values in constant 2013 dollars.

[49] Fuel Savings = 2,040,458 passengers diverted from air / 99.6 passengers per plane * 127 seats per plane * 310 miles per flight = 806,554,533 seat-miles / 71.52 seat-miles per gallon * $4.14 per gallon = $46,688,140. All values in constant 2013 dollars.

[50] Methodology described in PB 2014 Benefit Cost Analysis, p10. 2040 calculated as 27,225,280 diverted passenger trips / assumed 1.5 occupancy / 365 days per year * (0.5 * $321/surface space + 0.5 * $1068/covered space). All values in constant 2013 dollars.

[51] Calculated as a ratio of the 50-year present value, based on the observation that most 2040 undiscounted values are around 20 percent of the present value.

Example Results: The quantitative outcome of the 2012 Economic Impact Analysis Report's review of land development potential is based on existing planning documents at 7 of 15 stations, but does not employ the market assessment to a significant degree to attempt to estimate development potential at other stations. The outcome of CS's economic impact work is a land use efficiency gain of 1.3 percent in the northern portion of the network. PB's 2012 economic analysis follows the collection of inputs and presentation of outputs described in Chapter 4 closely, but does not necessarily provide an example of linking these pieces of analysis. CS's 2008 work also does not quite meet Chapter 4's recommendations, because land use changes are not identified around stations but only in urban areas as a whole.

Table C.13. Land Development Impacts (2040) from California HSR

Measure	**Regional (San Francisco to Merced)**[52]	**Station Areas (Full Corridor)**[53]
Population Gain/ Residential Development	149,000	7,000 units
Employment Growth/ Commercial Development	94,000	18 million sq. ft.
Urbanized Land Increase	9,900 acres	N/A
Efficiency Gain	1.3 percent	N/A

Economic Impacts

Description: The economic impact of a HS&IPR project is calculated by estimating how the economy of the study area would be different in a scenario with the project completed, compared to what would be the case in a scenario of baseline (no build) conditions. The total economic impact reflects the consequences of improved productivity (from time and cost savings and enhanced market access effects) as well as effects of inward investment on business attraction and expansion.

Economic impacts are measured during at a given point in time or over a specific period. Statistical models based on elasticity responses or structural economic simulation models are used to forecast effects on growth and change in the economy over time. Economic impacts are often reported in terms of jobs, wages paid, value added or gross domestic product, and business output.

Example of Methodology: The 2012 economic impact study published by the California High-Speed Rail Authority uses a ratio of jobs created per dollar of capital spending to estimate construction and operations and maintenance (O&M) employment impacts (20,000 job-years per $1 billion in capital spending, in 2010 dollars). The ratio represents an average across several studies. Chapter 4 recommends a more region-specific approach (not based on national averages) that differentiates

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[52] Values based on Table 5.3-7, p5-17 of the *2008 Bay Area to Central Valley HST Final Program EIR/EIS* prepared for the California High Speed Rail Authority by Cambridge Systematics, Inc. Only considers San Francisco to Merced section. Based on Pacheco alignment that was advanced in later planning documents. That wide impacts reach 320,000 jobs and 500,000 population from this project segment.
[53] PB 2012, *Economic Impact Analysis Report,* p46. Based on existing plans at 7 of 15 stations.

among direct, indirect, and induced impacts. PB (2012) also provides an example of a statistical elasticity based long-term effect, drawing on literature examples from European rail studies. CS (2008) and USCM (2010) both utilize the TREDIS simulation model which shows similar results.

Example Results: Between 49,500 and 62,300 average annual jobs could be created during construction of Phase I of California HSR. This is based on an estimated 990,000-1.2 million job-years over a 20-year period (1 job-year equals 1 job sustained over a single year). By 2040, O&M will support an estimated 2,900 permanent jobs. Looking only at the LA metro area about 55,000 jobs are attributed to high speed rail. These numbers seem to scale reasonably to network wide estimates that include the other large economic center in the Bay Area and significant expected development in the Central Valley.

Table C.15. Economic Impacts (Jobs) from California HSR

Source	**Network-Wide**	**Metro (LA)**
Long-Term Economic Impact Jobs	200,000 jobs[54]	55,000 jobs[55]
Construction Jobs	49,500 to 62,300 average annual[56] during construction years	N/A
O&M Jobs	2,900 in 2040[57]	N/A

[54]Jobs reported in PB 2012 *Economic Impact Analysis Report*, p31, which was not updated for 2014, as ranging from 100,000-400,000 jobs. Cambridge Systematics 2008 "Chapter 5 Economic Growth and Related Impacts", *Bay Area to Central Valley Environmental Impact Report* reports a value of 320,000 jobs in 2030 from the state-wide impacts of the northern segment with roughly 30 percent in counties of study region. The higher CS number includes time travel savings and other connectivity effects not reflected in PB 2012.

[55] USCM 2010 reports total impacts of 55,000 jobs in 2030 based on travel time savings, visitor spending and market access. About 50 percent of this impact is attributed to accessibility changes based on other case studies from USCM report.

[56] Low end of range based on 990,000 job-years over a 20-year period; PB 2012 *Revised 2012 Business Plan*, p9-12. High-end of the range based on 1.2 million job-years over a 20-year period; PB 2012 *Economic Impact Analysis*, p29.

[57] PB 2012 *Revised 2012 Business Plan*, p9-13.

Outcome Results for a Future Year

Table C.15 shows the value of benefits for a single future outcome year after completion of the planned HSR project: 2040. This outcome-oriented form of presentation (focusing on 2040 in this case) is most relevant for portraying (a) national benefits associated with environmental and energy resource use and (b) community and economic development effects – both categories representing effects whose consequences accumulate over time. The outcome oriented presentation is also useful for informing audiences about how actual travel conditions (and associated access, safety and noise effects) will be different in the future. These outcomes, which reflect the accounting perspectives of EIA and SIA, can also be used as a basis for assessing the effectiveness of alternative project proposals in achieving future goals.

