The Future of Intercity Passenger Transportation

SCHOOL OF PUBLIC AND
ENVIRONMENTAL AFFAIRS
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EXECUTIVE SUMMARY

The purpose of this report is to explore the future of intercity passenger transportation in the United States. The report forecasts the share of travel that will be completed in 2060 by each of four modes—air, auto, bus, and rail. Specifically, a conditional logit model is used to predict consumer choice among the modes. The model predicts consumer choice based on two primary variables: user price and trip time. The forecasts incorporate anticipated technology advancements, as well as the economic and environmental factors expected to affect passenger transportation during the next 50 years. The primary factors that impact the consumer choice variables are fuel price, carbon price, rail subsidy, and level of innovation. Business travel and leisure travel are modeled separately due to the different attributes of business and leisure travelers.

According to the 2009 National Household Travel Survey, auto currently dominates leisure travel at the average intercity trip length of 244 miles, capturing 88 percent of mode share. Over the same trip length, air captures nine percent, bus captures three percent, and rail captures 0.32 percent of leisure mode share. At a trip length of 500 miles, auto captures 41 percent, air captures 56 percent, bus captures two percent, and rail captures 0.14 percent of leisure mode share. At a trip length of 1,000 miles, air dominates with more than 98 percent of leisure mode share. Business travelers place a higher value on time, leading them to choose air more frequently than leisure travelers, especially at the 500-mile distance.

Projecting out to 2060, this report forecasts only small shifts in mode share at short (less than 250 miles) and long (greater than 1,000 miles) distances, with auto continuing to dominate at short distances and air continuing to dominate at long distances. The largest shift in mode share occurs at the 500-mile distance, where auto captures mode share from air. Large relative increases in fuel efficiency for automobile relative to air account for this shift. The results of the model also indicate that carbon pricing, even at the highest levels, does not change overall mode share. Finally, the elimination of rail subsidies effectively reduces the mode share for conventional rail to zero.

In addition to projecting mode shares on the national level, the report forecasts the mode share that high-speed rail would capture within the California corridor from San Francisco to San Diego. The results indicate that high-speed rail would require large capital subsidies to capture more than a few percentage points of mode share. Furthermore, high-speed rail would be highly unlikely to achieve the ridership necessary to avoid additional subsidies for operations and maintenance. As with the national model, the addition of a carbon price has little impact on mode share in the California corridor.

In conclusion, this report predicts mode share in 2060 to remain similar to that in 2009, with the exception of a shift from air to auto travel at the intermediate distance of 500 miles. High-speed rail will only capture mode share with high levels of subsidization. Carbon pricing, even at high levels, does not strongly impact customer mode choice.

COURSE INFORMATION

Each year, the School of Public and Environmental Affairs at Indiana University, Bloomington, organizes several capstone courses intended to provide graduate students with the opportunity to apply their analytical knowledge and skills in a real-world interdisciplinary setting. Each course is designed to allow students in the various joint degree programs, including MPA/MSES, MPA/JD, and MSES/JD to employ their respective concentrations and address complex public policy issues in a collaborative manner in an effort to create logical and practical recommendations. The overriding goal of the capstone course is to challenge students and encourage them to delve into policy areas in which they may not be particularly familiar.

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LIST OF ACRONYMS

AAA	American Automobile Association
ACI	Airports Council International
AFV	Alternative Fuel Vehicles
AGV	Automobile à Grande Vitesse
AIP	Airport Improvement Program
ANAC	The National Civil Aviation Agency of Brazil
ATC	Air Traffic Control
ATC	Automatic Train Control
ATS	Automatic Train Stops
BAU	Business as Usual
BRDB	Biomass Research and Development Board
BTS	Bureau of Transportation Statistics
Cal DOT	California Department of Transportation
CENIPA	Center of Research and Prevention against Aeronautical Accidents
CFC	Customer Facility Charges
CH_4	Methane
CHSRA	California High-Speed Rail Authority
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CONAC	Civil Aviation Council
CPI	Consumer Price Index
CTL	Coal-to-Liquids
DECEA	Department of Airspace Control
DHS	Department of Homeland Security
DOE	Department of Energy
DOT	Department of Transportation
EIA	Energy Information Administration
EPA	Environmental Protection Agency
EV	Battery-Electric Vehicles
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FRA	Federal Rail Administration
FT	Fischer-Tropsch
GAO	Government Accountability Office
GARB	General Aviation Revenue Bonds
GE	General Electric
GHG	Greenhouse Gas
GPS	Global Positioning System
HAS	Homeland Security Act
HCCI	Highway Construction Cost Index
HFCV	Hydrogen Fuel Cell Vehicles
HRJ	Hydroprocessed Renewable Jet
HSIPR	High-speed and Intercity Passenger Rail
HSR	High-Speed Rail
HV	Hybrid-Electric Vehicles

IATA	International Air Transport Association
IBRD	International Bank for Reconstruction (World Bank)
ICE	Internal Combustion Engines
INFRAERO	Brazilian Airport Infrastructure Company
IPCC	Intergovernmental Panel on Climate Change
JAMA	Japan Automobile Manufacturers Association
JNR	Japan National Railway
JPDO	Joint Planning and Development Office
JR	Japan Railway Companies
JRTT	Japan Railway Construction, Transport, and Technology Agency
LPG	Liquefied Petroleum Gas
MPH	Miles per Hour
NAS	National Airspace System
NEC	Northeast Corridor
NGV	Natural Gas Vehicles
NHS	National Highway System
NHTS	National Household Transportation Survey
NMVOC	Non-methane Volatile Organic Carbons
NO_x	Nitrous Oxides
NRPC	National Railroad Passenger Corporation (Amtrak)
NTSB	National Transportation Safety Board
O&M	Operations and Maintenance
OECD	Organization for Economic Co-operation and Development
PFC	Passenger Facility Charges
PHEV	Plug-In Hybrid Electric Vehicles
PM	Particulate Matter
PNAC	Enactment of National Civil Aviation Policy
PNW	U.S. Pacific Northwest
PNW	Pacific Northwest
PTC	Positive Train Control
RICE	Regional Integrated Model of Climate and the Economy
SAC	Secretary of Civil Aviation
SCC	Social Cost of Carbon
SOGR	State of Good Repair
SPK	Synthetic Paraffinic Kerosene
SPP	Screening Partnership Program
TGV	Train à Grande Vitesse
TSA	Transportation Security Administration
USCB	U.S. Census Bureau
USPO	United States Post Office
USW	U.S. Southwest
WSDOT	Washington State Department of Transportation

Chapter I: Introduction

I. INTRODUCTION

This report analyzes the possible developments in intercity passenger transportation in the next 50 years. A timeframe of 50 years serves as the forecast period for several reasons but primarily because this duration represents a reasonable compromise between a minimum projection and a fairly lengthy interval of up to 100 years. Because most technological advancements typically occur every two to three decades, an assessment period of 50 years is generally ideal. Predicting the future of transportation too far into the future would inevitably involve many inaccuracies related to assumptions and uncertainties.

This report will focus solely on passenger transportation rather than freight or cargo. The decision to transport freight is often influenced by a number of factors, including the value-to-weight ratio and volume of the items being shipped, the time sensitivity of delivery, and the climate conditions during the actual shipping period. Overall, the transportation of freight is a much more complex topic that usually comprises a larger operational system. In an effort to alleviate some of the complexities associated with future transportation predictions, only the transport of humans, who can move themselves from one mode to another, will be discussed.

Other issues pertaining to the topic of this report is that of specific modes and distance traveled. Throughout this analysis, all major categories of transportation will be considered, passenger vehicles and buses, rail, and commercial aircraft. While ships and ferries also carry intercity travelers, these modes often are limited to only certain geographic regions and therefore will not be examined. Intracity transportation modes, including walking, bicycles, subway and light rail systems are omitted. Instead, this project focuses on intercity transportation, primarily because of the increased attention placed on expected future developments throughout the mix of intercity transportation, especially in regard to CO_2 emissions, policy agendas intended to support high-speed rail transport, the economic climate, and highway infrastructure.

International transportation will also be excluded from consideration in this report. However, the report includes case studies on intercity passenger transportation in Brazil, Japan, and France to compare intercity transportation systems that differ from the American system.

This report was prepared during a particularly salient time in transportation, as several issues central to intercity passenger travel have come to the forefront of public policy debates. In President Obama's 2011 State of the Union Address, he cited high speed rail projects as an example of infrastructure's role in economic growth, stressed the need for a climate and energy bill, and affirmed his campaign goal to put one million plug-in vehicles on the road by 2015. High-speed rail (HSR) in particular has made headlines recently due to several state governors' decisions to decline federal funding for HSR projects due to concerns about bearing operating cost subsidies for the life of the rail system. Furthermore, crude oil prices above $120/barrel and consumers facing

$4.00/gallon for gasoline are powerful reminders of the economic implications of a transportation sector that relies heavily on petroleum.

This report examines how intercity transportation will change over the next fifty years based on changing policies and market factors. With the current policy debates in mind, the following research questions were addressed:

1) How will the mode share of intercity passenger travel change in fifty years?

2) How will the mode share of intercity passenger travel differ from the baseline scenario if a price on carbon is implemented? If the pace of technological innovation to improve efficiency and reduce carbon intensity is accelerated? If fuel prices rise dramatically? If all transportation users are required to pay the full cost of their travel (i.e. rail subsidies are eliminated)?

3) Would high-speed rail capture mode share in certain corridors? How would the factors listed above (carbon price, innovation, fuel prices, and subsidization) affect its mode share?

We begin by examining the background of all three modes of transportation – highway, air, and rail travel – looking at the direct user price, full costs, and external costs of each. We then move on to cover the current mode share and briefly examine the security and safety issues present in intercity transportation. Chapter IV provides an overview of the model we used to project the mode shares of transportation in 2060. Chapter V discusses our 2060 projections for our national model and justifications for particular forecasts. We then discuss the scenarios modeled and the results from our national analysis. Following that discussion, we analyze the potential for high-speed rail in the United States by examining potential corridors for the mode, including the Northeast Corridor and specifically look into California's potential capacity for high-speed rail service. Finally, we present our results and conclusions on the policy implications for high-speed rail. We also include three case studies that provide comparative information about aviation in Brazil and the high-speed rail systems in Japan and France.

Chapter II: Overview of Key Concepts

II. OVERVIEW OF KEY CONCEPTS

Transportation Costs and Subsidies

The cost of transportation—both prices paid by the users and costs incurred by non-users—is a major theme of this report. Costs impact travelers, transportation providers, and governments. The cost paid by users of the mode (also called price) differs for each mode. User price for bus, rail, and air are determined by ticket price, while cost for auto travel consists of an array of costs including depreciation, insurance, and fuel. In most cases, taxes also are in the user price. These out-of-pocket prices for travel are the costs that users use to make the choice on which mode of transportation to take.

Aside from government subsidies, other costs not paid by users of a particular transportation mode include negative externalities and other social costs, and the tax dollar expenditures to close the gap between the full cost of a transportation system and the revenues it generates. The next sections will discuss subsidies and these additional costs as they relate to each mode in further detail.

Throughout the report, we will make a distinction between user prices and non-user prices. User costs include the total costs a person pays to own and operate a personal vehicle and the costs associated with traveling on highway infrastructure. Non-user prices include, for example, the costs that taxpayers contribute toward railroads, even though they may not be directly benefitting from or using a rail system for transportation. Infrastructure is the dominant element of public transportation associated with subsidies, particularly development and maintenance. Although some people may not directly see the benefits from such subsidizations, a number of related positive externalities may exist, including environmental improvements, decreased congestion and traffic, and enhanced passenger safety.

Fuel Prices

Fuel is the major variable cost for the three major modes of intercity passenger transportation. The price at the pump is the major, and most visible, variable cost paid by drivers; airline and bus companies pass on the cost of fuel to customers. Complex geopolitical forces, in part, determine the supply of fuel. Increasing global population and economic development will cause the demand of fuel to rise. This report does not attempt to predict fuel prices in 2060 with high accuracy, given the complex nature of predicting fuel prices, but examines the effect of relatively high and low fuel prices on overall mode share in the United States. For this report, fuel prices matter to the extent that they change people's choice in mode of travel.

Subsidies

A major theme throughout the report is transportation's relationship with federal subsidies. Transportation subsidies are generally referred to as the net flow of funds to or from the federal government for public transportation purposes. Government provision of transportation infrastructure is often necessary because the infrastructure qualifies as either a public good or a toll good. It can be difficult to exclude parties from use of transportation infrastructure, and, absent congestion, one individual's use of the road, rail track, or runway does not reduce other's ability to use that good. These traits mean that the market would under provide transportation infrastructure.

By charging user fees or levying taxes, such as the motor fuel tax, governments can internalize the costs it incurs to provide this infrastructure. For highway specifically, revenues generated to fund highways comes from a host of sources–federal and motor fuel taxes, state motor vehicle taxes and fees, toll collections, state and federal appropriations from general funds, increments of state sales taxes, and the issuance of bonds—the vast majority of which are paid by highway users (U.S. Department of Transportation, Office of the Inspector General, 2009). Similarly, most of the cost of air travel is passed on to the consumer through ticket prices. Prominent sources of air infrastructure funding comes from user fees include ticket taxes, security fees, passenger facility charges, and retained earnings— comprised of landing fees and fuel taxes, and land-side, such as parking fees, concessions and gate leases. Fuel and waybill taxes paid by those who ship cargo also contribute to air infrastructure funding.

The National Railroad Passenger Corporation, commonly known as Amtrak, is heavily dependent on federal taxpayer subsidies, and even subsidized passenger fares do not cover the full cost of operating the system. Furthermore, although many citizen advocacy groups are excited by the promises of HSR, operations costs will also likely require large taxpayer subsidies. The Congressional Research Service cautions that low average infrastructure costs per passenger will depend on high demand for HSR (Congressional Research Service, 2009).

Travel Time

Travel time is a major factor in a traveler's decision on which mode of transportation to take. Components of travel time consist of more than average speed of travel. For air, bus and rail travel, frequency of departure, wait times, security, travel to the station or airport, and potential for delay also are included in total ravel time. For shorter travel distances, personal automobile travel is fastest, and for cross-country trips, air travel is significantly faster than any other mode. People are generally willing to spend more money for shorter overall travel times. Business travelers place a higher value on their time, so they are more likely to choose the faster mode and are less sensitive to user price. Leisure travelers still place a value on time, but less so than business travelers, and are more sensitive to user price.

Transportation Externalities

The three modes of transportation create several negative environmental externalities, the costs of which are not borne by the users of the infrastructure.

Effects of Emissions
Transportation has a large impact on the environment through direct and indirect sources of emissions such as carbon dioxide (CO_2), methane (CH_4), halocarbons, carbon monoxide (CO), nitrous oxides (NO_x), particulate matter (PM), and non-methane volatile organic compounds (NMVOC). All of these emissions have the potential to change the composition of Earth's atmosphere on a global scale. Particulate matter (PM) has the most effects on human health, though it is a local pollutant and is therefore less harmful in intercity travel where emissions tend to occur away from high density population centers.

Greenhouse gases (GHGs) are emitted by natural and anthropogenic activities such as fossil fuel combustion. More heat is then trapped in Earth's atmosphere due to the accumulation of GHGs, causing global temperatures to increase, and result in long-term effects that are predicted to severely impact the global climate systems (EPA, 2011b). CO_2 has the largest influence on the climate due to its lengthy residence time. Furthermore, CO_2 is mixed throughout both the troposphere and the stratosphere (Uherek, Halenka, Borken-Kleefeld, Balkanski, and Berntsen, 2010).

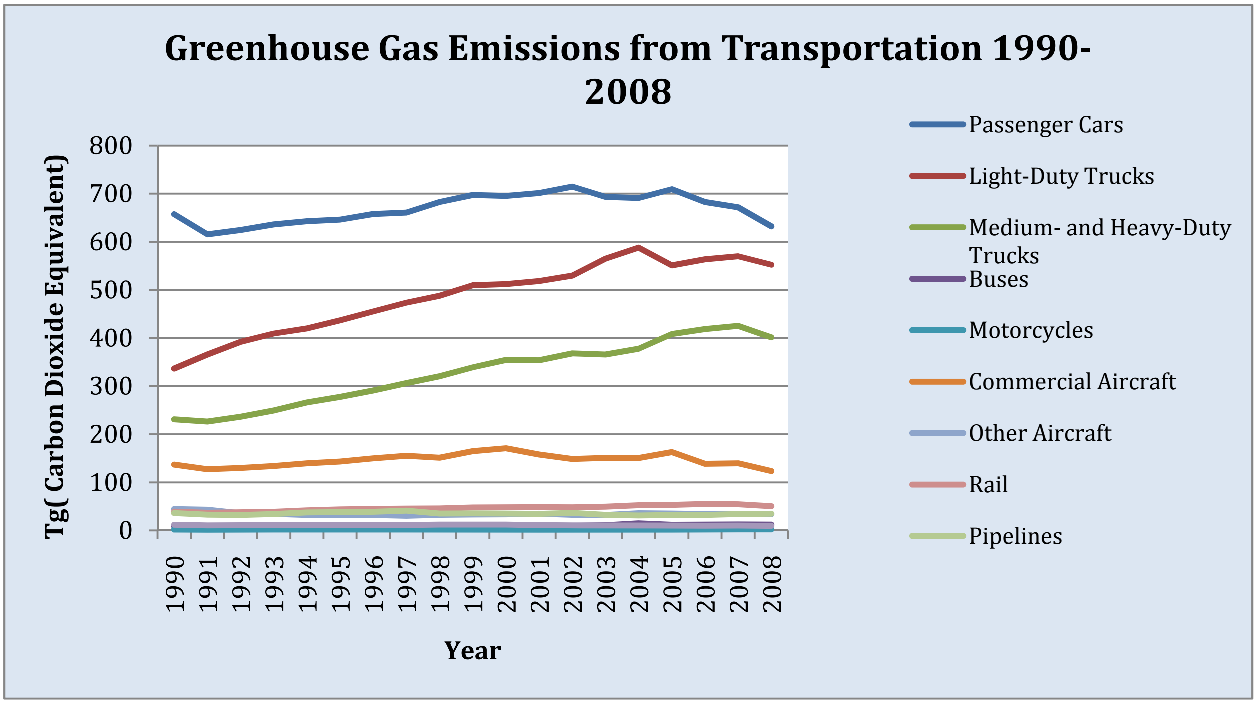

Figure 1: Greenhouse gas (GHG) emissions (Tg = terragrams) attributed to transportation sources from 1990 – 2008 in the United States.*Source:* Environmental Protection Agency (2010). Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2008. EPA 430-R-10-006. Washington D.C: Government Printing Office.

A significant portion of emissions contributing to climate change have been emitted in the past 50 years (Uherek et al., 2010). Total GHG emissions have increased by 14 percent from 1990 to 2008 (EPA, 2010). GHG emissions from transportation account for 47 percent of that increase (EPA, 2011b). Fossil fuel combustion from transportation accounted for 32 percent of all CO_2 emissions in 2008. Fifty-three percent of those emissions were released by gasoline combustion in personal vehicles (EPA, 2010). CO_2 is the most common GHG and the transportation industry is the "largest end-use source" (EPA, 2011b).

Other Externalities

There are other environmental effects that indirectly result from transportation activities. These other externalities include environmental damages besides emissions such as oil spills, noise pollution, damages to physical property and human lives due to transportation accidents, and visual intrusion of transportation infrastructure on natural surroundings. The severity of each of these externalities varies by mode and will be discussed further in Chapter III.

Alternative Fuels and Technologies

The costs of emissions and other externalities to society have forced policymakers and developers to consider alternative technologies and fuels. These technologies include, but may not be limited to, ethanol, biodiesel, battery-electric vehicles (BEVs), hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), hydrogen fuel cell vehicles (HFCVs), natural gas vehicles (NGVs), coal-to-liquids (CTL), oil shale, and tar sands. Improvements to conventional diesel and gasoline internal combustion engines (ICEs) are also under development.

Current fuel production continues to change in response to social goals, technology, fuel options, consumer demand and public policy. The cost of fuels is important in relation to consumer demand, carrier costs, and user money costs that influence these factors.

Additionally, multiple sources examine the relationship between CO_2 regulation and the transportation sector: carbon regulation's effects on the transportation sector, the relation between carbon prices and gas taxes, price elasticities, or other interactions. There exist numerous, wide-ranging estimates of the social cost of carbon, which are used to produce carbon price estimates. Further explanation of how a carbon price will affect the future of transportation is addressed in following sections.

Business versus Leisure Travel

Mode choice is also dependent on the purpose of travel. The Bureau of Transportation Statistics' National Household Travel Survey (NHTS) has listed the characteristics of either business or leisure travel and how these circumstances affect mode choice. The primary difference between business and leisure travel is the average trip distance. On average, business travelers take shorter rail trips than leisure travelers. Furthermore, the length of leisure trips varies much more widely than the length of business trips. This outcome is logical given that business travelers are generally on tighter schedules and place more emphasis on traveling quickly between two points. Leisure travelers often have more available time and may value the trip itself rather than just the timely arrival at a destination.