Table C.15.California HSR: Value of Benefits in Future Year (2040) ($ billions)

1. Travel Benefits (System-wide)	**Rail**	**Hwy**	**Air**	**Total**
Travel Time	7.6	3.1	0.013	10.7
Travel Cost	1.2	0.1	0	1.3
Reliability	0.9	N/A	0	.9
Traveler Productivity	1.4	0	0	1.4
2. Societal Benefits: National Scale				
Traveler Safety Improvement	N/A	1.189	0	1.189
Reduction in Greenhouse Gas (CO_2)	- 0.002	0.021	0.005	0.024
Energy Resources: Oil Import Reduction	N/A	- 0.005	0.003	0.008
3. Regional Benefits (of National Significance)				
Agglomeration (market access productivity effect)	6.1	0	0	6.1
Emissions Reduction for Pollutants	N/A	0.025	0.013	0.038
4. Local Benefits (of National Interest)				
Noise Reduction	- 0.008	0.010	0	0.002
Station Area Development[58]	4.2	0	0	4.2
Regional Econ Growth beyond Station Area				
Gross Effect (not to be added to above numbers)	20.2	0	0	*
Net (less Agglomeration + Station Area Effects)	11.9	0	0	11.9
Total National + Regional Benefits	17.2	4.4	0	21.6

Table C.16 shows additional effects on revenues and expenses for modal operators. This form of presentation can be useful in showing how the financial position of facility owners and infrastructure or equipment operators will be affected with vs. without HSR service in place.

[58] Estimate for illustration purposes, calculated here assuming 30 percent of new business growth will occur near stations

Table C.16. California HSR: Value of Costs in Future Year (2040) ($ billions)

Operator + Owner Net Cost Adjustments	Rail	Hwy	Air	Total
Change in Revenues from Operating Facilities & Services	1.719	0	0	1.719
Savings in Expense of Operating Facilities & Services	4.77	-0.055	-0.059	-0.114

Present Value of Benefit and Expense Streams for a Period of Time

Table C.17 shows the discounted present value of a stream of benefits for a period after completion of the planned HSR project: 2022-2071. The benefits are again classified into four groups as defined in earlier section 5.1.5(A): travel benefits, societal benefits, regional benefits and local area benefits.

This form of measurement, totaling effects over a period of years, is most relevant for portraying travel related benefits that grow over time and have recurring consequences (and associated money valuations) for travel time, cost, safety, productivity and emissions. This form of measurement is not particularly useful for portraying station area development or community economic growth impacts, as those effects are better illustrated with the outcome-oriented presentation shown earlier.

Table C.17. California HSR: Present Value of Benefit Stream Over 2022-2071 ($ billions)

1. Travel Benefits (System-wide)	Rail	Hwy	Air	Total
Travel Time	34.7	15.4	0.04	50.1
Travel Cost	5.4	0.3	0	5.7
Reliability	5.3	N/A	0	5.3
Traveler Productivity	7.2	0	0	7.2
2. Societal Benefits: National Scale				
Traveler Safety Improvement	N/A	5.83	0	5.83
Reduction in Greenhouse Gas (CO_2)	-0.017	0.169	0.037	0.189
Energy Resources: Oil Import Reduction	0	0.395	N/A	0.395
3. Regional Benefits (of National Significance)				
Agglomeration (market access productivity effect)	30.5	0	0	30.5
Emissions Reduction for Pollutants	N/A	0.025	0.013	0.038
4. Local Benefits (of National Interest)				
Noise Reduction	- 0.032	0.078	0	0.046
Station Area Development	N/A	N/A	N/A	N/A
Regional Econ Growth beyond Station Area Gross Effect (not to be added to above numbers) Net (less Agglomeration + Station Area Effects)	N/A	N/A	N/A	N/A
Total National + Regional Benefits	**83.0**	**22.1**	**0.1**	**105.2**

Table C.18. California HSR: Present Value of Cost Streams Over 2022-2071 ($ billions)

Project Cost Element	**Rail**	**Hwy**	**Air**	**Total**
Capital Cost	29.4	0	0	29.4
Operating & Maintenance Cost	4.77	0	0	4.7
Salvage Value (remaining life of facilities)	-0.069	0	0	-0.069
Operator + Owner Net Cost Adjustments	**Rail**	**Hwy**	**Air**	**Total**
Change in Revenues from Operating Facilities & Services	10.0	0	0	10.0
Savings in Expense of Operating Facilities & Services	See above	-0.251	-0.355	-0.606

Midwest Regional Rail

The proposed Midwest High Speed Rail System will eventually connect a Chicago hub with lines south to St. Louis, west to Minneapolis-St. Paul, east to Cleveland and southeast to Indianapolis and Cincinnati. Case study data is drawn from reports for the Midwest High Speed Rail Initiative by TEMS (2004 and 2006), from the US Conference of Mayors (2010), from HDR (2010) for the Iowa Department of Transportation, from TranSystems (2012) and AECOM (2011) for the Midwest High Speed Rail Association.

Cost Elements

Project costs are the sum of the economic resources required to bring about the expected outcomes of an HS&IPR project (FRA, 2016a). Consistent with the description in Chapter 4, there are four cost elements that are calculated for applicable years:

5) Preliminary costs,
6) Capital investment costs,
7) Operating and maintenance costs, and
8) Asset replacement cost and the value of assets' remaining life.

Preliminary costs

Description: The preliminary costs include the expenses to conduct engineering design and environment review processes and studies for the feasibility of the projects. The cost for this category may be not be reported by all the BCA and Economic Impact studies.

Capital investment costs are the sum of the monetary resources needed to build a project and acquire relevant assets. FRA (2016a) provides the standard categories of the capital investment costs which are also discussed in Chapter 4.

Example of Methodology: TEMS (2004) provides a detailed estimation of the capital investment costs for the Midwest regional rail project. The operating plan focuses on construction costs and does not consider many soft costs or past planning costs. This treatment is consistent with the methodology described in Chapter 4.

Example Results: The total capital investment costs for the Midwest regional rail project is $ 8.3 Billion in terms of the 2002$ value. The analysis period is from 2000 to 2040.

Operating and maintenance costs

Description: Operating and maintenance (O&M) costs pertain to a wide array of costs that are necessary on a continuous basis to support HS&IPR functions to provide a given level of service. The O&M costs of an HS&IPR project throughout the entire analysis period should be included in the BCA. FRA (2016a) also recommends the standard categories for O&M costs which are discussed earlier in Chapter 4.

Example of Methodology: An example of O&M cost estimation for the Midwest regional rail can be found in TEMS (2004). TEMS includes a detailed operating analysis in section 10 that is consistent with best practice as described in Chapter 4.

Example Results: The operating costs start to occur from the year 2008 and are analyzed up to the year 2040. The total O&M costs in terms of constant 2002 dollars is estimated to be $14.1 Billion.

Assets replacement and remaining assets life cost

Description: The railroad project consists of assets whose expected life may be shorter than the period of the BCA analysis. Such assets should be replaced and repurchased which incurs additional cost during the repurchase time. On the other hand, some railroad assets such as bridges and tunnels have expected life exceeding the analysis period. Any remaining life of the infrastructures should be discounted at the end of the analysis period.

Example of Methodology: The operations planning and financial analysis appears to consider only routine maintenance of equipment, track and ROW. The asset replacement costs are not found in TEMS (2004) for the Midwest region, nor are remaining life values included in the benefit cost analysis. We are not aware of any other full cost estimation studies that have been done and would allow calculation of this category.

Example Results: It is not feasible to estimate this category for this case study considering the lack of documentation from which to work.

"User" (Traveler) Benefit Elements

Affected "users" of the transportation system may include travelers who travel on high speed trains or on roads, aircraft or conventional trains. Benefits may accrue to those who switch to high speed rail from other modes, and to those who remain traveling on those other modes. For travelers (of any mode), the primary benefits of high speed rail are likely to be measured in terms of:

A. Travel Time
B. Travel Cost
C. Congestion and Reliability

Travel Time

Description: As discussed in Chapter 4, travel time savings can accrue to both HSR users and remaining users of other modes. Often HSR can offer faster travel times than highway travel, as well as greater in-transit amenities. HSR service may to increased travel speed, service frequency and the convenient access to/egress from long distance travel hubs, relative to previously available intercity travel options. Users of other modes including highway and air travel also experience the savings in travel time due to reduced congestion at those modes.

Example of Methodology: TEMS (2006) calculates consumer surplus benefits of the MWRRS which includes travel time and travel costs savings to users. Consumer surplus is defined as the additional benefit users receive above the price paid for that commodity or service. The COMPASS model, developed by TEMS, estimates the consumer surplus by calculating the increase in regional mobility, traffic diverted to rail, and the reduction in travel cost measured in terms of generalized cost for existing rail users. The term generalized cost refers to the combination of time and fares paid by users to make a trip.

A later report by TranSystems (2012) uses similar estimates of ridership in various corridors and time savings per trip to estimate travel time savings in 2030 from a higher speed network. TranSystems (2012) considers users switching from highway to HSR and standard rail to HSR individually, but does not report times savings or losses for previous air users.

Example Results: The results from several examples are summarized in the table below. Because TEMS 2006 is based on a generalized cost methodology, the results include both travel time and travel cost. It is not clear if TEMS (2006) divided users into business and non-business travelers. However, TranSystems (2012) did not, attributing a constant value of time to all users instead. Future studies would benefit from calculating and reporting travel time for each mode and traveler class explicitly as described in Chapter 4 to better understand the impacts of HSR on different users.

None of the existing studies look specifically at delay savings for remaining users although results from TEMS 2006 reported in section 5.2.2(C) may be mostly due to delay rather than reliability.

Table C.19. Time Travel Savings from Midwest HSR

Type of Cost	Ridership	2030 Value	40-year Present Value
Total Consumer Surplus (includes time, all modes, 110mph)	14,823,786	$344.8 million[59]	$5.0 billion[60]
Current Rail User Travel Time (220 mph)[61]	2,686,900	$83.6 million	$0.86 billion[62]
Switching Highway User Travel Time (220 mph)[63]	32,784,006	$1.1 billion	$11.4 billion[64]

Travel Cost

Description: Travel cost include the direct cost of travel such as out-of-pocket expenses such as fares for line haul intercity rail, fares for access to/from intercity rail via taxi or public transit, and if accessing via car, then all associated costs of fuel, vehicle wear-and-tear, tolls and parking costs. For

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[59] TEMS 2004, p3-3, Exhibit 3-2 shows the reduction in travel times in the 9 corridors graphically. In the benefit cost analyses presented in TEMS 2004 and TEMS 2008, consumer surplus is not divided between travel cost and travel time, by mode or by corridor. Annual value is based on the calculated relationship between reliability benefits and their present values to provide a value for example purchases.
[60] Constant 2002 dollars. PV calculated using a 7 percent discount rate. Analysis period listed as 40-year present value ending in 2040 with initial capital upgrades beginning in 2004 and full system implementation in 2014. See TEMS 2006, p8, Exhibit 2 and TEMS 2004, p8-4 to p8-14.
[61] Transystems 2012, p16, Table .
[62] Assumes constant linear growth from 75 percent of 2030 savings in 2015 through 2054. Constant 2011 dollars. Discounted at 7 percent.
[63] Transystems 2012, p16, Table .
[64] Assumes constant linear growth from 75 percent of 2030 savings in 2015 through 2054. Constant 2011 dollars. Discounted at 7 percent.

users of other modes, there are similarly fares for bus or airline travel and vehicle costs if traveling by car. Travelers who switch to HS&IPR have net travel cost changes calculated as the difference in expense between the old and new mode. Travelers of other modes may also see changes if the addition of HS&IPR services leads them to a change in fares or fees. When information is not available on the cost of prior alternatives (including non-rail modes), then a “consumer surplus' approach is used which estimates the incremental benefit of switching alternatives (e.g., from air or bus to high speed rail) to be half of the savings per trip that applies for those already traveling by rail.

Example Methodology: TranSystems (2012) provides an example of the Chapter 4 methodology for travel costs savings. The analysis compares HSR fares and access/egress costs with costs for air or transit costs between the various city pairs which have stations. The analysis does not consider costs travel costs for those currently using intercity rail and switching to HSR. TEMS (2006) combines travel cost and travel time savings and reports them within the “Consumer Surplus” category.