For the past several decades, highway vehicle travel has been the primary travel mode, accounting for 89 percent of all trips (Federal Highway Administration, 2010). More specifically, personal vehicle travel accounts for 90 percent of leisure trips. Nearly 80 percent of all business trips are also made by automobile. As trip distance increases, people are more likely to travel by air. At trip distances of 1,500 miles and greater, only 15 percent of travelers choose to drive.

Most business trips are relatively short in terms of miles traveled. The median one-way distance for business trips in the United States is 123 miles and 74 percent are less than 250 miles. Trips of over 1,000 miles make up only seven percent of all long-distance business trips. However, likelihood of travel by air increases with trip distance. Air travel takes over as the most popular mode choice in trips over 500 miles and makes up 64 percent of trips in the 500-749 mile range, 85 percent in the 750-1,500 mile range, and 90 percent of trips over 1,500 miles (BTS, 2009b).

According to the 2009 NHTS, intercity rail travel is split almost evenly between business and leisure trips. For all rail trips greater than 50 miles, 50.9 percent of trips in the survey were taken for business purposes and 49.1 percent were taken for leisure. For all rail trips greater than 100 miles, 47.3 percent were for business and 52.7 percent were for leisure (BTS, 2009b). In the following mode sections, the role of trip purpose will be discussed more thoroughly as it relates to specific modes.

Chapter III: Background

III. BACKGROUND

HIGHWAY BACKGROUND

Introduction

The beginning of motorized transportation by road started at the turn of the 19th century and was used primarily for circulating postal mail and transporting goods. Over time, an increased attention by government combined with technological innovation, created a surge of passenger travel, termed the "Superhighway Movement" (FHWA, 2010). President Franklin D. Roosevelt's advocacy created advancement in roadways, progressing roads from dirt and gravel to pavement and ultimately created the passing of the 1938 Federal Highway Act. In 1956, President Dwight Eisenhower signed the Federal Aid Highway Act committing the government to put its energies toward a national network of interstates in hopes of improved national security (FHWA, 2010). Ninety percent of the costs of the new highways were funded by this law, while state governments had to cover the remaining costs. In the 1960s road standards were developed, leading to more four lane roads and fewer roads that intersected with railroad crossings (Handfield, 2006). Additional consideration was given to making roads easy and accessible for military convoys such as building overpasses high enough for missile transportation (Handfield, 2006). Government subsidies were given to states to encourage them to further develop and expand state highways.

In 2002, the United States had 46,726 miles of interstate highway (FHWA, 2010), contributing largely to both the country's cultural and economic environment. Some contend that the construction of U.S. interstates was the number one growth factor in the U.S. economy in the 1950s and 1960s (Handfield, 2006). For the past several decades, highway vehicle travel has been the primary travel mode, accounting for 89 percent of all trips (BTS, 2011b).

With both private personal investments into cars, and public investments into the national highway system, the United States has grown to be unparalleled in ease and openness of intercity auto travel. Driving is the primary mode for trips, across all income levels. Households with incomes greater than $75,000 reveal a sharp decline in driving miles. On the other hand, household income below $25,000 reveals a greater reliance on trips by bus than any other mode. Nearly four percent of long distance trips are made by bus in this income range, compared to only two percent of households in the higher income bracket using this mode. While this lower income bracket is a larger consumer of bus trips than other household incomes, 80 percent of these households still own at least one car. Even households without a car are still twice as likely to travel by personal vehicle, either borrowing a car or carpooling, because personal transportation is more efficient than public transportation in many cases (Balaker, Staley, Rowman and Littlefield, 2006).

While highway growth has been vast, highways are becoming increasingly expensive to build. The National Highway Construction Cost Index (NHCCI) reveals that costs for highways are increasing at a higher rate than the consumer price index. Alongside higher costs to build, highway user prices have increased over time. Highway user prices include both fixed and variable costs that occur from owning, maintaining, and driving a personal vehicle. Other costs surrounding highways are the cost of fuel production, auto manufacturing, roadway engineering, energy use, greenhouse gas emissions, and safety. The following sections explore these topics in more depth.

Highway User Prices

Cost of Owning, Maintaining, and Driving a Personal Automobile

There are many aspects that go into placing a value on the costs of owning, maintaining, and driving a personal vehicle. These items can be divided into fixed and variable costs. Fixed costs include purchasing or leasing a vehicle, insurance, registration and licensing, taxes, depreciation, and finance charges. Variable costs include vehicle maintenance (including parts and labor), oil, tires, and fuel. The type of car and driving habits of the owner are also key factors in determining vehicle cost. The U.S. Bureau of Transportation Statistics (BTS) maintains a dataset of average costs per mile of owning and operating an automobile, assuming 15,000 miles per year of driving in a medium-sized sedan in stop-and-go traffic (BTS, 2010d).[1] The data are reported from 1975 to 2009, are collected by the American Automobile Association (AAA) and are published annually as *Your Driving Costs* on the AAA web site (AAA, 2011).[2]

In 2009, the average total cost per mile was 56.6 cents. Table 1 contains the breakdown of vehicle ownership costs for 2009, as presented in the BTS dataset.

Table 1: 2009 Vehicle Ownership Costs

Average Total Cost per Mile (2009 ¢)	56.6
Gas	11.4
Gas as Percent of Total Cost	20.1%
Maintenance	4.5
Tires	0.8
Average Total Cost per 15,000 Miles (2009 $)	8,487
Variable Cost	2,511
Fixed Cost	5,976

Source: BTS. (2010).

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[1] Other key assumptions as described by BTS: "Prior to 1985, the cost figures are for a mid-sized, current model, American car equipped with a variety of standard and optional accessories. After 1985, the cost figures represent a composite of three current model American cars. The 2004 fuel costs are based on average late-2003 U.S. prices from AAA's Fuel Gauge Report: www.fuelgaugereport.com. Insurance figures are based on a full-coverage policy for a married 47-year-old male with a good driving record living in a small city and commuting three to ten miles daily to work. The policy includes $100,000/$300,000 level coverage with a $500 deductible for collision coverage and a $100 deductible for comprehensive coverage. Depreciation costs are based on the difference between new-vehicle purchase price and its estimated trade-in-value at the end of five years. American Automobile Association analysis covers vehicles equipped with standard and optional accessories including automatic transmission, air conditioning, power steering, power disc brakes, AM/FM stereo, driver- and passenger-side air bags, anti-lock brakes, cruise control, tilt steering wheel, tinted glass, emissions equipment, and rear-window defogger."

[2] AAA data is proprietary, therefore the only assumptions known are those made available through BTS, described in the above footnote.

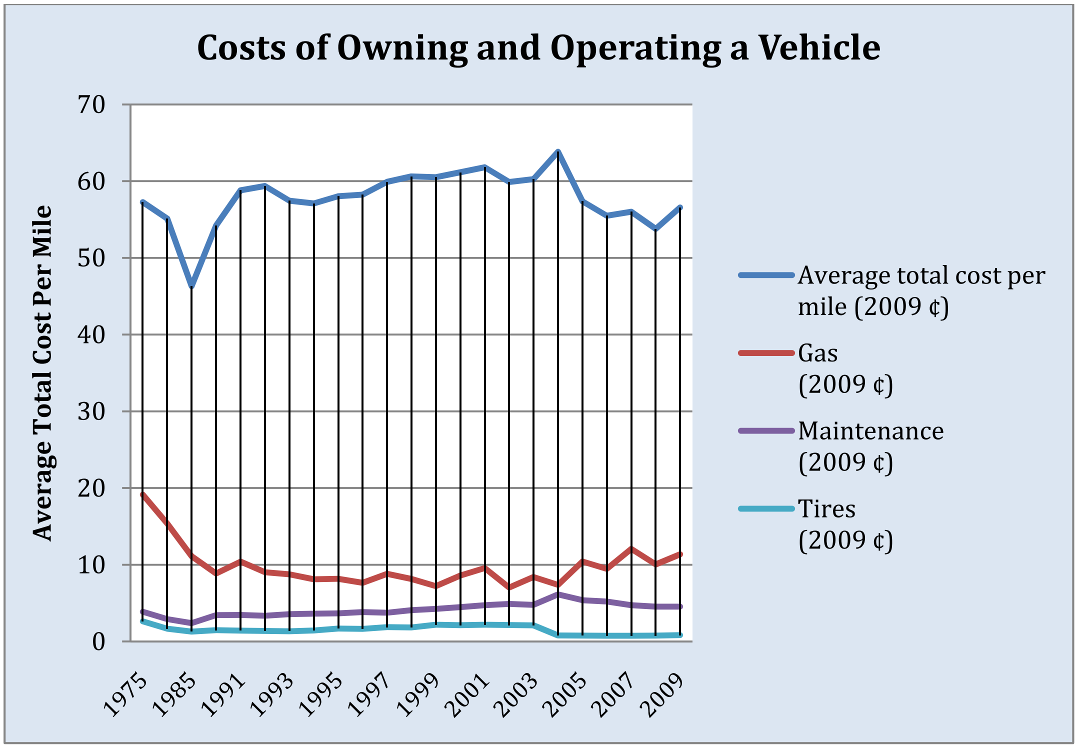

Figure 2: Average Costs per Mile to Own and Operate a Vehicle from 1975-2009. Costs are shown in 2009 dollars. (Source: http://www.bts.gov/publications/national_transportation_statistics/#chapter_3)

The average total cost per mile (adjusted for inflation) appears relatively steady in the past two decades though it has declined since 2004; however, due to variations in methodology on the part of the AAA, it may not be appropriate to compare these values across years. The latest change in methodology took place in 2004; the rate of change in total per mile cost from 2004 to 2009 was 1.64 percent.

Gasoline Prices

Retail gasoline prices represent the major variable cost for traditional passenger vehicle usage and are one of the most visible costs to the consumer aside from monthly vehicle payments. Alternatively fueled vehicles do not follow this rule, but they represent a very small percentage of the present market—less than 1 million were in use as of 2008 and they are used primarily in urban transportation (Energy Information Administration, 2010e).

Many factors play into fuel prices, including the current federal gas tax of 18.4 cents per gallon. Figure 3 illustrates the makeup of retail motor gas prices in the United States (EIA, 2011b). Wholesale crude oil prices represent the major variable cost of retail motor gas prices.

Components of Gasoline Prices per Gallon in the United States

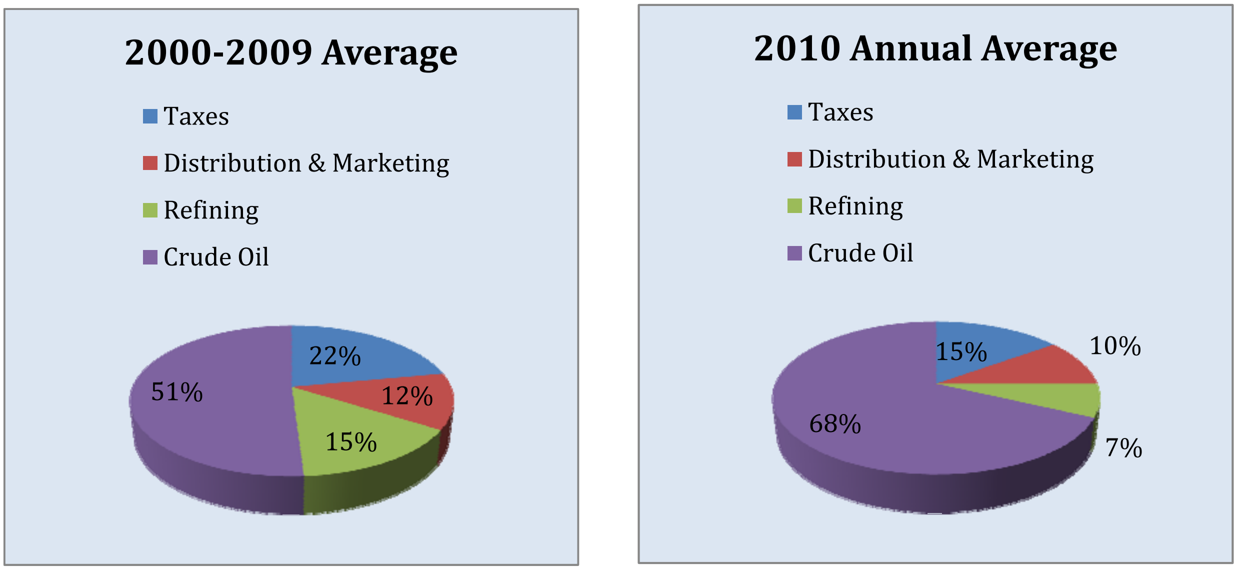

Figure 3: Components of the Price of a Gallon of Gasoline in the United States.
Source: EPA. (2011). Fuel economy data. Retrieved from www.fueleconomy.gov.

Highway Full Costs

As of 2008, the National Highway System (NHS) consisted of approximately 160,000 miles of roadways (US DOT, 2008) equating to approximately 572,000 lane-miles (US DOT, 2009c). These included the Interstate system, the Strategic Highway Network, intermodal connectors, and principal arterial roadways. This is a rather small percentage of the estimated 815,000 miles of roadway under state ownership (Hartgen, Karanam, Fields and Kerscher, 2010). Funding for the highways is derived from a variety of sources. In 2008, Federal Highway Administration (FHWA) data showed that the federal government provided roughly 22 percent of highway funding, state governments provided 51 percent, and local governments provided approximately 27 percent (Basso, 2011). A whole host of sources generated the revenues, including both federal and state motor fuel taxes, state motor vehicle taxes and fees, toll collections, state and federal appropriations from general funds, increments of state sales taxes, and the issuance of bonds (FHWA, 2009b).

The federal motor vehicle tax is currently 18.4 cents per gallon of gasoline and 24.4 cents per gallon of diesel fuel; both have remained at that rate since 1997. State gasoline taxes range from 7.5 cents per gallon in Georgia to 37.5 cents per gallon in Washington (FHWA, 2009d). Of the 18.4 cent tax on gasoline, 15.44 cents is directed to the highway account of the Federal Highway Trust Fund, 2.86 cents goes to the Mass Transit account to fund public transit systems, 0.1 cent goes to the Leaking Underground Storage Tank Trust Fund. Similar amounts are diverted to transit and storage tanks from the tax on diesel fuel (FHWA, 2006). Approximately 16 percent of revenues going into the Federal Highway Trust Fund are obtained from the trucking industry in the form of taxes on tires and sales of both trucks and trailers. Trucks also pay a "heavy vehicle" use tax based on the usage and vehicle weight (U.S. Government Accountability Office, 2005).

The Federal Highway Trust Fund is the most well-known source of funding for highways but it does not make up the bulk of highway funding. In 2005, the Federal Highway Trust Fund collected roughly $31.17 billion for construction and maintenance of the nation's highways. A larger percentage of highway construction funds are derived from state and local governments, collectively accounting for $121.63 billion in funding in 2005 (FHWA, 2006).

The Federal Highway Trust Fund has been setup as a pay-as-you-go fund, thus it cannot distribute funds beyond its estimated receipts (Congressional Budget Office, 2008). Since 2001 outlays from the trust fund have exceeded revenues, and by 2008 Congress appropriated an additional $8 billion from the General Fund to the Highway Trust Fund (FHWA, 2011a). A total of $21.7 billion from the General Fund was added over FY 2009 and FY 2010 to provide the trust fund with solvency until Congress could address changes to its funding mechanisms. Additionally, the American Recovery and Reinvestment Act resulted in $27 billion in federal funding for nearly 13,000 projects that begun in 2009 and 2010 (Hartgen, et. al, 2010).

The cost of constructing highways varies significantly from state to state and project to project. At the beginning of 2011, Florida lists the "generic cost per mile" for "new construction of four-lane divided rural" roadway at $2.9 million per mile. For comparison, the cost for new four-lane urban interstate highways is listed at $7.5 million per mile (Florida State Department of Transportation, 2011). A 2004 examination of construction costs by the Washington State Department of Transportation (WSDOT) listed the largest factors influencing construction cost as the "existing soil and site conditions," mitigation of "environmental impacts," the inclusion of interchanges or other structures such as bridges, and the right-of-way cost (Washington State Department of Transportation, 2004). When examining trends in construction costs, Washington has begun tracking prices for seven widely-used construction materials, including structural steel, roadway excavation, hot mix asphalt, concrete, and steel reinforcement (WSDOT, 2009). Of 15 projects selected from around the country, WSDOT examined the cost per lane mile and found costs ranged from $1.9 million to $188 million. In 2002, WSDOT conducted a survey of 25 states to determine the estimated costs for construction of a typical "diamond interchange" in each state. The costs ranged from $4 million to $26.6 million. The cost to construct a single "lane-mile" of the interchange ranged from $1 million to $8.5 million. These highly variable construction costs are generally financed by charging highway users through fuel taxes and other fees, which will be discussed further in Chapter IV of this report.

Highway External Costs

Highway transportation has a large impact on the environment through direct and indirect sources of emissions via manufacturing activities and fossil fuel combustion. Carbon dioxide

(CO_2), methane (CH_4), halocarbons, carbon monoxide (CO), nitrous oxides (NO_x), particulate matter (PM), and non-methane volatile organic compounds (NMVOC) are emitted (EPA, 2010). All of these emissions have the potential to change the composition of the Earth's atmosphere on a global scale. Particulate matter (PM) has the most significant negative effects on human health. CO_2 has the largest influence on the climate due to its lengthy residence time therefore there is a need to account for historical levels of CO_2 and radiative forcing by CO_2 that increases the potential of global warming (Uherek et al., 2010). Radiative forcing is used as a quantitative measure of natural and anthropogenic influences on climate change (Intergovernmental Report on Climate Change, 2007).

With emissions rising 22 percent from 1990 to 2008, transportation across all modes is the second largest contributor to GHG in the United States, and 20 percent of this increase in emissions is specifically CO_2. Emissions from highway vehicles (including passenger cars, light duty trucks, medium/heavy duty trucks, buses, and motorcycles) have increased 29.5 percent from 1990 to 2008. Emissions in passenger cars, however, have decreased by 3.8 percent since 1990 whereas light duty and medium/heavy trucks have increased emissions released by 64.2 percent and 73.6 percent. Hydroflorocarbons are responsible for a substantial portion of these increases (EPA, 2010).

In 2003, buses contributed about 0.5 percent of total transportation GHG emissions and 0.6 percent of on-road emissions (EPA, 2006). Bus GHG production has increased by approximately 15 percent from 1990 due to significant growth in the industry (EPA, 2006). Of the total GHG emissions produced by the bus sector, only 16 percent is attributed to intercity bus travel (EPA, 2006). Most intercity buses run on diesel fuel, which is one of the largest sources of particulate matter (EPA, 2003). Diesel engines also produce ozone-forming nitrogen oxides and toxic air pollutants, which cause long damage and aggravate existing respiratory diseases, like asthma (EPA, 2003). In response to climbing GHG emissions, alternative fuels are beginning to play a significant role in bus travel, specifically B20 biofuel and compressed natural gas (CNG).

There are other environmental effects that indirectly result from highway transportation activities, including oil spills, leaking underground storage tanks, highway noise barrier construction, people residing in high noise areas, scrapped motor vehicles (BTS, 2009c). Mobile air conditioners contribute to emissions. Highway transportation increases cloudiness and decreases visibility in the atmosphere. On the other hand, highway transportation has been shown to increase the quality of life (Uherek et al., 2010).

Highway Innovation

Auto Manufacturing

The majority of automotive technology articles that do not focus on alternative energy sources discuss efficiency-enhancing improvements to the mainstream internal combustion engine. Given the current demand for gasoline and diesel automobiles and the infrastructure in place to support them, auto manufacturers will continue to improve gasoline and diesel engines in the next fifty years.

There is a tradeoff between efficiency and vehicle size and performance (Greene and DeCicco, 2000). Most of the efficiency-enhancing innovations realized between 1987 and 2006, a period that saw engine efficiency growth of nearly 1.4 percent annually, went to produce larger, higher performance, and better equipped vehicles (Knight, 2010). If mandated by law, or if the price of fuel continues to increase, auto manufacturers will most likely respond by increasing energy efficiency. Today's consumers are unwilling to sacrifice performance for efficiency (Greene and DiCicco, 2000), but this could change if fuel or emissions costs drastically increase and if consumers have better information to determine vehicle lifetime cost savings resulting from efficiency (Greene, 2010).

Some researchers think that vehicle improvements that enhance efficiency, and thereby reduce emissions, by as much as 25 percent without reducing performance will increase vehicle retail costs by less than $1,000 in the short run (Greene and DiCicco, 2000; Ogando, 2001; National Research Council, 2002; Knight, 2010). Many of the technologies have been in development for at least a decade, and some manufacturers are already implementing such technologies. Manufacturers will most likely respond to demand for increased efficiency with solutions that deliver high efficiency gains at lower costs, and the technologies that deliver these gains will be different for different vehicle manufacturers; efficiency gains and added costs will be different for different manufacturers and depend on the quality of the baseline engine (Knight, 2010; National Research Council, 2002).

Although stop-start systems, hybrid engines, and other technologies provide improvements to intracity transportation, their impact on efficiency at cruising speeds is negligible. Table 2 shows the most promising and practical current technologies for increasing efficiency for intercity travel follow, based on the highest average efficiency gain to cost ratios.

Table 2: Emergent technological improvements to internal combustion engine, with increases to efficiency and initial added costs

Technology	Efficiency Gain	Added Cost
Homogeneous compression engines	10-12%	$250-700
Cylinder deactivation at cruising speeds	3-6%	$100-250
Supercharging or turbocharging	5-7.5%	$120-690
Weight reduction	0.7% for each 1% weight reduction	$210-350
Low rolling resistance tires	1-2%	$6-50
6-speed transmission, with improved shifting logic	0.5-2.5%	$10-280

Sources: Greene, D. L. & DeCicco, J. (2000). Engineering-economic analyses of automotive fuel economy potential in the United States. *Annual Review of Energy and the Environment 25*, 477-535; National Research Council. (2002). Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards. Retrieved from http://www.nap.edu/openbook.php?isbn=0309076013; Knight, B. (2010). Better mileage now. *Scientific American 302*(2): 50-55.

Roadway Engineering

Highways are becoming increasingly expensive to build. Changes in the Highway Construction Cost Index (HCCI), which includes prices on several of the inputs of road construction, demonstrate that prices for highways are increasing at a higher rate than the CPI. (Gunasekera and Ship, 2010). There exist several process and material technologies that reduce the cost of highway production. The most practical technologies to reduce highway build costs follow (Skinner, 2008):

- Use of recycled asphalt
- Prefabricated elements of roadways
- Industrial by-product additives to concrete, such as coal fly-ash and metals manufacturing silica fume, to strengthen and reduce quantity necessary
- GIS modeling for design
- Superpaving, or engineering based on climatic and roadway use factors

The costs of raw material inputs will likely become more relevant in the next 50 years as developing nations devote resources like steel and concrete to infrastructure projects. Also, the inputs are fairly energy-intensive and produce waste, so the environmental aspects must also be considered.

Innovation in Alternative Fuel for Automobiles

The availability and accessibility of alternative fuels will be a major driver of automobile transportation demand in coming years. Innovation and technological developments that improve the processes of extraction, production and distribution of these fuels will continue to materialize, increasing their use so long as costs are competitive and low enough to create demand. There is great uncertainty about future costs of alternative fuels, which depend on three key factors: 1) cost of raw materials, 2) costs of converting raw materials to final fuels, and 3) costs of distribution (MacLean and Lave, 2003).

As of 2008, CNG, LPG, and E85 Ethanol were the most widely consumed alternative fuels (other than biodiesel) in the United States (EIA, 2010e). Most research and development of alternative fuels in the United States is focused on biofuels. Major projects are underway to reduce the cost and increase efficiency of producing biofuels. In the transportation sector, ethanol is the most widely used biofuel in the world. Figure 4 shows the dramatic increase in U.S. ethanol production, consumption, and trade in the past decade.

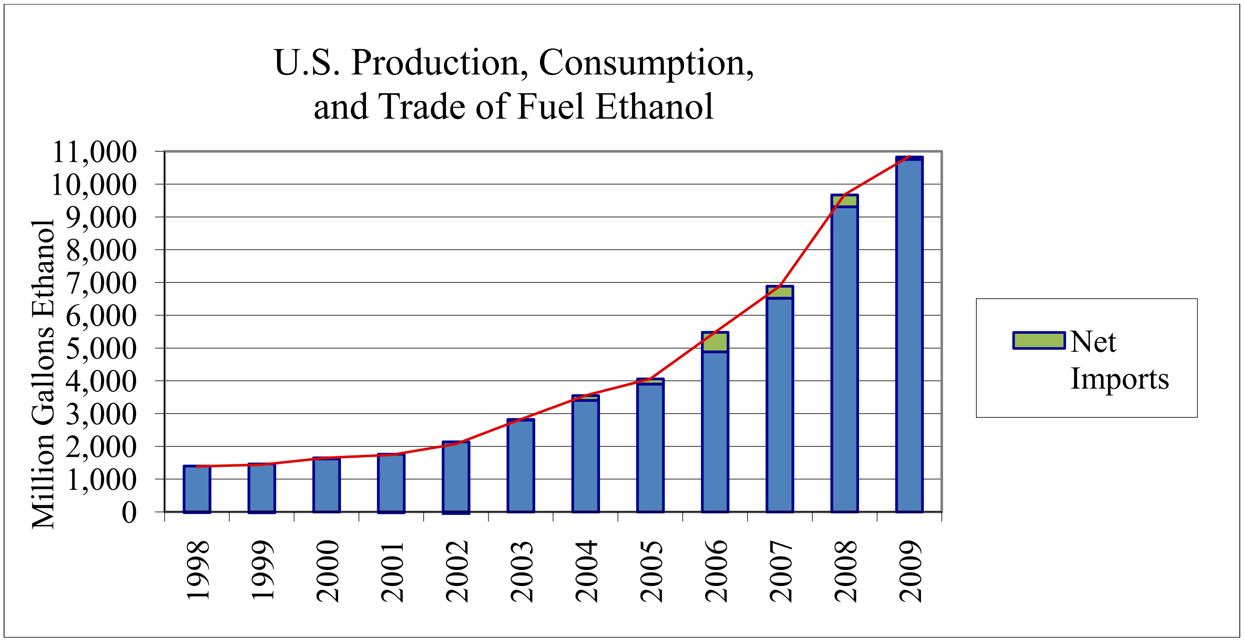

Figure 4: U.S. Production, Consumption, and Trade of Fuel Ethanol.
Source: U.S. Department of Energy. (2010). Ethanol production. Retrieved from http://www.afdc.energy.gov/afdc/ethanol/production.html

U.S. ethanol is primarily produced from corn crops, and for this reason is highly criticized for competing with land space from the agricultural sector (Cascone, 2008). However, ethanol produced by cellulosic feedstocks is thought to surpass many of these barriers. Public and private research and development projects will continue to advance cellulosic ethanol technology. Innovations in biofuel production and distribution could be a major driving force in the coming years and hold potential to greatly impact the alternative fuel market.

AIR BACKGROUND

Introduction

The United States Post Office (USPO) gave rise to the commercial airline industry in the early 20th century with its airmail delivery. By 1925, the USPO was maintaining regular flight schedules and delivering up to 14 million letters and packages a year via airplanes. That same year, the first major step toward privatizing the airlines was taken in what is known as the Contract Mail Act of 1925. The U.S. government then began contracting out airmail service to private companies creating the current major commercial airlines of today, including American Airlines and United Airlines (Freeman, 2009).

Commercial passenger air travel as it is known today was largely shaped by the Airline Deregulation Act of 1978. That act relinquished government control of routes, fares, and other meaningful airline business decisions. Since that time, the national and international airline industry has grown—generating over $1.5 billion in operating revenue. In 2009, U.S. passenger revenues alone totaled over $91 million (U.S. Department of Transportation, 2009). See Appendix C for definitions of operating revenue and passenger revenue. In 2009, U.S. passenger revenues alone totaled $91,502,937 (Federal Aviation Administration, 2010b).

Even after the 1978 Act, the federal government did not turn a blind eye toward the air travel industry. The Federal Aviation Administration (FAA), a division of the Department of Transportation (DOT), is responsible for the regulation of air travel in the United States. Such jurisdiction extends from regulating aviation safety to pilot certification to air traffic control and beyond. Within the Department of Homeland Security (DHS), the Transportation Security Administration (TSA) holds specific responsibilities associated with ensuring the security of American air travel. The TSA was created in response to the terrorist attacks of September 11, 2001, taking control of security operations at airports within a year (Transportation Security Administration, 2011d). It began as a constituent of the FAA, but later moved to the DHS after that department's formation in 2003.

In 2009, scheduled domestic enplanements totaled more than 618 million (BTS, 2009c). Of all public transportation modes, approximately 85 percent of passengers use air travel for business purposes, approximately 43 percent use air travel for personal business, and approximately 69 percent use air travel for leisurely purposes (BTS, 2009b). Recent data from the Bureau of Transportation Statistics (BTS) shows that in 2009, approximately 701 million airline passengers originated in the United States and traveled 763 billion miles, collectively. Moreover, 88 percent of those originating passengers had a destination within the United States (BTS, 2011f).

Despite the harsh economic climate, rising fuel prices, concerns related to environmental impact, and increased regulations, the FAA projects that commercial airlines will fly 1 billion passengers per year by 2023, which represents over a 40 percent increase over 2009 (FAA, 2010).

The corresponding development of airport infrastructure in the United States faces its own challenges. According to Airports Council International (ACI) development and maintenance necessary to keep pace with growing passenger demand and airport capacity constraints represent a nearly $15 billion in annual capital outlay over the next five years (2009). Further, airports continue to encounter encroaching urban environments, increasingly lengthy expansion projects due to private protests, and extensive cost overruns stemming from accelerating construction costs, which limit their flexibility in adjusting to future transportation scenarios. Outdated technology also is a potential impediment on the further advancement of airports and air traffic systems. In an effort to tackle challenges posed by aging technology, Congress established the Joint Planning and Development Office (JPDO) in 2003; a multi-agency initiative comprised of the U.S. Department of Transportation, U.S. Department of Defense, U.S. Department of Commerce, U.S. Department of Homeland Security, Federal Aviation Administration, National Aeronautics and Space Administration, and the White House Office of Science and Technology Policy. These departments were tasked with coordinating interagency efforts to design a new air traffic management system.

The new satellite-based system, referred to by the FAA as NextGen, would ideally replace the current radar-based air traffic control (ATC) system.

For passengers, the likelihood of travel by air increases with trip distance. Air travel takes over as the most popular mode choice in trips over 500 miles and makes up 64 percent of trips in the 500-749 mile range, 85 percent in the 750-1,500 mile range, and 90 percent of trips over 1,500 miles (FAA, 2010b). According to the 2001 NHTS, 40.6 percent of air travel is for business purposes and 50.5 percent is for pleasure/leisure. Other travel purposes include personal business, eight percent, and other .9 percent (see Table 3).

Table 3: Purpose of Air Travel[3]

	Percent ±*
Business	40.6 ±2.7
Pleasure/Leisure	50.5 ±2.6
Personal business	8.0 ±1.4
Other	0.9 ±0.6
Total	**100.0**

* 95% Confidence Interval Limits
Source: BTS. (2001). Highlights of the 2001 National Household Travel Survey. Retrieved from http://www.bts.gov/publications/highlights_of_the_2001_national_household_travel_survey/pdf/entire.pdf

Consumer activity and the future of airport infrastructure, including its development and maintenance, are dependent on a number of factors. In the following sections, airline fares and user fees, airport infrastructure, externalities associated with air travel and connectivity of air and other modes are discussed.

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[3] U.S. Department of Transportation definitions:
Business: "includes trips taken to attend conferences and meetings or for any other business purpose other than commuting to and from work. Trips are classified as business so long as business is the primary purpose, even though the traveler may have done some sightseeing or other pleasure activities."
Pleasure: "includes vacations, sightseeing excursions, as well as trips taken for the purposes of rest and relaxation, visiting friends and family or outdoor recreation."
Personal and family business: "includes medical visits, shopping trips, and trips to attend weddings funerals, etc."
Work: "trips to and from work, commonly referred to as commuting trips."

Air User Prices

As a competitive industry, most of the cost of air travel is passed on to the consumer through ticket prices. There are some costs dealt with through taxation and limited subsidies, which are discussed later in the report. The majority of user prices for air travel is captured in the fare price; in 2009 the average fare was $309 (BTS, 2010c). See Appendix C for definitions.

Unlike the other modes of transportation discussed in this report, air travel becomes significantly cheaper per mile over longer distances and in higher density markets. Takeoff and landing – and their related activities at airports – account for a significant portion of the cost of air travel. As a result, increasing the distance of flights decreases the cost per passenger mile. In higher density markets, airlines are capable of operating larger planes, which tend to be cheaper per passenger mile, without pushing down load factors—how many passengers are flying compared to the number of seats available.

In addition to the fare, consumers are also charged a number of fees with their plane ticket to cover the cost of providing airport infrastructure and security. User charges contributed nearly 50 percent, or $5.1 billion, of committed government project financing in 2009. Passenger Facility Charges (PFCs) represent roughly 44 percent, while Airport Improvement Program (AIP) fees attributable to commercial hub utilization encompass nearly 36 percent. Security fees, CFCs (Customer Facility Charges) and retained earnings collectively comprise roughly 20 percent of airport infrastructure costs paid by commercial users (ACI, 2009). The use of these funds will be discussed further in the following section on the full costs of air travel.

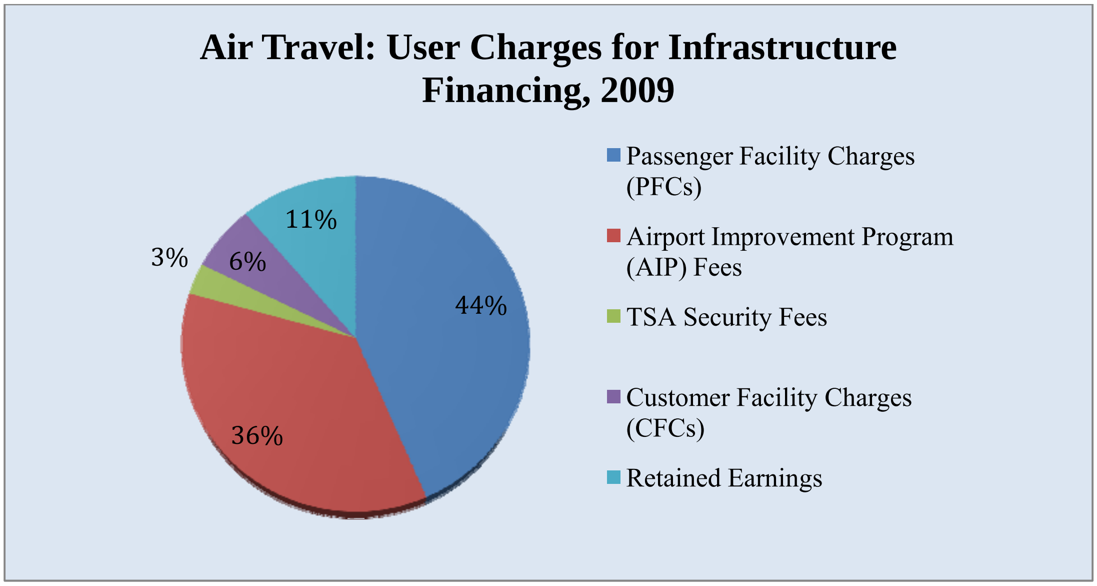

Figure 5: ACI. (2009). Airport capital development costs 2009-2013. Retrieved from www.airports.org

Air Full Costs

According to the FAA, roughly 3,400 airports comprise the national airport system, including commercial hubs of various sizes and smaller general aviation airports (2010c). While this broad system represents infrastructure assets deemed critical to the overall aviation network, the focus of this report requires only a subset of commercial hubs, which number 140 facilities, yet collectively account for nearly 99 percent of enplanements (ACI, 2009).

For 2009, ACI estimates that commercial airports will require over $16 billion to meet traffic demand and to ensure operational continuity. Of this total, projects with secured or expected funding (committed projects) account for $10.2 billion. The remaining $5.9 billion falls into the uncommitted category indicating a need pressing enough for inclusion in the appropriate local plan that cannot proceed due to unidentified funding (ACI, 2009).

Since 2005, total airport development and maintenance costs have increased over 40 percent with annual capital needs increasing from $11.4 billion to over $16 billion (ACI, 2005 & 2009). Considering recent FAA projections in construction costs, passenger growth, and cargo demand, continued cost escalation is expected (FAA, 2010b).

Airport funding structures encompass a diverse set of capital sources. Table 4 highlights the most prominent forms of airport financing.

Table 4: Types of Airport Financing

Financing	Definition
General Aviation Revenue Bonds (GARBs):	These tax-exempt bonds issued by the city, county, state or airport authority are backed by airport revenues, lease payments or the financial strength of airlines using the facility.
Passenger Facility Charges (PFCs):	An FAA program enabling fees up to $4.50 per enplaned passenger for use on approved projects enhancing safety, security, capacity, noise reduction or competition.
Airport & Airway Trust Fund:	The Trust Fund provides FAA operating revenues, including funds associated with the Airport Improvement Program (AIP), through various excise and user fees, including passenger ticket, domestic cargo and fuel taxes.
State & Local Governments:	Individual sub-federal entities provide a spectrum of loan and grant programs to assist airports in financing development and maintenance efforts.
Transportation Security Fees:	Due to the increased costs of security initiatives, the TSA collects a $2.50 fee per enplaned passenger.
Retained Earnings:	Airports generate both air-side, including landing fees and fuel taxes, and land-side, such as parking fees, concessions and gate leases, revenues, which legislation dictates must be reinvested into the facility.
Customer Facility Charges:	Generally collected from rental car providers, airports utilize these funds to improve terminal and ground transportation systems.
Other Forms of Private Capital:	While generally associated with high borrowing costs, private lenders are periodically engaged to provide various forms of project financing. Airports use obtained financing on a spectrum of different projects. In 2009, terminal, capacity and accessibility improvements accounted for 65 percent of the anticipated airport need.

Air External Costs

Aside from the direct costs associated with air travel, air transportation also produces environmental costs that are not borne by passengers or the airlines. Noise pollution, surface water degradation from airport runoff and increased tropospheric ozone from nitrogen oxide emissions are a few localized external costs. Aircraft emissions also produce widespread external costs. Carbon dioxide, methane, and nitrogen oxide emissions at the cruising altitude of aircraft are estimated to have three times the global warming potential of equivalent emissions at sea level (Royal Commission on Environmental Pollution, 2003). While emissions per passenger mile have been decreasing since the late 1970s, the potential emissions reductions from efficiency gains have largely been negated due to the increase in passenger miles per year (FAA, 2005; EPA, 2011b). As of 2003, aircraft accounted for nine percent of transportation-related greenhouse gas emission (EPA, 2006). In addition to emissions of GHG, aircraft emit water vapor and particulate matter that form contrails, which aid in the formation of cirrus clouds. Cirrus clouds produce a net warming effect because the absorption rate of outgoing heat is greater than the reflection rate of incoming solar radiation (Greene, Baker, and Plotkin, 2011).

Air Innovation

According to Hileman et al. (2009), future fuel prices will drive innovation as airplane manufacturers will strive to produce more fuel efficient aircraft. Airbus estimates that fuel accounts for 40 percent of operating costs for long-haul jetliners and 30 percent of operating costs for single-aisle operations (Airbus, 2011). Therefore, the development of alternative fuels, more advanced engines and airframes, and the implementation of NextGen (see page 62), can enhance fuel savings and reduce emissions.

Airframe and Engine Retrofits

IATA notes that the utilization of available technology, such as wingtips, more efficient gas turbines, and composite secondary structures, could reduce fuel consumption by seven to 13 percent compared to the baseline (IATA, 2009).[4] The estimated retrofit cost ranges from $5.21-$52.1 million. The price of a new Boeing 737-600, which has similar technical specifications (Boeing, 2011a) to the baseline, is $56.9 million (Boeing, 2011b).

Some technological innovations, such as the utilization of active load alleviation, light-weight advanced alloys and composite primary structures, are too complex for existing aircraft retrofits (IATA, 2009). However, they are available for current production aircraft. The cost of these innovations is included in the price of the aircraft. The inclusion of these innovations in the current

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[4] The baseline is a 120 passenger aircraft that weighs 132,000 lbs with a fuel capacity of 6,550 gallons. A one percent reduction of fuel burn or CO_2 emissions is equivalent to a fuel savings of 65.5 gallons (IATA, 2009). A Boeing 737-600 has similar specifications as the baseline. The 737-600 is a 110 to 132 passenger aircraft, which has a 145,000 maximum takeoff weight. It has a fuel capacity of 6,875 gallons. The total cost of the 737-600 is $56.9 million (Boeing, 2011).

production aircraft could enhance fuel savings by seven to 18 percent, compared to the baseline (IATA, 2009).