Example Results: The total 40-year present value of benefits (time & cost) from the TranSystems (2012) study are roughly 6 times those of TEMS (2006) due to both the higher speed of travel tested, and the additional modal diversion caused by that travel speed. TranSystems (2012) estimates that cost savings are larger than the value of time savings. HDR (2010) also examines Vehicle Operating Cost savings, which is a component of travel cost for those switching for highway to rail travel. Table compares these different studies over a 40-year time frame. HDR (2010) reports a present value of $99.6 million for their 31-year analysis period.[65]

To agree with the Chapter 4 methodology, the other intercity modes such as bus and existing passenger rail should be included in the cost analysis, even if riders receive disbenefits in this category. The methods employed by TranSystems suggest they had access to that data, however we are not able to provide estimates for this case study without that source data. There is also not explicit consideration of induced riders which suggests their benefit may be either over estimated or underestimated. HDR (2010) did include a category induced travelers, but reported a cumulative present value of $0. New travel allowed by reduced travel costs is an important area of benefit Chapter 4 suggest including.

[65] See document page 218, appendix page 10, Table 6: VOC Net Savings to New Users and Induced Demand Benefits. It is not clear if it is net of fares or not.

Table C.20. Travel Cost Benefits from Midwest HSR

Type of Cost	**Ridership / VMT**	**2030 Cost Savings**[66]	**40-Year Present Value**[67]
Switch from Air to HSR (220 mph)[68]	3,999,219 trips	$0.3 billion	$3.3 billion
Switch from Highway to HSR (220 mph)[69]	32,784,006 trips	$1.6 billion	$16.6 billion
Switch from Highway to HSR (110 mph) (Chicago-Iowa City Scaled to MWRRS)	915.8 million VMT[70]	$380.2 million	$3.9 billion

Congestion and Reliability

Description: Travel time variability increases as transportation systems become more congested due to travel volumes exceeding facility capacity. By providing an alternative mode HS&IPR can reduce congestion on other networks, therefore improving those system's reliability. Reliability can often be measured using a buffer time or planning time concept.

Example of Methodology: The Benefit Cost and Economic Analysis report[71] accompanying the 2004 operating plan, considers reductions in congestion for both airports and highways in 9 Midwest states and 4 additional adjacent zones.

The value to remaining users of each diverted trip is based on the Federal Railroad Administration's (FRA) 1997 High Speed Ground Transportation for America report. The value of a diverted air trip considers both airline operating and passenger time costs. The number of diverted trips from air or highway modes are updated using TEMS travel demand model results.

As well as capturing reliability benefits, this FRA's congestion analysis also includes travel time savings for travelers remaining on other modes. Due to the methodology employed, it is not possible to separate out travel time from buffer time improvements, although the airport savings are more

[66] Value of time is $22.00 for all users.
[67] Assumes constant linear growth from 75 percent of 2030 savings in 2015 through 2054. Constant 2011 dollars. Discounted at 7 percent.
[68] Transystems 2012, p19, Table .
[69] Transystems 2012, p19, Table .
[70] TEMS 2004 predicts 68.3 percent of 14.8 million riders will divert from highway trips (derived from TEMS 2004, Tables 4-10, 4-35 and 4-36). This percentage and the occupancy rate specified by HDR 2010 (TEMS 2004 never states the occupancy rate) can be used to determine highway VMT savings from the full MWRRI system based on 25.6 million miles per year saved by the single line.
[71] TEMS 2006

likely to skew towards reliability, while the highway benefits mostly come from speed improvements that affect travel time.

Example Results: Total annual savings are estimated at roughly $811.5 million on average.[72] This analysis is no longer consistent with best practice as described in Chapter 4.

Table C.21. Congestion and Reliability Benefit Results from Midwest HSR [73]

Mode	Diverted Trips	Annual Benefit	40-Year Present Value
Air	1.3 million	67.96 million[74]	$1.0 Billion
Highway	5.1 million	119.5 million[75]	$1.6 Billion

Several later case studies employed a buffer time concept using engineering relationships the portion of the network congested in terms of volume to capacity ratios and the amount of time travelers must plan to leave early to ensure a reasonable chance of on-time arrival when driving. These studies found reductions in congestion in the Chicago metro area between 0.6 percent and 1 percent, which equates to roughly the same reductions in buffer time.[76] These case studies considered 150-220 mph rail options rather than 110 mph.

A one percent reduction in buffer time relative the 3.8 billion annual hours of travel affected is savings of around 200 million hours. Valued at $15 in 2000 dollars, this would have a benefit of roughly $3 billion. Network based travel models, or use of metro area statistics for TTI regarding planning time and buffer time indexes should allow future studies to more closely follow Chapter 4 in separating our congestion delay and congestions impacts on reliability.

Broader Societal Benefit Elements

The broader societal benefits are sometimes referred to as "non-user" benefits or impacts because they can affect everyone in each area – including non-users. They include:

A. Safety
B. Noise
C. Emissions
D. Energy Resource Use
E. Accessibility and Intermodal Connectivity

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[72] TEMS 2006 indicates the analysis period is 40 years ending in 2040 with initial capital upgrades beginning in 2004 and full system implementation in 2014. The 2000 Benefit Cost and Economy Analysis used a period from 2000 to 2030.
[73] Developed based on TEMS 2006, p5.
[74] Each diverted trip results in $52.28 of savings for remaining air travelers. Constant 2002 dollars. Documentation does not specify what year trip diversions are for.
[75] Each diverted trip results in $23.43 of savings for remaining highway travelers. Constant 2002 dollars. Documentation does not specify what year trip diversions are for.
[76] US Conference of Mayors 2010 and AECOM & EDRG 2001.

Safety

Description: Safety represents cost savings that occur when vehicle and plane crashes are avoided, and added costs from train crashes. Safety impacts are nonlocalized, meaning that benefits and disbenefits are generally not confined to a specific geography.

Example of Methodology: A benefit-cost analysis prepared for the Iowa Department of Transportation used a safety value of $0.03 per vehicle mile traveled, drawing on FRA high-speed rail guidance and USDOT guidance on preparing benefit-cost analyses for TIGER grant applications.[77] Because the methodology is not as robust as that recommended in Chapter 4, we extend the Midwest analysis below. The authors estimate an average annual trip diversion of 205,436, which results in 25.6 million fewer VMT annually over the 31-year analysis period.

Like the California example, the Iowa DOT study accounts for reduced vehicle crashes but not reduced plane crashes and increased train crashes. Without information on diverted plane-miles and increased train-miles, we are unable to estimate associated safety impacts.