The IATA (2009) identifies potential technological advancements for new aircraft designs pre- and post- 2020. In regard to the pre-2020 design, the anticipated innovations include a new engine systems architecture, hybrid laminar flow, and natural laminar flow (IATA, 2009). It is anticipated that these advancements would enhance fuel savings by 25 to 35 percent. In regard to the post-2020 design, technological innovations include second generation variable cycle, a hybrid wing body, a truss braced wing, and a fuel cell system. These advancements are anticipated to enhance fuel savings by 25 to 50 percent (IATA, 2009).[5]

Alternative Fuels

Fuel prices, and the associated environmental impacts, are driving the research into and development of alternative fuels. These fuels offer the potential to counter rising conventional jet fuel prices and price volatility (Hileman et al., 2009). Table 5 (reproduced from Hileman et al. 2009) shows the compatibility of alternative fuels with current systems, fuel readiness level, production for potential jet fuel, production cost per gallon (economic viability) and merit for aviation use (Hileman et al., 2009). These costs, however, are expected to decrease as technology improves. The IATA forecasts that biofuels will become economical in 20 years as a result of technological advancements in the production of biofuels, rising petroleum prices and the implementation of a carbon tax (International Air Transport Association, 2010).

Fischer-Tropsch (FT) and Hydroprocessed Renewable Jet (HRJ) have surfaced as possible alternatives for conventional jet fuel. These processes produce a synthetic fuel with similar properties as kerosene (IATA, 2010). These types of fuels are known as Synthetic Paraffinic Kerosene (SPK) and a 50/50 blend of SPK[6] with kerosene-based jet fuel serves as a replacement for conventional petroleum jet fuel. This blend adheres to all necessary specifications for flight and does not require engine or distribution infrastructure modifications (IATA, 2010).

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[5] The estimate of enhanced fuel savings is relative to the baseline. The IATA's rough estimate of enhanced fuel savings is derived data and information from scientific literature and from industry partners. These partners are specifically involved in the airline, airframe, engine, Air Traffic Management and fuel industry (IATA, 2009).

[6] To date, SPK has been produced from algae, camelina, soy, palm, jatropha, and tallow (IATA, 2010)

Table 5: Compatibility of alternative fuels with current systems

	Compatibility	Fuel Readiness Level	Production Potential for Jet Fuel	Production Cost (per gallon of Jet Fuel)	Merit for Aviation Use
Ultralow Sulfur Jet A	Requires additives	Technology Ready	High	$0.04 - $0.05 more than baseline	Adequate
Oil Sands or VHO	Compatible	Widespread Commercial Production	Moderate	$1.19 - $1.55	Adequate
Oil Shale	Potential need for additives	Commercial Production beginning in 2022 - 2026	Low until 2020	No estimate	Adequate
Synthetic Fuel From Natural Gas	Compatible when blended with Jet A	Commercially available	Moderate	$1.40 - $2.50	Adequate
Synthetic Fuel From Coal	Compatible when blended with Jet A	Dependent upon Enhanced Oil Recovery and CCS technology	Moderate	$1.60 - $1.92	Adequate
Synthetic Fuel From Biomass	Compatible when blended with Jet A	Technology Ready	Low	$5.80 - $6.00	Adequate
Synthetic Fuel From Coal Biomass	Compatible when blended with Jet A	Technology Ready	Low	$1.97 - $2.39	Adequate
Biodiesel and Biokerosene	Problems with thermal stability	Test flights conducted	No estimate	No estimate	Blended use with Jet A Fuel
Hydro Processed Renewable Jet Fuel	Potential need for additives	Commercial flights conducted	Low to Moderately High	No estimate	Adequate

Reproduced from Hileman et. al. (2009). Near-term feasibility of alternative jet fuels. Retrieved from http://stuff.mit.edu

CASE STUDY 1: BRAZIL AVIATION

Brazil is the largest country in South America, encompassing a 3,287,587 square mile area, slightly smaller than the United States. In 2010, Brazil's Gross Domestic Product was estimated at $2.024 trillion (official exchange rate) with a per capita GDP of $10,900 (official exchange rate). In 2010, Brazil's population was approximately 201 million people (Central Intelligence Agency, 2010) with a population density of about 59 people per square mile (U.S. Census Bureau, 2007).

Most major Brazilian cities lie on the eastern coast of the country (Figure 1). The following major cities serve as hubs for both intercity transportation and international travel: São Paulo (10.9 mil. pop.), Rio de Janeiro (6.1 mil. pop.), Belo Horizonte (2.4 mil. pop.), Salvador (2.9 mil. pop.), Brasilia (2.5 mil. pop), Fortaleza (2.4 mil. pop), Curitiba (1.8 mil. pop), Recife (1.5 mil. pop), and Porto Alegre (1.4 mil. pop) (Central Intelligence Agency, 2010). Because of Brazil's large geographic size with several sparsely populated states, ground transportation is limited in many regions. Thus, Brazilians rely heavily on the aviation sector for intercity travel; domestic passenger traffic increased almost 50 percent between 2003 and 2010.

Figure 1: Map of Brazil. *Source:* Central Intelligence Agency, World Factbook. (2010). Retrieved from https://www.cia.gov/library/publications/the-world-factbook/geos/br.html

Historical Context of the Brazilian Air Transportation Sector

Brazil's civil aviation system consists of approximately 4,072 airports, of which only 726 have paved runways; 3,346 have unpaved runways (Central Intelligence Agency, 2010). It has approximately 10,000 aircraft that fly throughout the central airport hubs. These central airports include Guarulhos International Airport in São Paulo and Galeao International Airport in Rio de Janeiro. The industry has major airlines and a well-defined regulatory framework that features a dedicated regulatory body (ANAC, Brazil's Civil Aviation Agency, 2005).

Driven by Brazil's economic growth (GDP growth at an annual rate of 4.7 percent), air traveler in Brazil consists of more than 50 million trips a year. Air travel has increased approximately ten percent per year between 2003 and 2009 (Figure 2). Despite the recent global economic crisis, the demand for domestic air services has increased significantly and the demand for international air travel remains steady (McKinsey & Company, 2010).

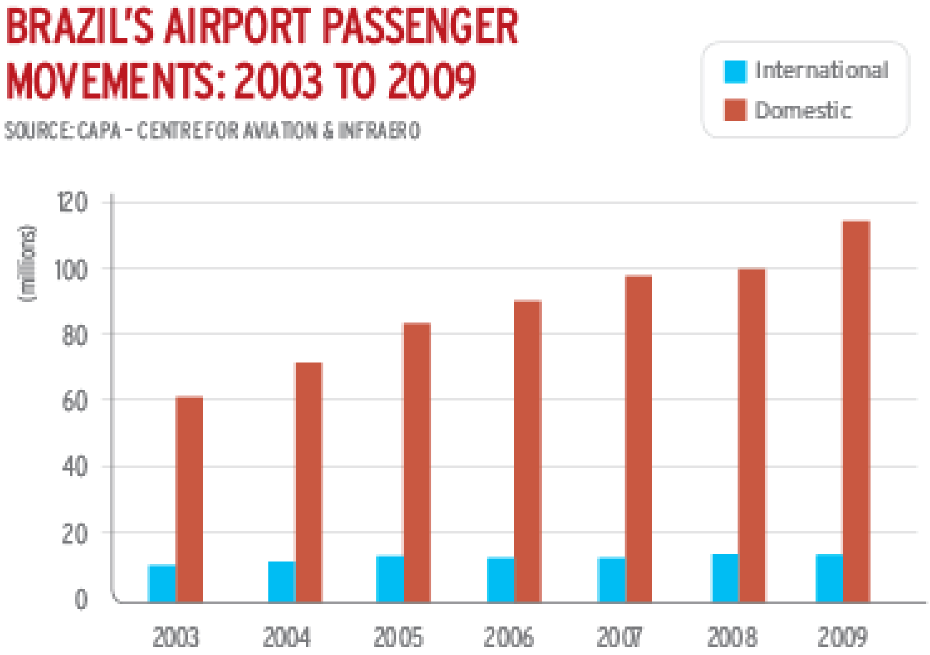


Figure 2: Traffic in Brazilian airports, 2003-09. *Source*: INFRAERO. Empresa Brasileira de Infraestrutura Aeroportuária: Retrieved from http://www.anna.aero/2009/05/08/brazils-rapid-growth-slows/

Brazil has the fourth largest domestic airline market, behind the United States, China and Japan. The National Civil Aviation Agency of Brazil (ANAC) has projected that domestic traffic could reach 165 million passengers by 2014, which would add another 40 million passengers to an already stressed system.

Passenger Demand

Brazil has seen a significant spike in international flights as the country's tourism industry has developed, particularly within the last decade. Despite increased tourism, domestic passenger air travel has increased at a faster rate than international passenger travel. TAM GOL Airlines, Brazil's largest domestic airlines, have reported significant increases in market share with the institution of Class B and C flight choices at cheaper rates. A 2006 report from Brazil Civil Aviation Agency, ANAC indicated the TAM and GOL's rapidly increasing market share in the domestic flight market. Figure 3 shows this below.

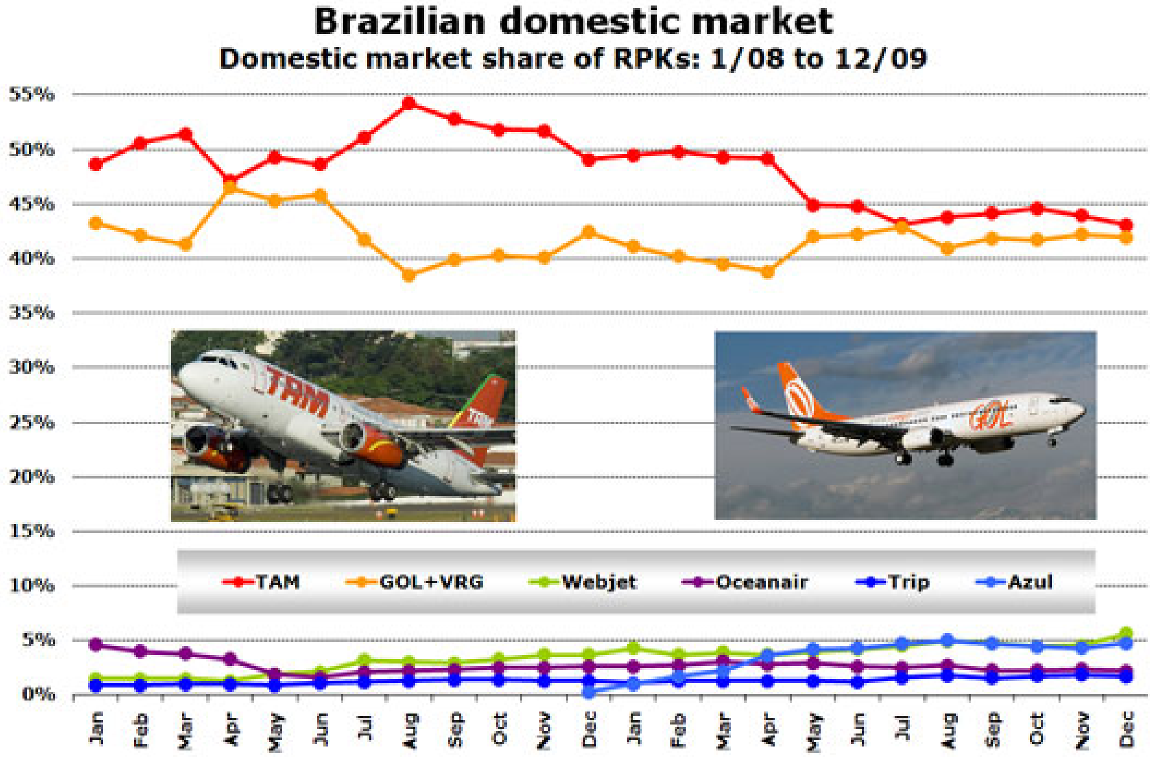
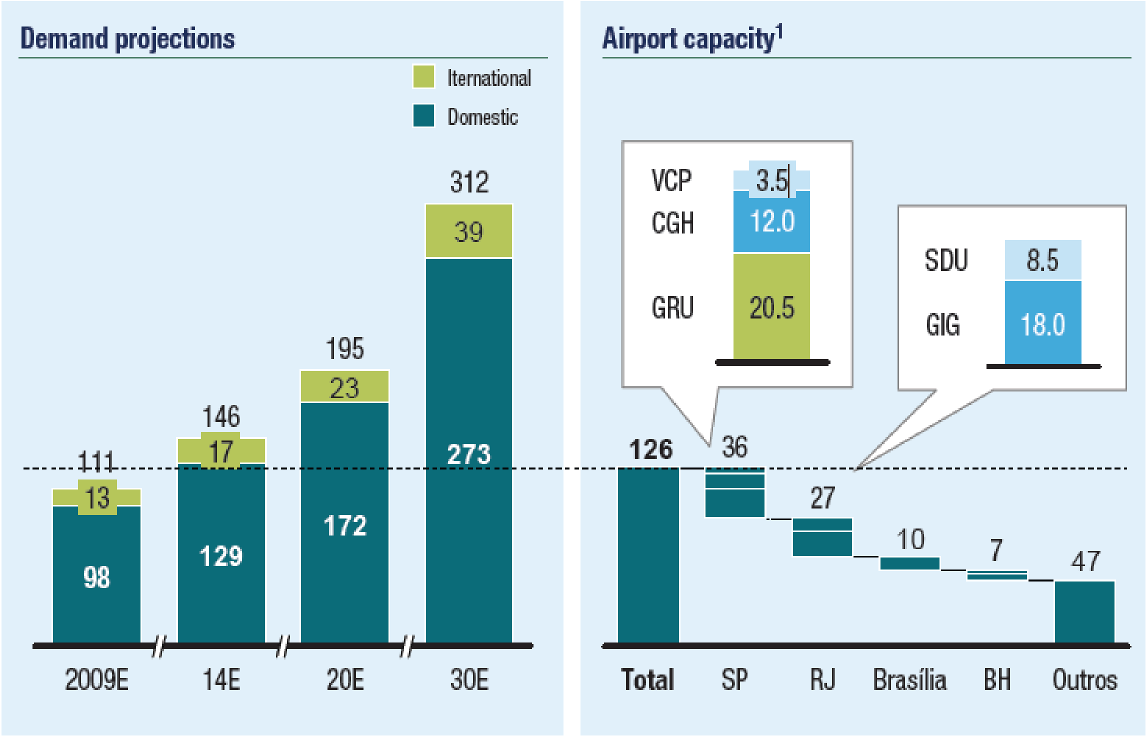


Figure 3: Brazilian domestic air travel market shares by carrier, 2008-09. *Source:* Agencia Nacional de Aviação Civil. (2006). Retrieved from (http://www.anna.aero/2009/05/08/brazils-rapid-growth-slows/

Concerns

Brazil's aviation sector has been criticized for to its inability to address the number of flight delays, airport bottleneck issues and runway congestion. Brazil has secured bids for the 2014 FIFA World Cup and 2016 Olympic Games and is under much scrutiny regarding current airport conditions and reliability. At least 13 out of 20 domestic terminals are beyond capacity in São Paulo and Rio de Janeiro. Demand for air services is expected to grow rapidly in Brazil over the next five years (ANAC, 2008). Figure 4 below, taken from an independent study conducted by McKinsey & Company, indicates that Brazil's domestic passenger demand is expected to grow some approximately 270 percent by 2030. This passenger demand growth is projected primarily for São Paulo and Rio de Janeiro airports, the two busiest Brazilian airports, which are over capacity and underdeveloped.



1 Airport operating capacity in 2009

SOURCE: Infraero; ITA; team analysis

Figure 4: Demand and airport capacity projections for Brazilian air sector. *Source:* McKinsey & Company. (2010). *Study of the Air Transport Sector in Brazil* . Rio de Janeiro: McKinsey & Company.

Brazilian Emissions Reduction and Efficiency Efforts

Since the 1990s, air transportation in Brazil has significantly contributed to air pollution and CO_2 emissions by the burning of fossil fuels. The energy consumption of air transportation in Brazil has increased over three million tons of gasoline and aviation kerosene since 1994 (Simoes & Schaeffer 2004). Correspondingly, CO_2 emissions from air transportation have followed a similar trend of about 10,000 Gg-CO_2 in 2002 (Simoes & Schaeffer 2004). Thus, Brazil has entertained several alternatives to mitigate CO_2 emissions in response to global warming. One such alternative is Brazil's development of an air traffic flow management system, called Gerenciamento de Fluxo de Trafego Aereo (GTFA), in an effort to improve the efficiency of aeronautical operations. For example, the GTFA can shorten flying times, and reduce fuel consumption. Brazil also has developed alternative energy sources, such as vegetable kerosene and hydrated alcohol, to reduce its dependency on aviation fuel imports and mitigate CO_2 emissions. There is no doubt that one of the main challenges facing Brazil's airline industry is how to balance the need for air transportation and the environmental costs of air pollution. As innovative solutions to jet fuel are proposed, Brazil stands at the forefront of this and can potentially be a serve as a model for the United States and the world.

Lessons for the United States

This case study indicates that while Brazil's aviation industry and responsible government entities have taken great efforts to develop its air system, the country still faces many problems associated with its lack of infrastructure, congested runways, airport bottlenecks, project mismanagement, and inefficient bureaucratic oversight. To date, Brazil's air transportation network is not as sophisticated and expansive as that of the United States. As Brazil continues to develop economically, the country will be challenged with managing growth issues such as congestion, scarce resources, and adequate regulation or deregulation of the sector.

Nonetheless, Brazil has taken great strides to expand its airport sector in anticipation of the 2014 FIFA World Cup and the 2016 Olympics. In concert with IATA, Brazil has invested over $1.3 billion in new airport infrastructure projects contracted to INFRAERO. As these projects begin to materialize, the IATA and the United States will be paying close attention to Brazil's management of air congestion and of domestic and international travel.

RAIL BACKGROUND

Introduction

Although rail was the dominant mode of intercity travel during the late 19th century and early 20th century, it declined as the automobile evolved and grew in popularity. Today, rail travel is undergoing a potential revival as the U.S. federal government seeks to build HSR corridors in several high-density areas. In 2009, the American Recovery and Reinvestment Act appropriated $8 billion for high-speed and intercity passenger rail (HSIPR) grants. Additionally, the Department of Transportation Appropriations Act set aside $2.5 billion for the HSIPR Program (Federal Railroad Adminstration, 2011c).

Although less than one percent of 2009 passenger travel occurred on rail, conventional rail travel offers several benefits. First, although trains are powered primarily by diesel fuel, the Northeast Corridor (NEC) uses electricity to power its lines, allowing for higher average speeds, shorter trip lengths and fewer emissions. In addition, intercity passenger rail only consumes an average of 0.35 MJ/seat mile, compared to 0.76 MJ/seat mile for petroleum-fueled cars and 2.9 MJ/seat mile on a 500-km passenger flight (de Rus and Nash, 2007). Passenger rail travel also has a strong safety record. In 2009, only three passenger fatalities occurred on Amtrak lines (FRA, 2011b).

However, there are several drawbacks to rail travel. Although Amtrak is the leader in intercity rail travel, it is heavily dependent on federal subsidies, and even subsidized passenger fares cannot cover the full cost of operating the system, except in the NEC, which earns enough only to cover operating expenses and not all capital costs (Amtrak, 2010a). Furthermore, although many citizen advocacy groups are excited by the promises of HSR, the high infrastructure costs and projected low ridership intensity make it difficult to point to HSR as a true competitor for future mode share.

High-speed rail has been considered a potentially attractive mode of transportation since the early 1960s when the Japanese built the world's first dedicated bullet train line, the Shinkansen, to link Tokyo and Osaka. Since then, France's TGV line, Germany's TR line and China's CRH rail network have been built, serving as principal examples of successful international high speed rail systems (Kunz, 2011). However, the rationale behind each of these nations' investments in HSR differs, including a desire to offset congestion in the highway and air modes and a desire to reduce carbon emissions. Other nations, including Brazil, Argentina and Morocco, are planning HSR networks in the 21st century as an alternative transportation option in the face of potential spikes in fuel prices (Kunz, 2011).

While international HSR systems serve as models for the United States, a number of questions remain as the United States turns its attention to HSR as a potential transportation option. The future of HSR and other forms of passenger rail could significantly affect the future mode shares of U.S. intercity transportation. Currently, intercity passenger rail service is controlled by Amtrak. In 2009, 5.91 billion passenger miles were traveled on Amtrak. Figure 6 outlines the current Amtrak operating lines. This represents a slight increase from 2000 when 5.57 billion Amtrak passenger miles were logged (FRA, 2011a). As seen in Figure 7, Amtrak ridership has remained relatively steady since 1995.

The Congressional Research Service (2009) also cautions that low average infrastructure costs per passenger will depend on high demand for HSR. Considering its extensive infrastructure needs, HSR must either run with very high load factors or very high subsidies in order for it to compete with other modes on cost per passenger-mile (Peterman, Fritelli, and Mallett, 2009). Additionally, HSR must compete on travel time and frequency in order to draw passengers from other modes. It is possible that achieving high load factors runs contrary to achieving short travel time because high load factors require many stops, thus reducing the average speed of an HSR trip across a particular distance. The following sections will address the current state of rail and how this will impact the potential for HSR development in the United States.

Amtrak Routes for the United States

Figure 6: Interactive route atlas. Retrieved from www.amtrak.com
Note: Amtrak routes for the United States - red lines indicate train routes and green lines indicate bus routes (Source: Amtrak, 2011)

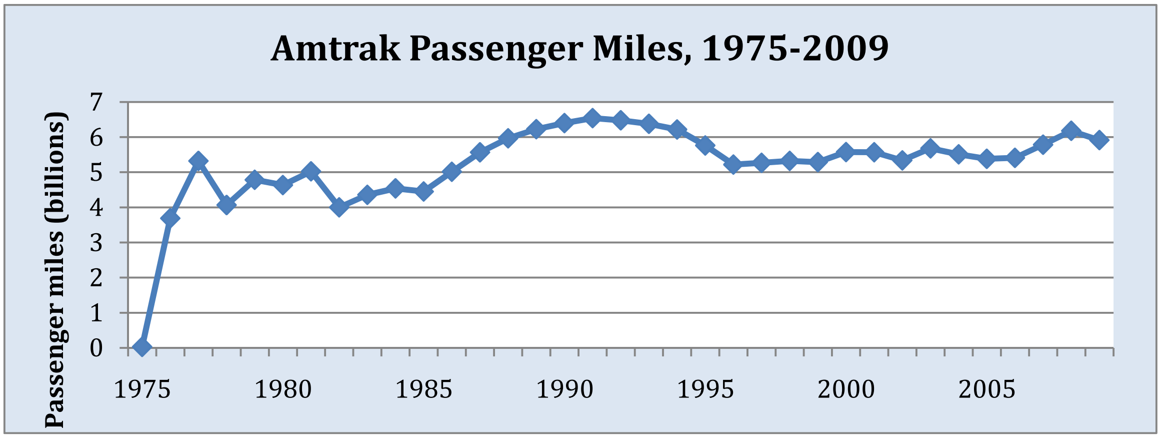


Figure 7: Amtrak passenger miles in billions, 1975-2009. *Source:* Amtrak. (2009a). Amtrak annual report 2009. Retrieved from www.amtrak.com

Rail User Prices

In real terms (2009 dollars), Amtrak ticket fares have changed little during the past decade. The lowest average fare was 24.3 cents per passenger mile in 1999. The highest average fare was 28.1 cents per passenger mile in 2002 and 2008. The average ticket fare in 2009 was 27.1 cents per passenger mile. Overall, the average Amtrak ticket fare between 1999 and 2009 was 26.5 cents per passenger mile. Given an average passenger trip length of 216.8 miles, the average fare in 2009 was $58.75. The total passenger-related Amtrak revenue, which includes food and beverage sales in addition to ticket fares, was 28.1 cents per passenger mile in 2009. Given that Amtrak operated approximately 5.9 billion passenger miles in 2009, Amtrak earned roughly $1.6 billion in passenger-related revenue that year (Amtrak, 2009a). However, as explained in the discussion of full costs below, Amtrak's operational costs regularly exceed its revenues, resulting in an ongoing need for federal and state subsidies.

Rail Full Costs

In 2009, Amtrak's total operating expenses equaled 30.9 cents per seat mile. Given an average load factor of 50 percent, the total expense per passenger mile was twice this amount, or 61.8 cents per passenger mile. In other words, if Amtrak's fares covered its full operating costs, the average fare would increase from $58.75 to $133.98, based on the 2009 average passenger trip length of 216.8 miles. The difference between Amtrak's ticket fares and its full costs are made up primarily through state and federal subsidies. In 2009, these subsidies included a federal operating grant of $563 million, general capital funding of slightly more than $1 billion, and American Recovery and Reinvestment Act funding of nearly $1.3 billion (Amtrak, 2009a).

The bulk of Amtrak's expenses are due to salaries, wages and benefits, which totaled nearly $1.7 billion in 2009. Other 2009 expenses included $246 million for train operations, $273 million for fuel, power and utilities, $209 million for materials, $168 million for facility, communication and office-related expenses, $106 million for advertising and sales, $49 million for casualty and other claims, $563 million for depreciation net of gain on sale-leasebacks and $194 million for other expenses, including indirect costs capitalized to property and equipment. Altogether, Amtrak's 2009 expenses totaled more than \$3.5 billion, leading to a net operating loss of roughly \$1.15 billion when balanced against total revenues of approximately \$2.35 billion. In comparison, the greatest net operating loss during the prior decade was approximately \$1.18 billion in FY 2001 and the smallest net operating loss during the prior decade was \$765 million in FY 2000 (Amtrak, 2009a).

Rail External Costs: Conventional Rail

Amtrak trains run on two sources of energy: diesel fuel and electricity. Diesel-electric locomotives use a diesel-fueled combustion engine to drive an electrical generator which provides power to electric traction motors. Electric locomotives use power from an electrified rail or overhead lines in the railway. Amtrak's diesel-electric trains operate on about 20,000 miles of track and haul about two-thirds of the system's passenger miles (Amtrak, 2010h). Since 1990, Amtrak's diesel consumption has remained relatively steady, with slight declines in the late 1990s, yet peaking in 2000 and 2001 at close to 100 million gallons. However, since 2001, Amtrak's total diesel consumption has declined by around 34 percent, even as ridership has increased by more than five percent (BTS, 2010a).

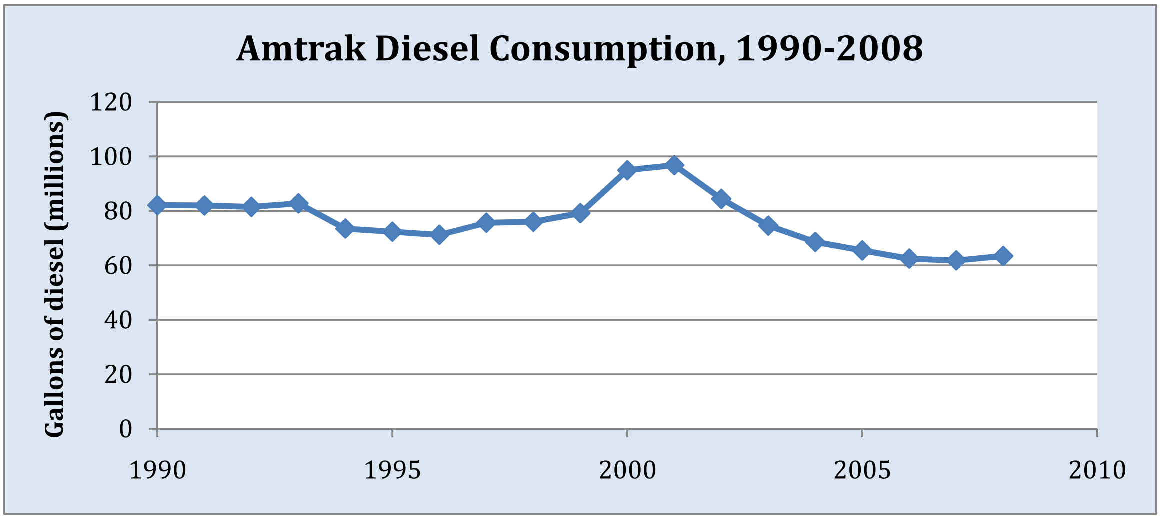


Figure 8: Amtrak diesel consumption from 1990-2008 (millions of gallons), showing peak consumption levels in 2000-2001 at approximately 100 million gallons. *Source:* BTS. (2010). Amtrak fuel consumption and travel. Retrieved from www.bts.gov

Using national average CO_2 emissions levels per gallon of diesel fuel used in transportation and applying that figure to total diesel consumption by Amtrak, we estimated that diesel-electric passenger trains emitted 666,482 metric tons of CO_2 in 2009, a 32 percent drop from Amtrak's peak diesel consumption, which resulted in 979,484 metric tons of CO_2 emissions in 2001. This 2009 level of emissions translates to 0.154 kg CO_2 emissions per passenger-mile, a 38 percent drop from 2001 levels (EIA, 2010c). These changes indicate that Amtrak has accomplished major fuel efficiency gains in its diesel-electric fleet over the last decade.

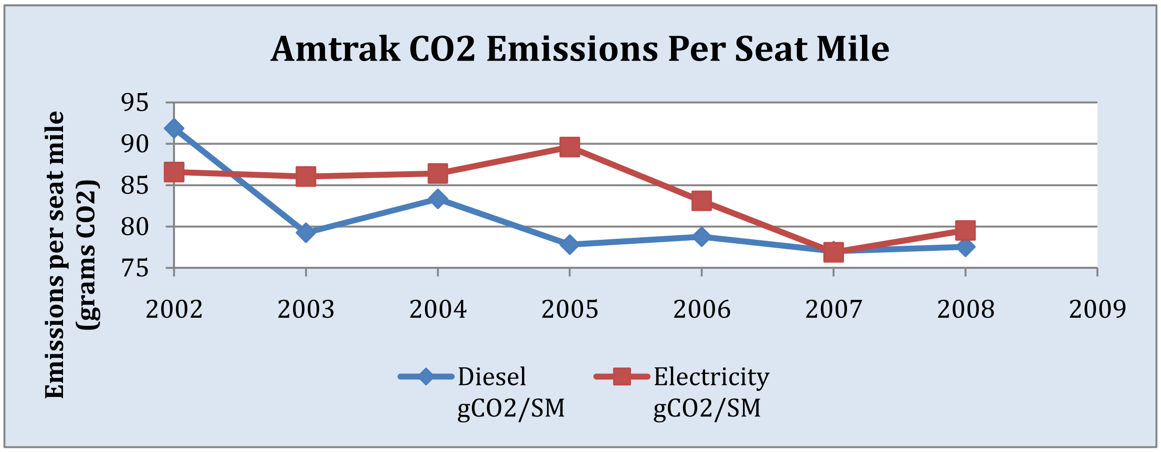


Figure 9: Amtrak CO_2 emissions per seat mile from 2002-2008 (grams CO_2). Levels of electricity emissions surpassed diesel emissions in 2008.
Sources: Energy Information Administration. (2010j, August 19). [Table of annual energy reviews]. Table 8.2a: Electricity Net Generation: Total (All Sectors), 1949-2009. Retrieved from http://www.eia.gov/aer/txt/ptb0802a.html; Energy Information Administration. (2010h). Table 10: U.S. Carbon Dioxide Emissions from Transportation Sector Energy Consumption, 1990-2008. [Data file]. Retrieved from http://www.eia.gov/oiaf/1605/ggrpt/excel/tbl10.xls; Energy Information Administration. (2010c). [Table of environmental data]. Table 11: U.S. Carbon Dioxide Emissions from Electric Power Sector Energy Consumption, 1990-2008. Retrieved from http://eia.gov/environment/data.cfm; Energy Information Administration. (2009e). U.S. total distillate adjusted sales/deliveries transportation total. Retrieved from http://tonto.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=KD0VATNUS1&f=A Energy Information Administration. (2009d). State electricity profiles. Retrieved from http://eia.gov/cneaf/electricity/st_profiles/e_profiles_sum.html; Amtrak. (2011b, January 21). Amtrak monthly performance report for September 2010. Retrieved from: http://www.amtrak.com/servlet/ContentServer?c=Page&pagename=am%2FLayout&p=1237608345018&cid=1241245669222

Almost all of Amtrak's electric locomotives operate in the congested Northeast Corridor (NEC). Since a large expansion of electrified track in the late 1990s, almost all of the passenger miles in the NEC have been traveled using electric locomotives. Not surprisingly, Amtrak's electricity consumption in the NEC has risen steadily over the last decade as more track has been electrified. Since 2001, the electricity consumed by Amtrak trains, measured in kilowatt-hours (kWh), has risen by 27 percent (BTS, 2010a). Electrified tracks allow passenger trains to reach maximum speeds of 150 mph, whereas diesel-electric locomotives are limited to approximately 80 miles per hour (mph). The slower speeds of diesel-electric trains are largely due to the engineering limitations of tracks constructed primarily for freight travel (GAO, 2009b). To operate at higher speeds, passenger trains require dedicated track for the sake of safety and scheduling logistics (GAO, House Committee on Appropriations, 2001).

We estimated the emissions from electric locomotives using a regional average electricity generation mix in New England. Trends in the electricity generation mix of the NEC indicate a decreasing dependence on coal-fired electricity and an increasing use of natural gas, resulting in a less carbon-intensive Amtrak system. The regional average mix of coal has declined from about 39 percent in 2000 to 35 percent in 2009; the share of natural gas-fired electricity has grown from 15 percent in 2000 to about 22 percent in 2009; and petroleum has almost completely disappeared, declining from six percent in 2001 to one percent in 2009 (EIA, 2010e). In addition, New York generates about 20 percent of its electricity from hydropower, and New Jersey, New York and Pennsylvania generate large amounts of their electricity from nuclear power (51 percent, 31 percent and 35 percent, respectively). These sources further reduce the emissions from electric-powered trains. Despite these declines in the CO_2 intensity of the electricity generating mix in New England, the total emissions from Amtrak's electric trains in the NEC have grown slightly over the past decade due to increased electricity consumption (GAO, House Committee on Appropriations, 2001). However, emissions per passenger-mile have declined since reaching a peak in 2005; this decline can be attributed to higher Amtrak ridership numbers in the NEC (Amtrak, 2008a and 2010g).

An important implication for Amtrak CO_2 emissions and a potential carbon-pricing scheme is that the increased efficiency of diesel-electric locomotives has narrowed the gap between diesel and electric trains in terms of CO_2 emissions per-passenger mile. If ridership on non-NEC trains were to increase while ridership on NEC's trains remained constant, then diesel-electric trains could feasibly be considered the cleaner option. However, it will be difficult to significantly increase ridership outside of the NEC since total haul time on diesel-powered Amtrak lines is significantly longer than auto travel times. In addition, the trends in electricity generation indicate that the share of natural gas will continue to increase in the Northeast, thus decreasing the CO_2 emissions from electricity. Finally, increases in renewable electricity generation would contribute to further decreases in CO_2 emissions from Amtrak travel on electrified tracks in the NEC.

Rail External Costs- High Speed Rail

A new HSR network in the United States would require all new dedicated track in order to achieve the high speeds. HSR is powered by electricity, which increases the maximum speed and achieves faster acceleration. HSR results in a number of externalities that are not included in traditional accounts of the cost of HSR. One social cost associated with HSR is noise pollution, which is created from several sources, including wheel-on-rail noise, aerodynamic noise, and electrical noise (Hanson, 1990). The resulting damages include sleep deprivation, productivity loss, and discomfort and annoyance. The monetary cost of these damages has been estimated at approximately $0.004 per passenger mile when operating at 125 mph and $0.0069 when operating at 200 mph (Levinson, Mathieu, Kanafani, and Gillen, 1997).

Another social cost associated with HSR is visual intrusion. Construction of an HSR network requires a significant amount of land disturbance, which can greatly affect the natural surroundings in a rural area. In urban areas, HSR can require the removal of buildings, parks, or other elements impeding the construction path. These costs can be quantified in the lost aesthetic benefits of the surrounding areas (de Rus and Inglada, 1997; de Rus and Nash, 2007).

The construction of an HSR network also creates social costs in the form of environmental impacts. HSR emits fewer greenhouse gases than highway or air transportation for regional journeys, but when other pollutants are examined, it is no longer as clear which mode has the least environmental impact in regard to air pollution (de Rus & Nombela, 2006). Levinson et al. (1996) assume that since HSR will be electrically powered, the air pollution externalities caused by operation would be negligible, and thus no environmental costs would arise. However, the real environmental costs would be found in the emissions from the generation fuels required to make the electricity used by HSR (de Rus & Nombela, 2006). The estimated energy requirement for HSR is between 1.22 MJ per passenger mile and 1.32 MJ per passenger mile (de Rus & Nash, 2007; Essen, Dings, and van den Brink, 2003; van Wee, Van Den Brink, and Nijland, 2003). The exact environmental costs would depend on the operating region's energy generation methods.

In addition, the construction and operation of HSR lines results in the destruction and degradation of land and the creation of a barrier effect along the rail line (de Rus and Nash, 2007). Some studies have estimated that the average land take for implementing an HSR network is as great as 5.15 hectares per mile (Janic, 2003). As with air pollution, these costs must be weighed against those of the alternatives to realize the true net benefits of HSR. Thus, it is necessary to explore if the environmental benefits from investing in HSR could be secured much more cost-effectively by investments other than spending on rail subsidies (de Rus and Nash, 2007).

Rail Innovation

The United States is lagging relative to countries such as China, Japan, France, and Spain in the development and utilization of HSR. HSR systems are basically made up of three components, including the train, the track, and the signal and communications network. What follows is a brief introduction to a few of the technological innovations involving these components.

Train Innovations

There are mainly two types of rail systems in operation. One is the standard, steel wheel on steel rail technology. The other uses magnetic levitation or "maglev" trains. Most HSR systems utilize steel wheel on steel rail technology. This system is powered by either a traditional diesel-electric locomotive or power is externally supplied, generally from overhead wires. These trains are able to travel much faster than traditional diesel-electric engines due to their relatively lighter weight. Locomotives do not have to carry fuel on electrified lines. These trains are able to accelerate and decelerate more quickly and can reach speeds up to 357.2 mph. --- a world record set in 2007 in France (Rousseau, 2007). The French company, Alstom has developed and manufactured the very popular Train à Grande Vitesse (TGV) --- literally translated as "High-Speed Train" in French --- since the 1980s. A supercharged TGV is the train that enabled the French to reach 357.2 mph in 2007, although the standard TGV model tops out at approximately 200 mph. Alstom has also developed the Automotrice à Grande Vitesse (AGV), which translates to "High-Speed Self-Propelled Unit". The AGV design places engines under each car doing away with the need for locomotives in front and back that drive the TGV. This results in increased fuel efficiency, more passenger space, and a speed of about 224 mph (Fletcher, 2008).

General Electric (GE), a long-time manufacturer of traditional diesel-electric locomotives has designed the *Evolution Series Locomotive*. The Evolution Series uses a 12-cylinder diesel engine that produces the same 4,400 HP as its 16-cylinder predecessor, resulting in reduced fuel consumption and fewer emissions. GE is also in the process of designing a hybrid diesel-electric locomotive that will capture energy dissipated during breaking (similar to hybrid automobile technology) and store it in a series of batteries. This energy can be used to reduce fuel consumption and emissions (General Electric Transportation, 2011).

Maglev trains use electromagnets to suspend or levitate the train above a guide way, as well as to propel the train. Maglev trains are able to reach very high speeds as a result of the lack of friction between wheel and rail. Rather than a traditional engine, Maglev trains use the magnetic field created by the electrified coils in the guide way walls and the track to propel the train (Bonser, 2011). The Shanghai Transrapid line uses Maglev technology to connect the city center to the Pudong Airport 19 miles away. The train travels at an average speed of 267 mph and takes less than ten minutes to make the trip (Bonser, 2011). The world speed record for any train was set by a Japanese Maglev train in 2003, reaching 361 mph (Peterman, Fritelli, and Mallett, 2009). Maglev technology has proven to be expensive, however, which has hindered further development.

Track Technology

HSR systems need dedicated lines in order to reach their full potential. Dedicated passenger train lines do not transmit freight traffic and are designed to maximize speed. A HSR track must be very straight with more restrictive curvature limits than traditional rail. For instance, a minimum three-mile radius curve is required versus a ½ mile radius for traditional commuter rail track (Amtrak, 2010b). As mentioned above, electrified lines enable much faster speeds. However, much of the current rail infrastructure in the United States is not electrified and many rail lines are not designed to support HSR systems. The technology exists to reach speeds well above what we currently see in the United States. However, the track systems are not currently equipped to accommodate these speeds and without major investment in this infrastructure, so it is unlikely that speeds will increase significantly relative to current speeds. With projected increases in population and income throughout the NEC, an installation of Smart Grid technology might improve the efficiency (and possibly the amount) of electrified rail lines.

Signal and Communication Networks

HSR systems use electronic train control systems, sometimes referred to as "positive train control," or PTC (Peterman, Fritelli, and Mallett, 2009). Better signal performance can increase efficiency of operation reducing the risk of crashes and human error. Companies around the globe are working to improve signal and communication networks, increase efficiency through advanced onboard operating systems, and design smarter transportation networks. IBM is just one company developing innovative technologies for the signaling and communications networks of rail systems. For a more detailed description of these types of systems, see IBM's Chairman and CEO Samuel J. Palmisano's presentation at the 2010 annual meeting of the Intelligent Transportation Society of America (Palmisano, 2010).