Example Results: Using the methodology from Chapter 4 (with crash rate and cost values found in the 2014 California study) benefits are as follows: $1.9 million from reduced fatalities, $1.9 million from reduced injuries, and $66,289 from reduced property damage (in 2011 dollars). Using the more alternative methodology, the total safety benefit is $3.9 million.

Table C.22. Safety Benefit Results from Midwest HSR

Mode	**Average Annual VMT Reduction**	**Average Annual Benefit Value**	**2015-2045 Present Value**
Highway (MWRRI)	915.8 million[78]	$27.5 million[79]	$264.6 million[80]
Highway (Ch4 Method)	915.8 million	$144.3 million[81]	$1,548.2 million[82]

Noise

Description: Noise pollution is a localized impact that can be measured on a per-mile basis. Noise reduction resulting from diverted vehicle trips represents a benefit while added noise from high-

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[77] See HDR 2010 "Appendix B" *Chicago to Iowa City High-Speed Intercity Passenger Rail Program Service Development Plan.*
[78] See footnote 70.
[79] Base on $0.03 per mile accident cost recorded in HDR 2010 "Appendix B" Table 2.
[80] Constant 2011 dollars. Present value calculated using a 7 percent discount rate.
[81] Constant 2013 dollars, based on values of accidents from PB 2014 *Benefit Cost Analysis.*
[82] Constant 2013 dollars, based on values of accidents from PB 2014 *Benefit Cost Analysis.* Assumes linear growth of travel from opening year volume of 246,800 to 2045 based on average VMT reduction per year.

speed rail represents a disbenefit. Below is an illustration of an applied methodology from the 2010 Chicago-Iowa City study.

Methodology: The example methodology relies on guidance from the USDOT—including guidelines for preparing TIGER grant applications—for per-VMT noise costs. Unlike in the 2014 California study, added noise from high-speed rail cannot be estimated for this example because the Chicago-Iowa City study does not include added train-miles (only ridership). The methodology is otherwise consistent with that recommended in Chapter 4, with noise impacts calculated on a per-VMT basis.

Results: The study does not estimate the noise improvement from reduced plane trips or additional noise from train trips. See Table C.23 for details.

Table C.23. Noise Benefit Results from Midwest HSR

Mode	**Average Annual VMT Reduction**	**Average Annual Benefit Value**[83]	**2015-2045 Present Value**[84]
Highway (Chicago-Iowa City Line Scaled to MWRRI)	915.8 million[85]	$915,800	$8.6 million

Emissions

Description: Benefit-cost analyses can estimate the amount and value of high-speed rail emissions and avoided emissions from diverted automobile, truck, and plane trips. Both criteria air pollutants and greenhouse gas (GHG) emissions are important to consider. Air pollution from mobile sources is localized, while stationary pollution is localized only if the source is located within the study region. Because GHG emissions enter the atmosphere and travel far distances from their point of origin, they represent a non-localized impact.

Methodology: The service development plan for Chicago to Iowa city provides an example of estimating the net impact on several criteria air pollutants and GHG emissions (CO_2) resulting diverted vehicle and plane trips and the introduction of high-speed rail.[86] Emissions are valued at $4,166/ton for NO_X, $174,976/ton for PM, $1,771/ton for VOC, and $34/ton for CO_2. These values are considerably lower than current USDOT guidance, and do not reflect the changing value of CO_2 over time. Updating these factors would result in higher magnitude benefits. Calculating individual pollutants provides additional transparency compared with the MWRRI Benefit and Economic Analysis which only utilizes a single value of all types of air pollution per mile. This methodology is generally consistent with Chapter 4, with emissions first estimated on a per-VMT basis and then monetized using various values per ton.

[83] HDR 2010 "Appendix B" values the externality of highway noise at one-tenth of a cent per VMT.
[84] Constant 2011 dollars. Present value calculated using a 7 percent discount rate.
[85] See footnote 70.
[86] HDR 2010 "Appendix B"

Results: When per-ton values are applied to the change in air pollution and GHG emissions (CO_2), the net environmental benefit equals -$12.6 million over the 30-year analysis period, discounted at 7 percent. Negative benefits from localized pollutants reflects higher emission rates from diesel locomotives than from gasoline automobiles. See Table C.24 for details. In 2012, TranSystems completed an analysis of Midwest rail with four 220-mph electrified lines.[87] This study shows 3-4 times as much ridership and very large CO2 savings as well as decreases in all criteria pollutants except SOx. The TranSystems analysis considered air, existing rail, auto, and upgraded rail markets separately, however it only reported metric tons of savings without monetizing results.

Table C.24. HSR Greenhouse Gas and Criteria Pollution Benefit Results from Midwest HSR

Analysis	**Pollutant (All Modes)**	**Cumulative Tons Reduced**	**Average Annual Benefit**	**Present Value**
Chicago – Iowa City Line Scaled to Full MWRRI[88]	VOC	10,441	$0.6 million	$-513.7 million[89]
	NOx	-130,083	-$17.5 million	
	PM	-6,722	-$37.9 million	
	CO_2	4.0 million	$6.2 million	$105.8 million[90]
MWRRI Benefit Cost Analysis	SOx, CO2, NOx, PM, VOC, and CO	Unavailable[91]	$60 million[92]	$0.6 billion[93]

Energy Resource Use

Description: Fuel savings achieved through reduced vehicle and plane miles traveled may lessen the need for oil imports, possibly leading to increased price stability and enhanced energy security.[94]

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[87] TranSystems 2012 *Midwest Network 220 mph High Speed Rail Network Benefits Study*

[88] There are about 36 times as many VMT saved on the two networks as the volumes reported by HDR for the single line. Because CO2 is the major emission relevant for airlines, these trips are included as well using the ratio between ridership in the two studies rather than just VMT.

[89] 31-year analysis period (2015-2045). Constant 2011 dollars. Present value calculated using a 7 percent discount rate.

[90] 31-year analysis period (2015-2045). Updated to follow published guidance from USDOT in the *2016 Benefit Cost Analysis Resource Guide.* Constant 2011 dollars, discounted at 3 percent.

[91] All pollutants were collapsed to a single per mile value. NOx, PM, VOC, and CO values in the original analysis varied by county based on attainment level.

[92] Calculated as an example based on other relationships between average annual values and present values being about an order of magnitude different.