Companies around the world are working to improve rail travel through technology and innovation. Engineering and design of the train itself, construction of designated lines designed to maximize speed and efficiency, improvements to onboard operating and software systems, as well as the creation of smart transportation networks are all sources of advancement in the rail transportation sector. Realistically, without major investment in the track infrastructure, the United States will continue to see the relatively low average train speeds we observe today.

There is growing policy interest in intermodal transportation options (Airport Cooperative Research Program, 2010; GAO, 2005). Most major airports in the United States have direct links to some intermodal services but are generally local transit connections rather than intercity or nationwide systems. Currently, 23 of the top 50 airports (ranked by 2009 passenger enplanements) have direct intercity bus connections, while only four have direct intercity rail connections (BTS, 2010c). Connectivity between airports and other surface transportation modes has the potential to expand the intercity travel system within the United States by providing extended service options to travelers.

The Airport Cooperative Research Program estimates that HSR infrastructure could divert up to 15 million airline passengers to rail each year in the United States (2010). These diversions are considered substitutive (rail trip instead of flight), but well-designed connections and cooperation between modes could also result in complimentary rail-air trips (rail as a flight "leg"), with combined ticketing for ease of transfer (Van Beek, 2010). In fact, substitutive rail trips have been increasing in the Northeastern corridor. In 1995, the mode share for trips between Boston and the New York City metropolitan area (air and rail only) was 84 percent air and 16 percent rail; with improved rail capacity and reduced travel time to 3.25 hours, rail trips grew to 50 percent by 2008 (ACRP, 2010). However, market trends are difficult to predict for all areas, and air-rail connectivity may prove to be most feasible only in the most dense population corridors where congestion is already high and shorter rail trips are economical. Cooperation between modes is also a challenge, as airport revenue restrictions do not typically allow for funding of intermodal facilities (GAO, 2005), and airlines may be hesitant to give up short haul flights to rail.

SAFETY AND SECURITY CONSIDERATIONS

Highway Safety

Despite significant positive steps made toward improving vehicle and highway safety over the last half century, accidents on U.S. highways still cause significant losses of economic resources and human life. The economic loss due to highway accidents in the United States was an estimated $230.6 billion in 2000 (National Highway Traffic Safety Administration, 2008). This estimate includes property damage, medical costs, productivity losses, legal costs, and travel delay costs. There is approximately one fatality for every 100 million vehicle miles traveled on intercity highways; resulting in approximately 10,000 fatalities annually (see Appendix D). The fatality rate for intercity travel has gradually declined over the last decade from 1.24 deaths per 100 million vehicle miles in 1996 to 0.99 in 2006 (see Appendix D). Although the intercity highway fatality rate is high compared to other modes, intercity travel on highways is less dangerous than other types of highway travel; in 2006, the national fatality rate was 1.41, compared to 0.99 for intercity travel only (NHTSA, 2006).

Valuing human life or quality of life is a controversial subject, but is necessary for many federal agencies in order to complete needed analyses of their policies and programs. The DOT has set the value of a human life at $5.8 million, and performs their analyses with both this figure and high-end and low-end estimates (Duvall, 2008). The costs associated with the estimated number of injuries and fatalities caused by intercity travel in 2008 are provided in Table 6 below, based on these DOT values. Despite these high figures, there is no mechanism for internalizing these costs currently being considered, and thus they do not enter into our mode choice model.

Table 6: 2008 Economic Costs of Intercity Highway Injuries and Fatalities with Different Values of Statistical Life (VSL)

			Costs (FY2005 dollars)		
	People Injured	**Fraction of VSL**	Low Value: $3.2 Million	Standard Value: $5.8 Million	High Value: $8.4 Million
Fatal Injuries	10,538	1.0000	$33,721,600,000	$61,120,400,000	$531,115,200,000
Serious Injuries*	63,228	0.7625	$154,276,320,000	$279,625,830,000	$3,761,545,693,500
Moderate Injuries*	587,283	0.0155	$29,129,221,920	$52,796,714,730	$86,068,540,740
Total	**661,049**	N/A	**$217,127,141,920**	**$393,542,944,730**	**$4,378,729,434,240**

Source: Adapted from FHWA. (2008). *Our Nation's Highways 2008* (FHWA-PL-08-021). Washington, DC: Government Printing Office.

*Serious and Moderate Injury Figures are Estimates. (See Appendix D).

Although safety is undeniably a concern for many Americans, it does not play a significant role in their decisions about what mode to take when traveling between cities. Although each mode carries some risk of injury or death, even highway travel has a relatively low fatality rate. At a fatality rate of less than one death per 100 million vehicle miles traveled, a car going on a medium-distance trip of

500 miles has only 0.000005 percent chance of having a fatal accident. Even a trip from Maine to California carries only a 0.00003 percent risk of a fatal accident. Furthermore, although highway travel is the most dangerous form of intercity travel, individual drivers can take steps to reduce their own risk of an accident, injury or fatality. Those who decided to wear a seat belt restraint have a reduced chance of perishing in a vehicle accident, as do those who are driving sober or who choose to drive in the morning (NHTSA, 2008).

Rail Safety

Amtrak, the primary operator of intercity passenger rail systems in the United States, has a strong safety record. From 1980 to 2009, Amtrak averaged 4.6 passenger fatalities per year and 270.8 passenger injuries per year (see Table 7 and Figure 10). This translates into fewer than 0.001 passenger fatalities per million passenger miles and fewer than 0.05 passenger injuries per million passenger miles (see Table 7 and Figures 11 and 12). These numbers do not include injuries or fatalities to Amtrak employees or to non-passengers who are injured or killed by Amtrak trains (FRA, 2011a; 2011b).

The number of Amtrak passenger injuries, both in terms of raw numbers and injuries per passenger mile, increased between 2000 and 2009 (see Figures 11 and 12). There is no clear reason for this increase in passenger injuries. The number of passenger fatalities remained steady during the same period. The number of passenger fatalities per passenger mile exhibits a spiky pattern, which can be explained by the nature of passenger rail accidents. Since a serious train derailment can cause large numbers of fatalities, fatality rates are notably higher during years in which one or more serious train derailments occurred than during years in which no serious train derailments occurred.

Table 7: Amtrak Injuries and Fatalities

	1980-2009 Average
Passenger Fatalities per Year	4.6
Passenger Fatalities per 1,000,000 Passenger Miles	0.00083
Passenger Injuries per Year	270.8
Passenger Injuries per 1,000,000 Passenger Miles	0.04908
Passenger Fatalities + Injuries per Year	275.5
Passenger Fatalities + Injuries per 1,000,000 Passenger Miles	0.04991

Source: FRA. (2011). FRA Office of Safety Analysis: Operational Data Tables. Retrieved from http://safetydata.fra.dot.gov/officeofsafety

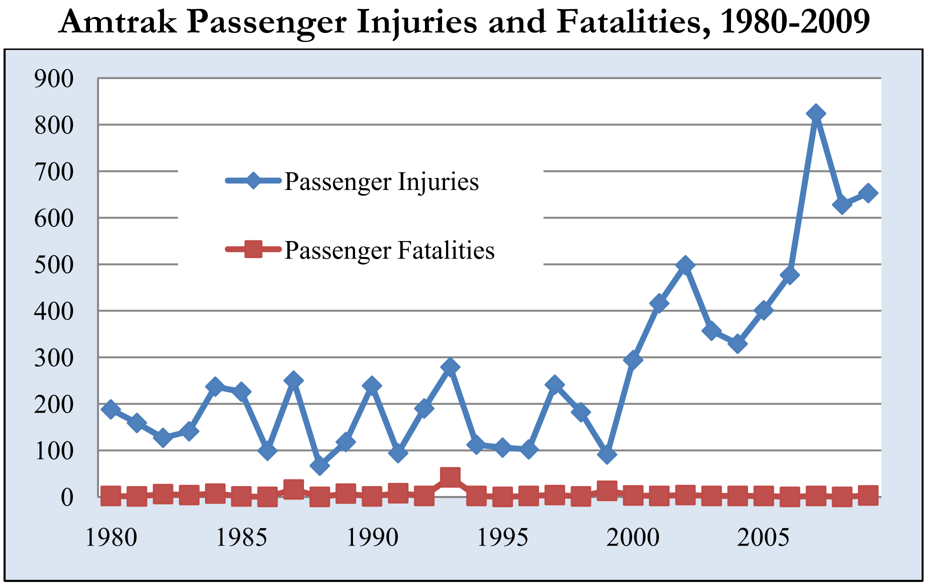


Figure 10: Amtrak passenger injuries and fatalities, 1980-2009
Source: FRA. (2011). FRA Office of Safety Analysis: Operational data tables. Retrieved from http://safetydata.fra.dot.gov/officeofsafety

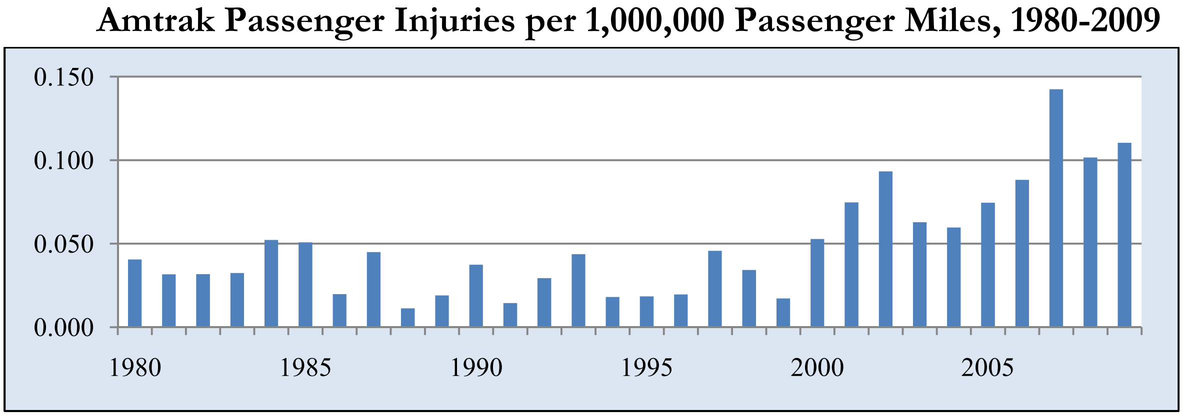


Figure 11: Amtrak passenger injuries per 1,000,000 passenger miles, 1980-2009 FRA.
Source: FRA Office of Safety Analysis: Operational Data Table; FRA Office of Safety Analysis: Ten Year Accidents/Incidents Overview by Railroad. Retrieved from http://safetydata.fra.dot.gov/officeofsafety

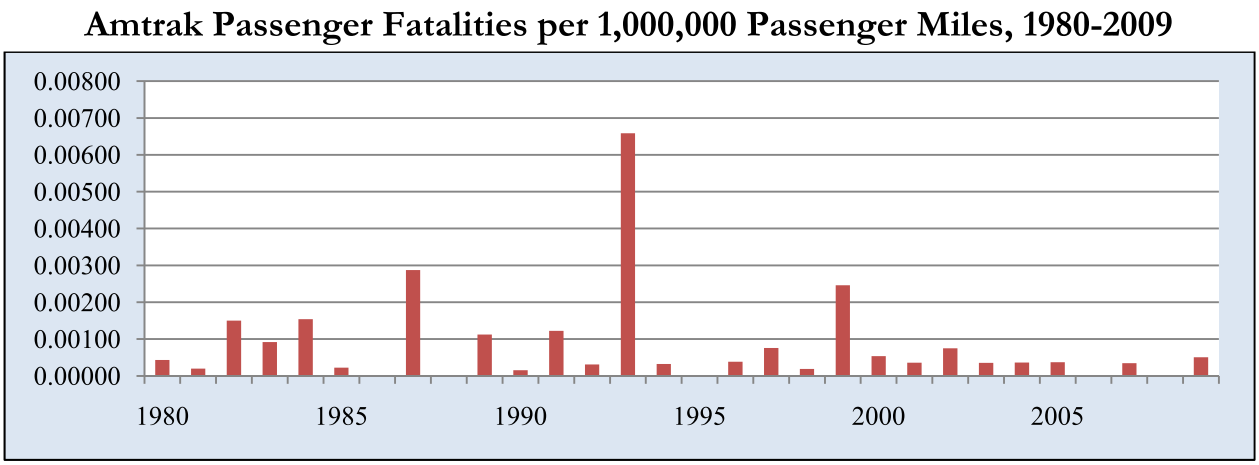


Figure 12: Amtrak passenger fatalities per 1,000,000 passenger miles, 1980-2009

Source: FRA. (2011a; 2011b). FRA Office of Safety Analysis: Operational Data Table; FRA Office of Safety Analysis: Ten Year Accidents/Incidents Overview by Railroad. Retrieved from http://safetydata.fra.dot.gov/officeofsafety

Air Safety

Air Carrier Operations

Air carriers are defined as operators that fly aircraft in revenue service and can be further broken down under Title 14 of the Code of Federal Regulations (National Transportation Safety Board, 2010). Title 14 CFR Part 121 operations refer to "commercial, passenger-carrying operations that are limited to controlled, towered airports and airspace that provide radar, navigation, weather, ground, and maintenance report" and "generally involve large jet and turboprop airplanes engaged in commercial, passenger-carrying operations." Part 121 includes both scheduled and nonscheduled operations (NTSB, 2010).

Part 135 applies to commercial airlines operating in airplanes other than turbojet that have a maximum seat configuration of nine seats. It is important to note a 1997 modification in regulations that changed Part 121 operations to include scheduled aircraft with ten or more seats as it resulted in a shift of a large portion of commuter carriers to be classified under Part 121 service (NTSB, 2010).

Table 8: Air Carrier Operations under Title 14 CFR Parts 121 and 135

Part 121	Scheduled Part 135	On-Demand Part 135
Includes air carrier operations involving airplanes with a passenger-seat configuration of more than 9 passenger seats—or in the case of cargo operations, airplanes having a payload capacity of more than 7,500 pounds. Part 121 includes both scheduled and nonscheduled operations.	Includes scheduled passenger-carrying operations in airplanes, other than turbojet-powered airplanes, having a maximum passenger-seat configuration of 9 seats or less and a maximum payload capacity of 7,500 pounds or less, or rotorcraft.	Air carrier operations for which the departure location, departure time, and arrival location are negotiated with the customer.

Source: National Transportation Safety Board. (2010). U.S. Air Carrier Operations Calendar Year 2006. Retrieved from www.ntsb.gov

Commercial air travel is generally very safe and characterized by very low accident rates. Part 121 operations have lowest accident rates of all commercial operations (see Table 9) and averaged .221 accidents per 100,000 flight hours and .360 accidents per 100,000 departures over the years 1990 to 2009. This average is lower than both scheduled and on-demand Part 135 operations suggesting that travel under Part 121 operations is an exceedingly safe mode of transportation.

Table 9: Air Travel Accident Data: 1990-2009*

	Average per 100,000 flight hours		Average per 100,000 departures	
	All	Fatal	All	Fatal
Part 121 (scheduled and nonscheduled)	0.221	0.019	0.360	0.030
Scheduled part 135	1.464	0.361	0.853	0.221
On-demand part 135	2.485	0.656	-	-

Source: National Transportation Safety Board. (2011). Aviation Statistical Reports. Retrieved www.ntsb.gov

* Rates averaged over 1990-2009

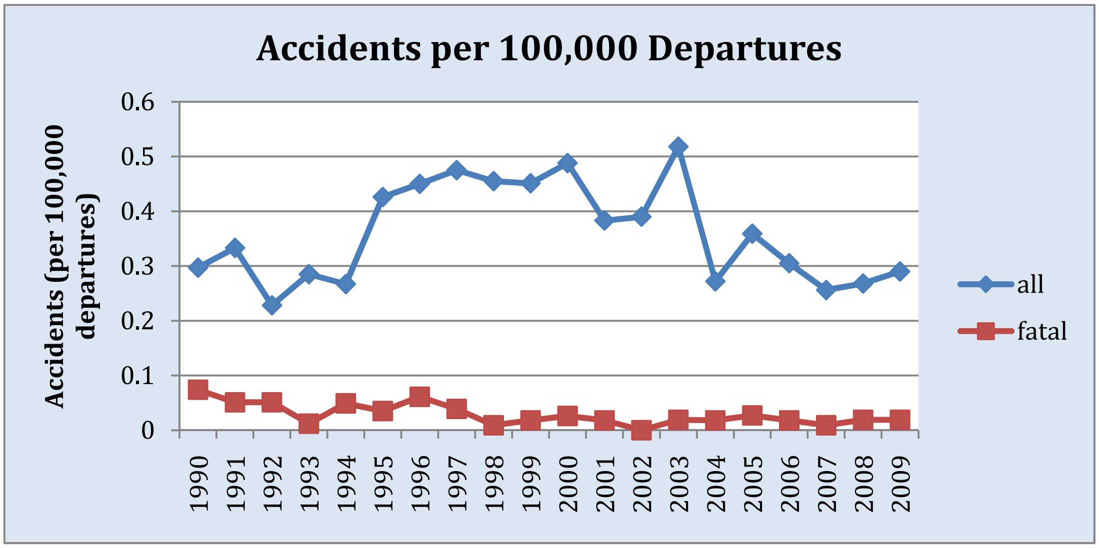


Figure 13: Accidents and fatalities per 100,000 Departures from 1990 -2009 for U.S. Air Carriers operating under 14 CFR 121, scheduled and nonscheduled service

Source: National Transportation Safety Board. (2011). Aviation statistical reports. Retrieved from www.ntsb.gov

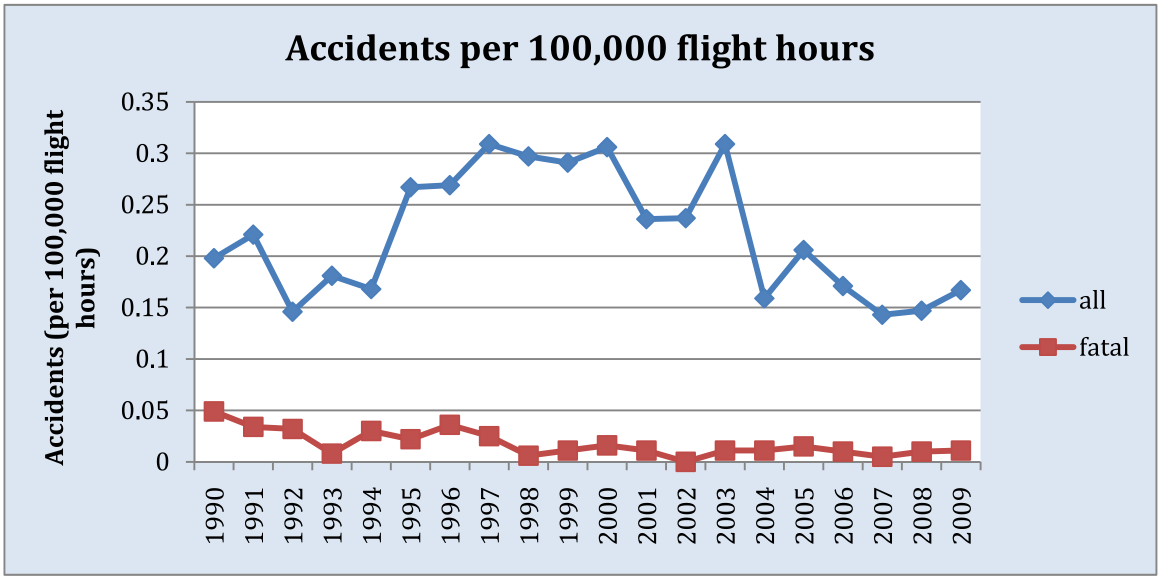


Figure 14: Accidents and fatalities per 100,000 flight hours from 1990- 2009 for U.S. Air Carriers operating under 14 CFR 121, scheduled and nonscheduled service

Source: National Transportation Safety Board. (2011). Aviation statistical reports. Retrieved from www.ntsb.gov

Security Overview

Even before the terrorist attacks of September 11, 2001, security was a high priority within the air mode of passenger transportation. Since the attacks, federal funding of air security has grown dramatically. However, funding for highway and rail security has remained relatively low. For example, the TSA was allocated more than $5.5 billion dollars in funding for air transportation security in the 2010 federal budget but received less than $0.25 billion dollars in funding for ground transportation security (see Figure 15) (Office of Management and Budget, 2011). This disparity in security funding across modes is due in part to public perceptions of safety, in part to the reactionary nature of security measures, and in part to the formidable obstacles to developing comprehensive security systems for the highway and rail modes.

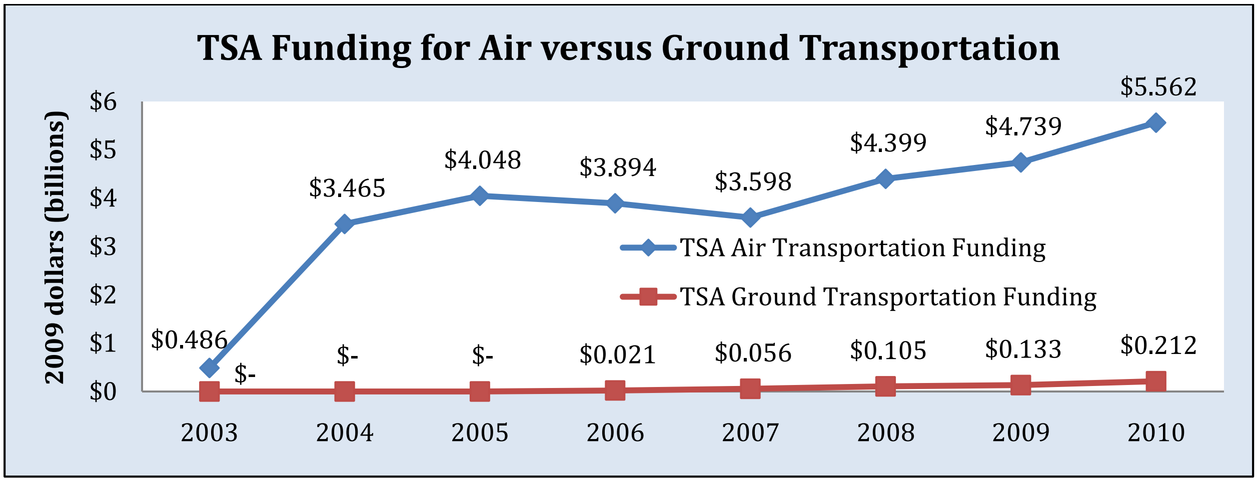


Figure 15: Comparison of Transportation Security Administration (TSA) funding for air and ground transportation in billions of dollars, 2003-2010

Source: Office of Management and Budget. (2011). Federal Budget: Supporting Documents. Retrieved from www.whitehouse.gov/omb/budget/supplemental

Although there are security risks associated with highway travel (e.g., the vulnerability of bridges and tunnels), the vast expanse of highway infrastructure and its many points of entry and exit make security for highways essentially infeasible. When security improvements for highway travel are discussed, recommendations center on engineering improvements that could be made to infrastructure, rather than measures that would affect the travel experience of highway passengers (see, e.g. FHWA, 2003). Rail transportation faces many of the same security concerns as highway transportation due to its wide-reaching infrastructure. However, recent international terrorist attacks on rail systems, as well as the limited entry and exit points to rail systems, have directed some attention to rail security. Nonetheless, air security remains the focus of transportation security in the United States. For all modes, the benefits of increased security must be weighed against the costs, such as the increased time costs of screening passengers. Ultimately, security is not a significant driver of consumer mode choice because other considerations, such as travel times and ticket prices, generally outweigh security concerns. In the future, the influence of security concerns on mode choice could increase if the number of terrorist attacks increased substantially on one mode relative to the other modes. However, given the inherent unpredictability of terrorism and the reactive nature of security measures, our model assumes that security measures and the time they add to travel in each mode will remain constant in 2060 relative to today.

Rail Security

The greatest obstacle to rail security is the large quantity of rail infrastructure, much of which is easily accessible to trespassers (FRA, 2007). A recent report by the Federal Railroad Administration (FRA) provides guidelines on technologies that could be used to detect trespassers at strategic points in the nation's rail infrastructure, such as bridges and tunnels. The guidelines are based on a multiyear study of a video surveillance system installed on a railroad bridge in Pittsford, N.Y. The system was deemed to be an "effective trespassing detection and deterrent system" (FRA, 2011d). However, the safety of trespassers remains a greater concern than the malicious intent of trespassers due to the approximately 500 deaths that occur among railroad right-of-way trespassers each year (FRA, 2011d).

Over the past decade, security concerns have increasingly focused on rail passengers due to terrorist bombings within rail stations and rail cars in several major cities, including Madrid, London and Moscow (Amtrak, 2010c). Recent advances in computer software have improved the ability of security cameras to detect suspicious behavior and notify security personnel of potential concerns. However, these systems, sometimes called "intelligent video" or "behavioral video," are not yet widely used in U.S. rail stations (FRA, 2007; Verton, 2004).

Since 2008, Amtrak has conducted random baggage screenings at rail stations through the country. In addition, as of April 2010, Amtrak had increased the size of its bomb-sniffing dog squad to 45 teams (Amtrak, 2010c). However, screening of all rail passengers and their baggage, similar to the screenings conducted at airports, would increase rail travel times, thus diminishing one of the key advantages of rail transportation. In addition, such screenings would increase the costs of rail transportation, which already heavily depends on government subsidies for its survival. Moreover, past terrorist attacks in rail stations and rail cars have targeted urban rail systems rather than intercity rail systems. As discussed above, intercity rail systems are more likely to face terrorist threats by trespassers along their long expanses of exposed infrastructure than by passengers on the trains.

As a result of such complications and tradeoffs, rail infrastructure and passengers are much less closely monitored than air infrastructure and passengers. However, rather than deterring intercity travelers from choosing rail, the light security at rail stations might attract travelers who are weary of security lines at airports. With that said, a terrorist attack on a rail station or rail line in the United States could lead to a rapid change in public perceptions of rail safety and a rapid increase in the level of government funding for rail security.

Air Security

Evolving Air Security Regulations

U.S. air security is highly responsive and evolves with security breaches. Securing passengers and cargo was historically the responsibility of private air carriers; the passage of the 1974 Air Transportation Security Act required U.S. airport operators to establish security programs in coordination with law enforcement entities. Additionally, the act mandated the FAA to establish regulations requiring weapons-detecting screening of all passengers and carry-on property (TSA, 2011a)

The TSA was established by The Aviation Transportation Security Act on November 19, 2001 following the September 11, 2001 terrorist attacks. With its passage, TSA assumed responsibility for civil air security including air passenger and baggage screening. TSA was moved to the DHS following its creation in 2002. TSA is responsible for all modes of transportation within the United States, including aviation, rail, transit, highway, and pipeline transportation. TSA was transferred from the DOT to the DHS following the Homeland Security Act (HSA) of 2002 (TSA, 2011d).

In accordance with "opt-out" provision of The Aviation Transportation Security Act, TSA offers the Screening Partnership Program (SPP) which allows private contractors to conduct screening operations under TSA oversight at selected airport operators. Airports participating in the SPP program must continue to follow security protocols and standards set by TSA for all commercial airports. Currently, privately contracted screeners are in place at sixteen airports in the United States (TSA, 2011c).

Screening Process

TSA requires all passengers to pass security checkpoints before accessing flights at the nation's commercial airports. The passenger screening process is three tiered and includes an x-ray and metal detector screening with additional screening as needed. Additional screening practices may include a hand-wand, pat down, and carry-on luggage screening. TSA utilizes a multi-layered approach to security and implements security measures beyond passenger and cargo screening. Intelligence analysis, passenger watch lists, and technological innovations, including advanced imaging technology, paperless boarding passes, and the use of biometrics continue to strengthen the security of commercial flights. These additional screening practices may have both positive and negative impacts on security wait times in the future (TSA, 2011c).

Current Mode Share

The primary difference between business and leisure travel is the average trip distance. On average, business travelers take shorter rail trips than leisure travelers, as indicated in Table 10. Furthermore, the length of leisure trips varies much more widely than the length of business trips. This outcome is logical given that business travelers are generally on a tight schedule and place great emphasis on traveling efficiently between two points whereas leisure travelers often have more time and sometimes value the trip itself rather than just the arrival at a destination (BTS, 2011b). However, one limitation of the dataset is that many observations do not specify the purpose of their travel. For example, the maximum trip distance is over 1,000 miles but is only included in the total numbers as the respondent did not specify business or leisure.

This difference between business and leisure travelers has important implications for future rail development. Unless HSR can begin to compete with the speed of air travel, business travelers will not be willing to travel long distances via rail. Therefore, it is important for the design of future rail lines, whether conventional or high speed, to determine how to attract business travelers.

Table 10: Average rail trip distance by leisure and business

	Total		**Leisure**		**Business**	
	Weighted	**Un-weighted**	**Weighted**	**Un-weighted**	**Weighted**	**Un-weighted**
Trip length > 50 miles	163.89	260.60	177.45	242.79	144.51	143.29
Trip Length > 100 miles	213.90	352.52	265.40	323.38	181.95	177.00

Source: Bureau of Transportation Statistics. (2011). National Household Travel Survey. Retrieved from http://www.bts.gov/programs/national_household_travel_survey/

Chapter IV: Overview of the Model

IV. OVERVIEW OF THE MODEL

An important goal of this report was to forecast the percentage of 2060 intercity passenger transportation achieved by each of four modes: air, auto, bus, and rail. This was accomplished by using a conditional logit model to predict the probability that a passenger would choose each mode based on the characteristics of the passenger and of the modes. Our primary data source was the 2009 National Household Travel Survey (NHTS, see Appendix C), supplemented with data on the cost to the user of each mode of travel. We identified several factors that are likely to act as drivers of change in intercity transportation through 2060. Most of these factors would exert their influence on mode share by changing either the user price per mile of travel or the average travel time. The primary factors that exert quantifiable changes were translated into scenarios for use in the model. There remain unpredictable variables that could potentially influence the future of intercity transportation that were not modeled, such as the safety and security concerns and some of the more dramatic technological innovations discussed in Chapter III. We acknowledge the potential of each of these factors to significantly affect intercity travel choices, but the highly unpredictable nature of each made inclusion of these factors into the model untenable.

The model includes the following variables: the projected trip price, the traveler's household income, and the total trip time, including travel time to public transportation hubs (stations and airports) as well as security wait times. Trip prices were projected for a variety of scenarios to account for different combinations of fuel prices, subsidy levels, carbon prices, and efficiency gains. In addition, the difference between business and leisure travelers was accounted for by varying the characteristics of the passengers. Finally, the model was used to predict mode choices for both the entire nation and for a single California corridor in order to gauge the potential impact of a HSR line on mode shares.

For the national model, HSR was not included, as the plans for HSR are limited to specific corridors, and the mode will not be available to all travelers (See Figure 16) (FRA, 2010).

To model the potential impact of the current plans to develop HSR, we chose to model what we found to be the most promising corridor for HSR: California. We assumed that the rail line would be built from San Francisco to San Diego with a one stop in Los Angeles—the small number of stops was chosen to maximize the speed the train could achieve and thus make the model favorable toward HSR (while acknowledging that no train from San Francisco to San Diego could be reasonably expected to bypass Los Angeles). We started with this favorable scenario to determine if HSR could achieve significant mode share under these conditions—if not, we could conclude that the mode was not viable in other conditions or contexts either. The model parameters stayed constant, while costs shifted to reflect California's fuel taxes and unique electricity generation mix. In order to simplify the model, conventional rail was excluded from the corridor model–all rail travel was presumed to be high speed. Further details on the California model can be found in Chapter VII.

High-Speed Intercity Passenger Rail Program Investment Map

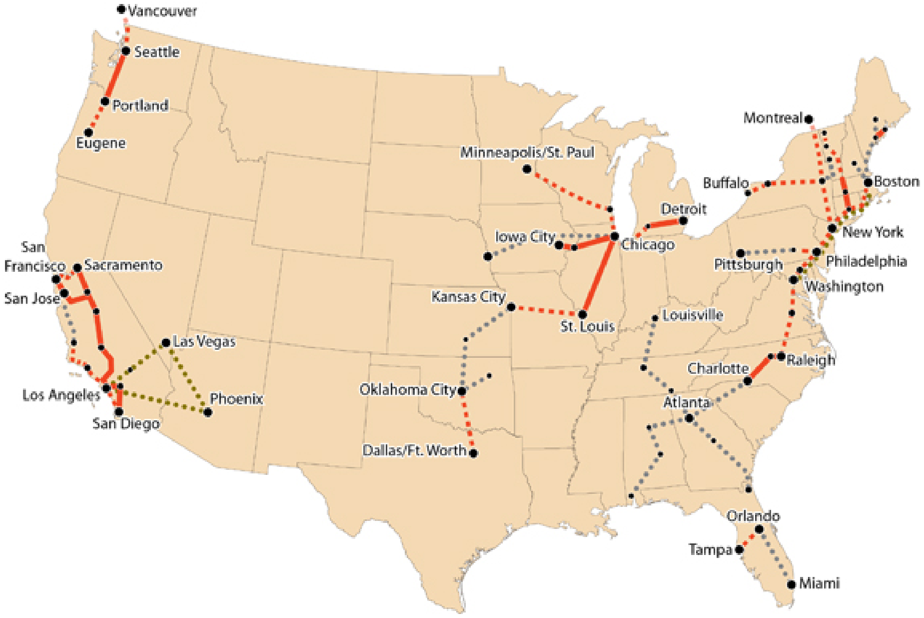


Figure 16: *Source:* FRA. (2010). Program investment map. Retrieved from www.fra.dot.gov

Model Description

Intercity transportation mode share is an aggregate of individual choices about travelling. These individual choices are represented by the utility function $U_i = x\beta$, where U_i is the mode chosen for the trip and $x\beta$ is the set of weighted factors considered by the decision maker. Considering this underlying individual economic decision, we estimated the national aggregate share of each mode in 2009 as the conditional logistic function:

$$Y_{ij} = \alpha_{ij} + \beta_{1ij}(\text{Time}) + \beta_{2ij}(\text{User Price})$$

Maximum likelihood estimation returned estimates for each parameter. Using the estimated parameters, future mode choice was predicted as the probability of a given individual choosing each of the four modes, based on both the characteristics of the individual and characteristics of the four modes. This model allows for changes in individual choice in reaction to changes in the modes. Thus, as the user price per passenger mile by auto increases relative to the user price of the other three modes, the probability that an individual will chose to travel on auto decreases, holding the effects of the other independent variables constant. This decrease in the probability of choosing auto increases the probability of choosing one or more of the other modes.

A more detailed description of the model, including a data description, a list of specific variables utilized, the derivations of time from trip distance, and an interpretation of model parameters and diagnostics are available in Appendix A. Descriptions of how baseline user prices were derived are available in the respective mode sections in Chapter V.

Characteristics of the Passengers and the Trips

We used the parameters of the model to estimate the probability that an average person would choose each of the four modes of transportation in this study for trips of various distances, given the travel time, price, characteristics of each mode, and the person's household income. Household income is the only variable which represents a characteristic of the traveler in the model; the other variables represent characteristics of the travel modes. We used separate median household income values for the average business and the average leisure traveler. For our projections of business travel, we used a value of $75,000, the median household income of business travelers from the 2009 NHTS travel day data set. For our projections of leisure travel, we used a value of $50,221, the 2009 estimated median household income from the U.S. Census Bureau. Additionally, our projections use the rounded weighted average number of travelers per trip from the 2009 NHTS data set – a one-person trip for business travel and a two-person trip for leisure travel.

Using the recorded length of the trip in miles from the 2009 NHTS, we estimated both the price paid by the traveler and the total trip time. By multiplying the price of each mode per passenger mile by the total mileage of the trip and then by the number of passengers, we estimated the total trip price. By multiplying the average speed of each mode by the total mileage, then adding in any added time for travel time to a transit hub, for delays, for stops, or for security screening, we estimated the total trip time. For more information on the estimation of trip price and related assumptions, see Appendix C. For more information on trip time calculations, see Appendix A.

In order to demonstrate how the average traveler responds at different trip distances, we projected the probabilities of choosing each mode in the national analysis at distances of 100, 264, 500, 1000, and 1500 miles for business travelers. The 264-mile trip distance is the average business trip length from the 2009 NHTS. For leisure travelers in the national analysis, we considered trip distances of 100, 244, 500, 1000, and 1500 miles. The 244-mile trip distance is the average leisure trip length from the 2009 NHTS. Since we had the origin and destination information for the California scenario, the trip distances varied by mode. The highway route for auto and bus was a distance of 502 miles, city center to city center. The air route was 458 miles from San Diego to San Francisco (BTS Inter-Airport Distance, 2011). The HSR route is a distance of 616 miles, the total track distance of the route proposed by the California High-Speed Rail Authority (2009). An explanation of how speed was calculated for this route can be found in Appendix A.

Chapter V: Model Scenarios

V. MODEL SCENARIOS

In this section we outline the methodology and justifications for the forecasts that underlie our modeled 2060 projections.

Fuel Price Projections

The Energy Information Administration's (EIA) *Annual Energy Outlook 2011* projects a 37.6 percent increase in motor gasoline prices, a 60.4 percent increase in jet fuel prices, and a 34.8 percent increase in diesel fuel prices during the 25-year period from 2010 to 2035 (EIA, 2010fa). Because of the long-term nature of the analysis and unpredictability of fuel prices, we assume the same rate of increase for the subsequent 25-year period from 2035 to 2060. This resulted in 2060 mid-range price estimates of $5.08 per gallon for motor gasoline, $5.47 per gallon for jet fuel, and $5.25 per gallon for diesel fuel (See Figure 17).

The U.S. Energy Information Administration (EIA) projects a reference price of $125 per barrel of low-sulfur crude oil in 2035. The EIA's high and low price projections for crude oil in 2035 are $200 per barrel and $50 per barrel, respectively (EIA, 2011b). These high and low prices represent a 60 percent increase and a 60 percent decrease relative to the reference price. Therefore, we adjusted our mid-range prices for motor gasoline, jet fuel, and diesel fuel by 60 percent in either direction to develop our high and low prices for these fuel types. The resulting high estimates were $8.13 per gallon for motor gasoline, $8.75 per gallon for jet fuel, and $8.39 per gallon for diesel fuel. The low estimates were $2.03 per gallon for motor gasoline, $2.19 per gallon for jet fuel, and $2.10 per gallon for diesel fuel.

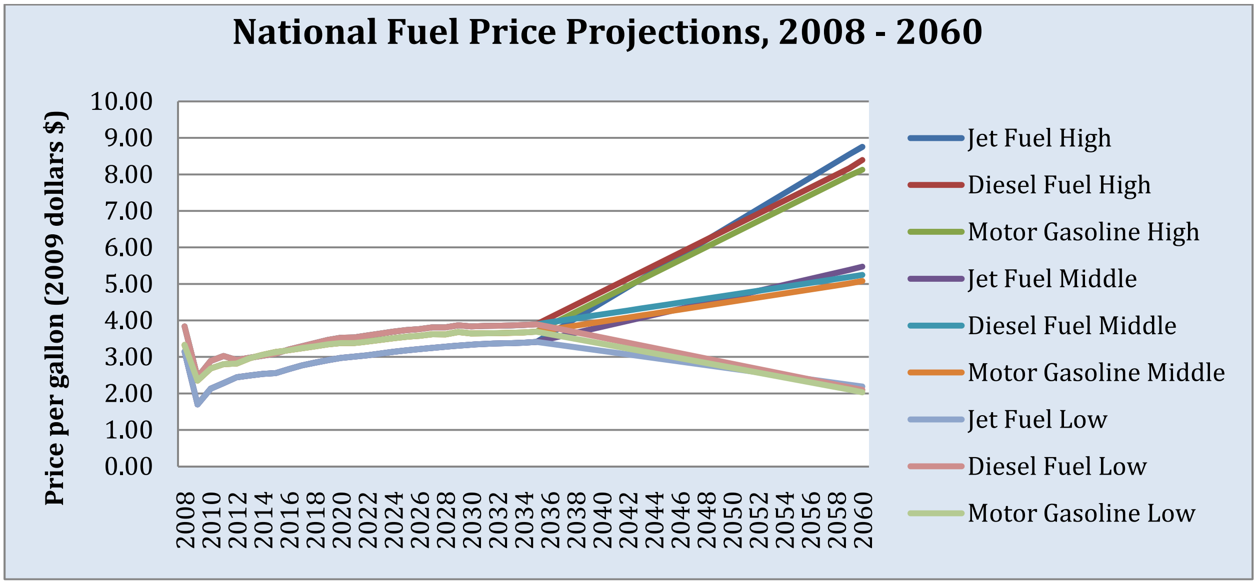


Figure 17: National fuel price projections through 2060 with high, middle, and low estimates for jet fuel, diesel fuel, and motor gasoline.
Source: EIA. (2011). Annual Energy Outlook 2011. Retrieved from www.eia.doe.gov

Carbon Price Estimation

Possible Results of Pricing Carbon

Carbon regulation in the transportation sector could occur through several mechanisms. Regulatory methods include explicit carbon taxes (Kim, Han, and Moon, 2011), implicit pricing through a cap-and-trade system (Greene, 2009), and other policies such as subsidies for ethanol (Tyner, 2007) and feebates (Greene, 2009). Furthermore, estimating the effects of carbon regulation on the transportation sector requires the examination of carbon prices, gas taxes, price elasiticites, and the interactions between these and other variables. Carbon prices would not be directly noticed by the consumer, but would translate into higher costs, such as implicit gasoline taxes; a carbon tax of $50 per ton of CO_2 would almost be a $0.50 tax per gallon of gasoline (Greene, 2009). The exact outcome of given policies is uncertain, similar to the uncertainty revolving around carbon prices. Consequently, the predicted effects on technology – along with policy goals – vary from study to study (Greene, 2009; Tyner, 2007; Kim, 2001; Karplus, 2010), and different scholars argue for different policies in different sectors of transportation (Greene, 2009; Tyner, 2007).