[93] 40-year analysis period. Constant 2002 dollars. Present value calculated using a 7 percent discount rate. Values used in TEMS 2006 are based on FRA's results using 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. TEMS 2006 uses $0.02 per vehicle mile reduced.

[94] National Highway Traffic Safety Administration, *Corporate Average Fuel Economy for MY 2011 Passenger Cars and Light Trucks* (Washington, D.C.: U.S. Department of Transportation, March 2009), II-2.

Methodology: The authors of the 2014 California study use a per-gallon cost of importing oil to estimate the value of reduced fuel consumption. The study uses NHTSA's cost of imports, which is $0.34 per-gallon in 2013 dollars ($0.33 in 2011 dollars) after being adjusted for inflation by the authors. For purposes of illustration, this methodology is applied to the Chicago-Iowa City high-speed rail characteristics, with the per-gallon cost multiplied by 10.8 million gallons of fuel saved over the 31-year analysis period.

As mentioned in the California section, impacts on energy resource use are not typically included in benefit-cost analyses; instead, they are typically included in social return-on-investment (SROI) analyses as part of the natural resource element. Because this Midwest example is based on the California study, it avoids double-counting energy resource benefits by including them in the benefit-cost analysis only.

Results: The estimated energy resource benefit equals approximately $442,000 in 2011 dollars after discounting the future value at 7 percent. See Table C.25 for details.

Table C.25. Energy Resource Benefit Results from Midwest HSR

Mode	Average Annual Reduction (Gallons Consumed)	Average Annual Benefit Value	2015-2045 Present Value[95]
Highway	12.4 million[96]	$4.1 million	$38.5 million

Accessibility

Description: HS&IPR potentially increases the amount of population and economic activity which can be reached for a given amount of travel time and cost. Statistical and regional economic simulation models can estimate the value of increasing access to these people and businesses. Access improvement is typically measured in terms of the increase in scale of population or business markets (defined by either a travel time threshold or a gravity model decay function).

Example of Methodology: An example of a statistical and continuous decay measurement strategy identified in Chapter 4 is offered by the MWRRI economic analysis.[97] Statistical analysis of the relationship between economic measures and the time and money costs for travel between cities in the Midwest based on existing infrastructure (weighted by observed frequency of travel between cities) is used to develop coefficient relating the two variables. Estimating the generalized cost after the addition of 110 mph rail service in the nine-state region and applying it to the estimated equation yields an estimate of economic measures in response to the MWRRI network build-out.

Another study uses response functions for labor market size and economic activity estimated from a national data set.[98] In this study only city pairs within 2 hours of each other using 150 or 220 mph

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[95] Constant 2011 dollars. Present value calculated using a 7 percent discount rate.
[96] 10.8 million
[97] TEMS 2006
[98] AECOM & EDRG 2011

rail are considered and further weighted by the number of induced trips predicted and the inverse distance between cities. This only considered four of the eight lines of the MWRRS with less service in Illinois, Iowa, Michigan, and Missouri especially, and only impact results occurring in the metro Chicago region rather than the other major cities in the network.

Example Results: Both example methodologies require information of travel patterns and costs between locations in the network and a set of economic data sufficient to estimate responses. For HS& IPR studies much of this information is collected during development and use of the travel modeling process, but is often not applied to understanding this impact category. As discussed in Chapter 4, there are a variety of different approaches available to understand accessibility with these examples only demonstrating some options.

The 2004 operating plan did not include direct airport connectivity at Chicago's O'Hare airport, which resulted in 35 percent fewer travelers diverted from air than earlier studies.[99] A 2011 report for analyzes options with connections between O'Hare and downtown and discusses the importance of providing a connection to long-distance and international flights to promote both business and leisure travel.[100]

Table C.26. Accessibility Impacts (gross regional product or value-added) from Midwest HSR

Mode	Network-Wide	Metro Chicago
Productivity Effect	$0.6 billion[101]	$0.8 billion[102]; $0.3 billion[103]
Business Attraction Effects	$1.0 billion	$1.6 billion; $0.5 billion

Local (Area + Stakeholder) Impacts

"Local" impacts refer to effects that are specific to certain parties, either because of their location or their stakeholder role in financing or operating high speed trains or related services. They include:

A. Service Operator and Facility Owner Effects,
B. Land Development,
C. Other Economic Impacts, and
D. Tax Revenue Changes.

Service Operator and Facility Owner Revenues and Expenses (all modes)

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[99] TEMS 2006, p5
[100] AECOM and EDRG 2011
[101] TEMS 2006, p19, Exhibit 14. 110 mph trains, constant 2002 dollars. Scaled from $1.1 billion of added income, based on a 70 percent of value added deriving from income, as shown in USCM 2010 and AECOM and EDRG 2011 for the Chicago region.
[102] AECOM and EDRG 2011, 150 mph trains, constant 2010 dollars.
[103] USCM 2010. 110 mph service, constant 2009 dollars. Results for 2035. Considers a much less extensive system than TEMS 2006 or AECOM & EDRG 2011. Total economic GDP impact of $1.5 billion reduced to account for 50 percent of benefits from market access and 30 percent of access benefits from in terms of productivity.

Description: Description: Road, rail and aviation modes involve facilities and services which may be owned and/or operated by public or private sector entities. In that context, HS&IPR may affect the revenues and expenses for rail and other modes, because of changes in use patterns. This may include reducing wear and tear and associated maintenance costs on highways by diverting travelers, or reducing fuel use and crew time by reducing airport congestion. In each case, the net revenue or cost change may be viewed as transfers between parties, as a change in user costs, and/or as a change in net government costs.

Example of Methodology: The chapter 4 methodology involves calculation of revenue and expenses based on simple multiplication of per traveler (or per vehicle) unit costs or fees, multiplied by the change in level of travel activity (rail or air travelers or cars).

Operating plans for MWRRS calculate annual revenue for the HSR system operator based on ridership and optimized fares in each corridor. The benefit cost analysis also considers airline operator savings from less terminal delay and highway agency savings can be calculated based on a factor for pavement deterioration per mile of travel documented in HDR (2010).

The included categories are executed in line with Chapter 4 methods, however, best practice would be to calculate several other categories. For example, competing mode's revenues will be affected by travelers switching travel modes to high speed rail. In the case of an airline, these lost travelers may also tip the scale towards shutting down an unprofitable regional flight that could save the airline money.

Example Results: Estimating revenues for owners and operators also may provide some insight into the value of transportation for the consumer based on what they are willing to pay for transportation. TEMS (2006) values the discounted system revenues at $4.7 billion over 40 years as a measure of consumers' value of purchased services. Annual values of for 3 reported categories of owner/operator benefits are shown in Table C.27.

Table C.27. Service Operator and Facility Benefit Results from Midwest HSR

Mode	Input	Annual Benefit	40-year Present Value
System Revenues	15 million HSR trips	$763 million in 2040[104]	$4.7 billion
Air Delay Cost Savings	1.3 million diverted air trips	$36.57 million[105]	$0.5 billion
Highway Cost Savings	1.45 billion diverted vehicle miles[106]	$4.35 million[107]	$48.6 million

Land Development

Description: HS&IPR increases the attractiveness of areas around the stations that it serves by making local business more accessible and giving residents more convenient access to other locations. This can spur construction of new buildings of greater density to take advantage of this accessibility benefit.

Example of Methodology: As mentioned in Chapter 4, the MWRRI studies value land development based on the same Economic RENT model used for measuring the employment and income effects of accessibility change. This is a simplified hedonic price model based on one major variable, but the final report also includes elements of the second valuation strategy mentioned in Chapter 4, without being a full-fledged market assessment. Over 80 percent of the proposed MWRRS stations were visited to complete a comparative assessment of station area development potential and validate model results.[108]

Example Results: Across the nine-state region's 102 stations total land development potential was estimated at nearly $5 billion. Additional market assessment of a few specific locations suggested the statistical approach could have under estimated total opportunity by as much as 50 percent.[109] Because station area development is a down allocation of region-wide development estimates, it does not exactly follow Chapter 4 methods, however, it demonstrates an innovative approach for combing local area knowledge with regional modeling.

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[104] TEMS 2004, p10-6, Exhibit 10-2. Constant 2002 dollars. See also p4-56, Exhibit 4-42, which shows revenue of $578.55 million in 2015 and $672.16 million in 2025.
[105] Constant 2002 dollars. TEMS 2006, p6. Neither airline ticket revenue reductions nor avoided flight costs are considered. $28.13 per diverted air trip.
[106] TEMS 2004, p4-48, Exhibit 4-35 shows 2.39 billion rail passenger miles. Using an occupancy of 1.5 passengers per auto, and assuming on average HSR trips are the 10 percent longer than auto trips as a conservative estimate, this could represent 1.45 billion VMT per year (2.39/1.5/1.1).
[107] Constant 2011 dollars. See HDR 2010, "Appendix B," *Chicago to Iowa City High-Speed Intercity Passenger Rail Program Service Development Plan,* p 216. $0.003 / diverted vehicle mile
[108] TEMS 2006, p20
[109] TEMS 2006, p36

Table C.28. Midwest (Chicago Hub) Land Development Results

Method	City-Wide	Downtown Station
Property Value	$1,150 - 1,725 million[110]	Unavailable
Square Feet of Development[111]	2.7 – 4.1 million	1.0 – 1.5 million
Income	$242 – 363 million[112]	$277 million[113]
Employment	12,200 – 18,375[114]	4,725[115] - 6,500[116]

Economic Impacts

Description: As mentioned previously, the economic impact of a HS&IPR project is calculated by estimating how the economy of the study area would be different in a scenario with the project completed, compared to what would be the case in a scenario of baseline conditions. Statistical models based on elasticity responses or structural economic simulation models are used to forecast effects on growth and change in the economy over time. Economic impacts are often reported in terms of jobs, wages paid, value added or gross domestic product, and business output.

Example of Methodology: The 2006 Midwest Regional Rail Initiative report (TEMS 2006) uses economic multipliers developed by the U.S. Bureau of Economic Analysis to estimate the economic impacts of high speed rail. TranSystems (2012) also uses these RIMS II multipliers, which come from a static input-output accounting model, are used to estimate the extent to which jobs are generated and occur within the designated study area within a single year. This methodology is consistent with the methodology outline in Chapter 4. TEMS (2006) uses a statistical regression approach develop using Midwest data. AECOM & EDRG (2011) and USCM (2010) are also included to show provide an example of a simulation based approach focused on Chicago. Both methodologies are endorsed by Chapter 4.

Example Results: Between 15,200-19,057 average annual jobs could be created during construction of Midwest HSR, with 4,593 occurring in the Chicago region alone. This is based on a 20-year period, with job-years converted to average annual employment. O&M will support an estimated 632 permanent jobs in the Midwest, 254 of which will be in the Chicago region. The results in Table show that the approaches to measuring economic impacts to accessibility in terms of jobs result in similar magnitudes of results considering the different geographic scope of the analysis.

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[110] TEMS 2006, p34, Exhibit 23. Potential final build-out.
[111] Based on employment estimate and 225 sq. ft. per employee. May underestimate visitor spending driven jobs.
[112] TEMS 2006, p34, Exhibit 23
[113] Based on ratio of employment impacts.
[114] TEMS 2006, p34, Exhibit 23
[115] AECOM & EDRG 2011, 150 mph service, considers only Chicago Union Station and urban core development.
[116] EDRG 2010 for USCM. 110 mph service, 2000 jobs from visitor spending remaining as business/office.

Table C.29. Midwest Economic Impact Results

	Network Wide	**Chicago**
Travel Improvement Jobs	N/A	21,000[117]
Visitor Spending Jobs	N/A	7,530[118]
Labor Market Access Jobs	58,260[119]	29,530[120]; 18,400[121]
Construction Jobs	15,200-19,057[122]	4,593[123]
O&M Jobs	632[124]	254[125]

Linkages with feeder services and last-mile modes are key to realizing the economic impact of accessibility and development changes. More than 50 percent of the increased visitor spending ($120 million), which results in job impacts, is transfers from diffuse spending in outlying areas to the downtown.[126] This aggregation of economic activity has the potential for beneficial synergies, including helping to drive the induced portion of visitor spending.

Tax Revenue Changes

Description: Some government expenditures can be directly recouped through tax revenue increases resulting from the resultant economic growth. Based on economic impact results at different geographic levels these revenue impacts can be estimated.

Methodology: TEMS's Benefit Cost and Economic Analysis calculates a tax benefit for the government based on applying a 5 percent tax rate to $15 billion dollars of new income over 30 years due to economic growth resulting from the project. The 5 percent rate is meant to represent both sales and income tax revenue.

Results: Over 30 years the calculated benefit is $750 million dollars.

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[117] AECOM and EDRG 2011, p92, Table .
[118] AECOM and EDRG 2011, p92, Table . 150 mph trains. Visitor spending includes 4,410 direct jobs, remaining jobs from indirect and induced economic activity.
[119] TEMS 2006, p19, Exhibit 14
[120] AECOM and EDRG 2011, p92, Table 9. 150 mph trains.
[121] USCM 2010. 110 mph service, considers a much less extensive system than TEMS 2006 or AECOM & EDRG 2011. Results for 2035.
[122] Low-end of the range from TEMS 2006, p48. High-end of the range from TranSystems 2012, p6.
[123] TranSystems 2012, p6.
[124] TranSystems 2012, p6.
[125] TranSystems 2012, p6.
[126] AECOM and EDRG 2011, p95.

Table C.30. Midwest Tax Revenue Benefit Results

	New Income	Tax Rate	Benefit
Sales and Income[127]	$15 billion	5 percent	$750 million (2002$)

Outcome Results for a Future Year

Table C.31 shows the value of benefits for a single future outcome year after completion of the planned HSR project: 2045. As in the earlier California case example, benefits are classified into four groups: travel benefits, societal benefits, regional benefits and local areas benefits.

The outcome-oriented form of presentation (focusing on 2045 in this case) is most relevant for portraying (a) national benefits associated with environmental and energy resource use and (b) community and economic development effects – both categories representing effects whose consequences accumulate over time. The outcome oriented presentation is also useful for informing audiences about how actual travel conditions (and associated access, safety and noise effects) will be different in the future. These outcomes can also be used as a basis for assessing the effectiveness of alternative project proposals in achieving future goals.

[127] TEMS 2006, p48

Table C.31. Midwest HSR: Value of Benefits in Future Year 2045 ($ billions)

1. Travel Benefits (System-wide)	Rail	Hwy	Air	Total
Travel Time	0.345	N/A	N/A	0.345
Travel Cost	*	N/A	N/A	*
Reliability	N/A	0.120	0.068	0.188
Consumer Surplus from Induced New Travel	*	0	0	*
2. Societal Benefits: National Scale	**Rail**	**Hwy**	**Air**	**Total**
Traveler Safety Improvement	N/A	0.144	N/A	0.144
Reduction in Greenhouse Gas (CO_2)	N/A	N/A	N/A	^
Energy Resources: Oil Import Reduction	N/A	0.004	N/A	0.004
3. Regional Benefits (of National Significance)				
Agglomeration (market access productivity effect)	0.6	0	0	0.6
Emissions Reduction for Pollutants	N/A	0.06	N/A	0.06
4. Local Benefits (of National Interest)				
Noise Reduction	N/A	0.001	N/A	0.001
Station Area Development	0.3	0	0	0.3
Regional Econ Growth beyond Station Area				
Gross Effect (not to be added to above numbers)	1.6	0	0	1.0
Net (less Agglomeration + Station Area Effects)	0.7	0	0	0.7
Total National + Regional Benefits	**0.945**	**0.328**	**0.068**	**1.341**

* Included in Travel Time as a Consumer Surplus calculation based on a generalized cost model.
^ Greenhouse gasses and local pollutants reported as a single value.

Present Value of Benefit and Expense Streams for a Period of Time

Table C.32 shows the discounted present value of a stream of benefits for a period after completion of the planned HSR project: 2012-2045. The benefits are again classified into four groups: travel benefits, societal benefits, regional benefits and local area benefits.

This form of measurement, totaling effects over a period of years, is most relevant for portraying travel related benefits that grow over time and have recurring consequences (and associated money valuations) for travel time, cost, safety, productivity and emissions. This form of measurement is not particularly useful for portraying impacts on station area development or community economic growth – as those other effects are better illustrated with the outcome-oriented form of presentation presented earlier.

Table C.32. Midwest HSR: Present Value of Benefit Stream Over 2006-2045 ($ billions)

1. Travel Benefits (System-wide)	Rail	Hwy	Air	Total
Travel Time	5.0	N/A	N/A	5.0
Travel Cost	*	N/A	N/A	*
Reliability	N/A	1.0	1.6	2.6
Consumer Surplus from Induced New Travel	*	0	0	*
2. Societal Benefits: National Scale	**Rail**	**Hwy**	**Air**	**Total**
Traveler Safety Improvement	N/A	1.5	N/A	1.5
Reduction in Greenhouse Gas (CO_2)	N/A	N/A	N/A	^
Energy Resources: Oil Import Reduction	N/A	0.039	N/A	0.039
3. Regional Benefits (of National Significance)				
Agglomeration (market access productivity effect)	8.7[128]	0	0	8.7
Emissions Reduction for Pollutants	N/A	0.6	N/A	0.6
4. Local Benefits (of National Interest)				
Noise Reduction	N/A	0.009	N/A	0.009
Station Area Development	N/A	N/A	N/A	N/A
Regional Econ Growth beyond Station Area Gross Effect (not to be added to above numbers) Net (less Agglomeration + Station Area Effects)	N/A	N/A	N/A	N/A
Total National + Regional Benefits	**13.7**	**3.14**	**1.6**	**18.44**

* Included in Travel Time as a Consumer Surplus calculation based on a generalized cost model.
^ Greenhouse gasses and local pollutants reported as a single value.
# Not included in totals. Gross affect additional reported as net lines.

Table C.33. Midwest HSR: Present Value of Cost Streams Over 2006-2045 ($ billions)

Project Cost Element	Rail	Hwy	Air	Total
Capital Cost	5.1	N/A	N/A	5.1
Operating & Maintenance Cost	4.0	N/A	N/A	4.0
Salvage Value (remaining life of facilities)	N/A	N/A	N/A	N/A
Operator + Owner Net Cost Adjustments	**Rail**	**Hwy**	**Air**	**Total**
Change in Revenues from Operating Facilities & Services	4.7	0	N/A	4.7
Savings in Expense of Operating Facilities & Services	See above	-0.05	-0.5	-0.55

128 Based on other present values of impact streams being about 14.5 times annual values.