Estimating a Carbon Price

The estimated social cost of carbon (SCC) varies widely depending on the study. Distributions noted by the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report (2007) and Tol (2009) are wide, partly because of varying assumptions. These include different emissions targets (Metz, Davidson, Bosch, Dave, and Meyer, 2007) and discount rates (Tol, 2009), along with scientific uncertainty (most notably in Lemoine and Traeger, 2010), among other factors. Some estimates are especially high due to the use of low discount rates (e.g. Stern, 2006), although the use of such low discount rates is criticized by many economists (Nordhaus, 2007; Tol, 2009). In general, the near-current SCC focuses (by mean or mode) around prices of $25 and $50 per ton of CO_2 given discount rates of three to five percent, as confirmed by analyses by the Interagency Working Group on Social Cost of Carbon (2010), Tol (2009), and Nordhaus (2010). These commonly assessed values, along with the given economic and scientific uncertainties, led to the use in this report of $25, $50, and $100 per ton of CO_2 for the modeling analysis.

Efficiency and Emissions Scenarios

The effect of the fuel price scenarios and carbon pricing on the cost to the user—and, ultimately, on mode share—will depend for each mode on the fuel efficiency and carbon intensity of that mode. Two innovation scenarios have been developed: an extended trends scenario that assumes that current trends persist through 2060 and a "green revolution" scenario that assumes the highest feasible improvements in efficiency and reductions in carbon intensity. The extended trends scenario is considered by the authors to be the likely scenario, where the green revolution scenario serves as a sensitivity analysis.

Across all modes, we have only assumed greater adoption of technologies that are currently commercially available. For example, the green revolution scenario for automobiles assumes that electric vehicles have achieved some market share, because electric vehicles are currently offered for sale, while more emerging technologies such as hydrogen fuel cells and NGVs are not included. In order to add carbon pricing to the statistical model, the assumption has been made that the passenger will bear the entire price assigned to carbon emissions. Carbon emissions produced by passenger intercity travel are the only environmental externalities considered for the purposes of this model—the social costs of criteria pollutants, fixed environmental costs from infrastructure, and any other environmental damages are excluded.

Auto Efficiency and Emissions Scenarios

Vehicle average mile per gallon fuel economy for the baseline case is estimated at 25 miles per gallon based on a survey of available literature and research. The average of all Environmental Protection Agency (EPA) mileage ratings in 2011 is 25 miles per gallon (EPA, 2011a) and the National Academy Press Report also states that new vehicle fuel economy is 25 miles per gallon. CAFE standards for 2011 require 27.5 miles per gallon. The average number of passengers per vehicle for long-distance travel used in the projections was 2.42 people per vehicle, based on 2009 NHTS data as there is no reason to suspect that this figure will significantly shift over time (BTS, 2009b). Please note that traffic congestion is excluded from this analysis since it is not a large issue when considering intercity travel only.

To determine the fleet efficiency for the two innovation scenarios, assumptions had to be made both about the percentage of efficiency and innovation gains that will result in improved fuel economy as well as the percentage of market share that will be held by AFVs. This report focuses on only intercity travel, therefore electric and plug-in vehicles are not considered as part of the extended trends scenario due to their current inability to travel long distances. However, given the current political interest in electric vehicles and the recent investments in battery research and development, there exists the possibility that a technological breakthrough could produce a battery able to travel intercity distances. The green revolution scenario assumes that such a breakthrough has occurred and electric vehicles are a viable intercity option. Hydrogen fuel vehicles, CNG, and liquefied petroleum gasoline (LPG) vehicles are left out of the market share due to existing safety concerns and lack of infrastructure. Deployment time for these alternative vehicles would be lengthy when considering that technology must improve, vehicles must be tested, infrastructure built, vehicle fleet replaced, and new vehicles marketed and sold. Therefore, it is not likely that hydrogen fuel, CNG, or LPG vehicles will obtain a significant amount of the market share in 50 years.

Gains in efficiency are set to increase fuel economy by 40 percent for the extended trends scenario and 80 percent for the green revolution scenario. Baseline fuel economy for gasoline is 25 miles per gallon for same reasons aforementioned. Baseline hybrid fuel economy is set at 30 miles per gallon based on a sample of current hybrid vehicles represented on the fuel economy web site sponsored by the EPA and DOE (www.fueleconomy.gov). Percentage efficiency increases were predicted following a literature review. In an MIT Energy Labor Report, Malcolm A. Weiss indicated that fuel consumption may decrease by 12 percent by 2020 due to advances in body design and weight reductions. Weiss noted an improvement of 61 percent if further technology innovations were included such as inverters, controls, motors, and regenerative braking (Weiss, Heywood, Drake, Shafer, and AuYeung, 2000). Knight predicted average efficiency improvements of about 35 percent with existing technology (Knight, 2010). In the National Academies Press report in 2010, CAFE standards are assumed to reach 35 miles per gallon by 2020. Based on these estimates, the percentages are predicted as examples of low and high levels of innovation.

Market share by conventional vehicles versus hybrid vehicles is assumed to be 85 percent conventional and 15 percent hybrid for the extended trends scenario. In a high efficiency scenario, it was assumed that the market share would be 55 percent conventional and 45 percent hybrid based on a literature review described below. The market share for the "green revolution scenario" is 45 percent conventional, 35 percent hybrids, and 20 percent electric vehicles. The EIA Annual Outlook for 2011 shows that the current market mixture is approximately 96 percent conventional gasoline vehicles and four percent AFVs (EIA, 2011b). Since the current market share consists of only four percent for all AFVs, the low scenario begins with a reasonably low percentage for hybrids of 15 percent. According to Heywood, plug-in and regular hybrid vehicles will gain 22.5 percent of the market (2010). Due to the many unknowns in the electric vehicle market, there is wide variation in predictions of the market share they will capture. Goldman Sachs predicts that there will only be a four percent global market share of pure electric vehicles and PHEVs by 2020 (The Goldman Sachs Group, 2010), while the IHS Global Insight Group projects nearly 20 percent global market share by 2030 (IHS Global Insight Group, 2010).

In order to complete the forecast, additional assumptions were made regarding the future emission factors for carbon dioxide for gasoline, ethanol, hybrid, and electric vehicles. The National Academies Press Report provides 2020 estimates utilizing Argonne National Laboratory's GREET Model to predict GHG emissions. The National Research Council Report predicts gasoline and ethanol 85 vehicles to emit 365 and 358 carbon dioxide by vehicle mile traveled respectively. Ethanol 10 emits very similar quantities as ethanol 85; and both are very close to the gasoline emissions when the energy required to produce the fuel is accounted for. Therefore, no distinction was made in the emissions calculations for ICEs using gasoline and those using an ethanol blend. Further, biodiesel is applied to buses and diesel-fueled trains later in the report because it is estimated that corn ethanol only produces 25 percent more energy than the amount needed to produce it, while biodiesel produces 93 percent more energy (Hill et. al, 2006). This analysis assumes that the net gain of energy from ethanol is not enough to justify its widespread market adoption, particularly at high mixture levels like E85 across millions of vehicles, while biodiesel use is assumed to be feasible based on its greater net energy production and the limited number of vehicles (buses and trains) in which it would be used. In addition, hybrid vehicle emissions reductions are a result of improved efficiency, so for all non-electric vehicles, the rate of emissions used was 0.0088 tonnes CO_2/gallon of fuel, based on the EPA estimates of gasoline emissions (EPA, 2005a).

For electric vehicles in the green revolution scenario, a simplifying assumption was made that all were battery-electric vehicles. However, since all costs are in terms of passenger miles, the scenario truly reflects 20% of total miles being fueled by electricity. These electric miles could be therefore driven by either plug-in hybrid electric vehicles or pure battery-electric vehicles. Additionally, the vehicles were assumed to travel three miles per kWh, based on estimates from Idaho National Laboratory (2011) and EPA's fuel economy labels for the all-electric Nissan LEAF state that the vehicle travels 100 miles on 34 kWhs (Barth, 2010). In the green revolution scenario, the electric generating sector reduces fossil fuel inputs by half with 15 percent efficiency gains in production and delivery resulting in emissions of 222g CO_2/kWh (further detail on electricity calculations is provided in the discussion on high-speed rail emissions).

Bus Efficiency and Emissions Scenarios

This analysis is intended to evaluate the internalization of environmental costs and its effect on intercity bus travel. For this analysis, a bus, or motorcoach, is defined as a vehicle designed for long-distance transportation of passengers. The definition of an intercity bus excludes city transit buses and city sightseeing buses (M.J. Bradley & Associates, 2008). In the extended trends scenario, in which current trends in fuel use are taken into consideration through 2060, we assumed that fuel use would be 25 percent B20 biofuel and 80 percent diesel, given that the motorcoach industry currently uses a small percentage of biofuel already. In the green revolution scenario, all buses are using B20 biofuel diesel fuel.

Biodiesel, which is already used in intercity bus transportation, was the only alternative fuel that is known to be viable for this use. The price and performance properties pure biodiesel and a lack of regulatory incentives have led to limited use of high blends of biodiesel in the market (National Renewable Energy Laboratory, 2009). The B20 blend was chosen in this report because it represents a good balance of cost, emissions, and performance (NREL, 2009). The other major alternative fuel being considered for bus applications is CNG but this fuel has limitations that make it incompatible with long-distance intercity travel. CNG vehicles have limited range (around 350 miles) so an extensive infrastructure would need to be built around the highway system (TIAX LLC, 2003). To build this infrastructure would be very costly—a high capacity, fast-speed pump can cost $200,000 or more (Pirraglia, 2003). Furthermore, B20 is a "drop-in" technology, meaning that it can be used in existing buses (it is currently approved by several manufacturers for use in their engines), while CNG buses require different engines (Kotrba, 2010).

In the extended trends scenario, we assumed a 40 percent increase in efficiency and an 80 percent increase in the green revolution scenario to correspond with the personal vehicle efficiency improvements. However, the bus fleet in the green revolution scenario has lower fuel efficiency than the extended trends scenario due to the relative efficiencies of B20 and pure diesel. The baseline fuel efficiencies used were 5.67 mpg for diesel (MJ Bradley and Associates, 2008) and 3.52 for B20 (Barnett, McCormick and Lammert, 2008). In both scenarios we assumed a constant passengers/bus rate of 21.2, derived from the BTS bus profile (BTS, 2008). Even with the greater efficiency improvement in the green revolution scenario, the passenger miles per gallon in the extended trends scenario was 152.3 compared to 134.3 in the green revolution scenario.

Using the known carbon dioxide emissions per gallon for both diesel fuel and B20 biodiesel fuel (10,084 and 8120 g CO_2/gallon, respectively[7]) we determined the different emission levels based on the two scenarios' fuel mixtures. (EPA, 2005) An important assumption to note is that idling emissions were not taken into account. The assumption was made that intercity buses spend little or no time stuck in traffic. Information was provided regarding the tonnes of carbon dioxide emitted per gallon of fuel consumed as well as the average miles per gallon for each fuel used in the projection model. Using this information the amount of carbon dioxide emitted per passenger mile was calculated for each scenario. The steps followed to get emissions data were:

$$\frac{(\%\,\text{fuel}) * \left(\frac{\text{tonnes}\,\text{CO}_2}{\text{gal}}\right) * \left(\frac{1}{\text{mpg}}\right)}{21.2(\text{passengers per vehicle})} = \frac{\text{tonnes}\,\text{CO}_2}{\text{passenger - mile}}$$

This equation was used for each fuel type and the tonnes of carbon dioxide per passenger mile for each fuel were added up to give the total emissions in a given scenario. To get the internalized environmental cost for each scenario, the carbon dioxide emission rate was multiplied by the carbon price.

Air Efficiency Scenarios

In order to internalize the environmental impacts of intercity air travel, the price of the environmental damages must be borne by the mode user. Calculations of fuel efficiency and ultimately emissions per passenger mile were determined using the following equation:

$$(\mathit{Fuel\ Consumption}) \times \left(\frac{\mathit{Domestic,\ Scheduled,\ Revenue\ Aircraft\ Miles}}{\mathit{Domestic\ CFR\,121\ and\ CFR\,135\ Aircraft\ Miles}}\right) \times \left(\frac{9.57\ \mathit{kg\ CO_2}}{\mathit{gallon\ Jet\ A}}\right) \times \left(\frac{10^3\ g}{kg}\right) \times \left(\frac{1}{\mathit{Domestic,\ Scheduled,\ Revenue\ Passenger\ Miles}}\right)$$

The calculations were performed on annual data from 1996 to 2009, and are fully explained in Appendix B. The substantial reductions in emissions per passenger mile from 1996 to 2009 (2.9 percent average annual decrease) can largely be attributed to load factors, which have increased from 68.0 percent in 1996 to 80.7 percent in 2009 (BTS, 2011f). In the future, lower rates of fuel efficiency gains will result because load factors will be unable to continue increasing at the same rate due to capacity issues. For forecasting calculations, this study assumes that average load factors and stage length will remain relatively constant, and will not have a significant effect on fuel efficiency.

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[7] Note that pure biodiesel is assumed to have zero CO_2 emissions, so the B20 figure was derived by calculating 80 percent of the diesel CO_2 emissions.

Emissions reductions were calculated based upon two levels of fuel savings estimated by the International Air Transport Association (IATA) and industry experts for composite airframe advances, engine efficiency increases, and operational improvements including air traffic control progress and active load alleviation (International Air Transport Association, 2009). For example, the 30 percent engine efficiency increase under the high carbon-pricing scenario is based upon the assumption that open rotor engine technology becomes the adopted engine design for the industry. According to Andrew Baker of Rolls Royce, this will result in a 30 percent increase in fuel efficiency (A. Baker, personal communication, March 30, 2011).

Table 11: Air Efficiency Scenarios

	2060 Efficiency Scenarios	
Carbon Price ($/tonne of CO_2)	**Ext. Trends**	**Green Revolution**
Technological Improvements and their resulting percent decrease in emissions:		
Composite Airframes	1	3
Engine Efficiency Increases	10	30
Operational Advances	2	5
Biofuels	0	20
Total Percent Reductions from 2009 Emissions per passenger Mile	13.0	58.0
Resulting grams CO_2 emitted per passenger mile	159.63704	77.06616

Average biofuel blend ratios were also estimated based upon scholarly reports of alternative fuels for aircraft. While numerous biofuel options are available, there are still many problems including energy content, thermal stability, engine compatibility, production potential, and price variability (Hileman, Wong, and Waitz, 2009). Therefore, the blend ratios between biofuel and Jet A were estimated to be 0/100 for the extended trend scenario and 20/80 green innovation scenario respectively. Due to the uncertainty and variability in lifecycle emissions across different biofuels, only wake emissions were assessed in the table below. It is important to note that the lifecycle emissions of certain biofuels are higher than Jet A fuel emissions (Stratton, Wong, and Hileman, 2010).

Emissions reductions from operational advances will be due in part to the airport and air traffic improvements that have been dubbed "NextGen" by the FAA. NextGen is the name given by the JPDO to the comprehensive overhaul process currently underway on the NAS. The focus of this renovation to the existing system is to make air travel more convenient and dependable, while providing the safest, most secure flight experience possible (FAA, 2011b). At its most basic, NextGen is a change from the ground-based system of air traffic control to a satellite-based system of air traffic management. This change entails using existing technologies, such as the GPS and developing aviation specific applications. When combined with new airport infrastructure and new procedures, "NextGen will allow more aircraft to safely fly closer together on more direct routes, reducing delays and providing benefits for the environment and the economy through reductions in carbon emissions, fuel consumption and noise" (FAA, 2011a).

Parts of these new procedures include having a highly effective governance structure. Two teams of FAA executives, the NextGen Management Board and the NextGen Review Board, serve as the governance structure of NextGen and work to ensure that the delivery of NextGen improvements is timely and cost-effective. The NextGen Management Board, which provides the necessary oversight and policy direction, is chaired by the deputy administrator and includes the heads of the FAA lines of business with primary responsibility for delivering NextGen. The NextGen Review Board acts as a mediator between agencies and helps the NextGen Management Board address implementation issues. While governance of aviation is primarily the responsibility of the FAA, the FAA has recognized that the implementation of NextGen requires a collective and comprehensive effort by many coordinating agencies, instead of implementing a series of independent programs by individual agencies. This effort includes "six transformational programs (Automatic Dependent Surveillance-Broadcast, Data Communications, System Wide Information Management, NextGen Network Enabled Weather, NAS Voice System, and Collaborative Air Traffic Management Technologies), seven solution sets and – new in 2011 – a suite of implementation portfolios" (Babbitt, 2011).

NextGen is not an inexpensive upgrade. The JPDO reported in 2006 that the total cost for NextGen infrastructure may range from $15 billion to $22 billion. The agency also noted that it expects a corresponding cost to system users, who will have to equip themselves with the advanced avionics necessary to realize the full benefits of some NextGen technologies, falling in the range of $14 billion to $20 billion. These ranges occur because of discrepancies in the projected cost versus the actual costs. For example, Airport Surveillance Radar Model 11 was originally estimated to cost $916.2 million to acquire 112 systems; the estimated cost at completion was reduced to $696.5 million to acquire 66 systems. Similarly, FSAS Operations and Supportability System was originally estimated to cost $249.4 million for installations at 61 sites; the estimated cost at completion was reduced to $169.0 million for installations at 16 sites. The costs are only half the picture, though. Estimates show that NextGen will also provide very tangible benefits, such as fewer delays: "The delay reduction will provide $23 billion in cumulative benefits from 2010 through 2018 to aircraft operators, the traveling public and the FAA, as well as saving about 1.4 billion gallons of aviation fuel during this period, cutting carbon dioxide emissions by 14 million tons" (FAA, 2010b).

Conventional Rail Efficiency and Emissions Scenarios

Emissions costs from Amtrak occur from both electricity and diesel fuel use. For each fuel type, three scenarios were examined. The average electricity mix is restricted to New England because all of Amtrak's electrified tracks are located in this region. The NEC electricity generation mix from fossil fuels is estimated with state net electricity generation figures from the electric power sector and by determining what percentage of the total regional electricity mix comes from coal, natural gas and petroleum. Net generation figures were used for CT, DC, DE, MA, MD, NH, NJ, NY, PA, RI, and VT. The national average gCO_2/kWh by fossil fuel source is assumed to be the same in the NEC. In 2008, each kWh generated from the electric power industry in New England is estimated to emit 347 gCO_2 from coal, 90 gCO2 from natural gas, and 12 gCO2 from petroleum (EIA, 2010e). The total gCO_2 per kWh in the NEC is estimated by multiplying the previous emissions figures for each energy source by the percentage of that energy source in the mix.

The baseline scenario applies the 2008 percentage mix of fossil fuels used in electricity generation from the electric power industry in the NEC states, which was 34.8 percent coal, 22.7 percent natural gas, and 1.4 percent oil, leading to emissions of 449 gCO2/kWh (US DOE 2010; Kosinski 2011). The "extended trends" scenario follows the EIA's projection of a two percent reduction of coal in the electricity mix by 2035, extrapolated out to 2060 as a four percent reduction (from 34.8 percent to 31 percent); additionally, following the EIA's projection of a two percent increase of natural gas in the electricity mix, this figure is extrapolated out to 2060 as a four percent increase to 26 percent. Employing this strategy allows for a conservative emissions estimate for electricity in the face of significant uncertainty considering the 50-year time scale. This provides a lower bound in our predictions, while the upper bound is covered by the green revolution scenario. A conservative estimate for the extended trends scenario increases the likelihood that the analysis captures all ranges of emissions reduction potential. The extended trends scenario also assumes a five percent efficiency gain in primary energy to electricity (consistent with historical progress), leading to emissions of 395 gCO2/kWh (US DOE 2010; Kosinski 2011). For the green revolution scenario, the fossil fuel inputs are reduced by half, leading to shares of 17 percent coal, 10 percent natural gas, and no oil, with 15 percent efficiency gains in production and delivery resulting in emissions of 183 gCO2/kWh (EIA 2009 and Kosinski 2010).

Energy consumption per seat-mile for electric NEC trains is estimated based on 2008 Amtrak data, which show that 582 million kWh's of electricity were consumed for about 3.5 billion seat-miles in the NEC, resulting in about 0.18kWh/seat-mile (RITA, 2010; Amtrak, 2010f). The lower bound for NEC Amtrak train energy consumption is borrowed from Lukaszewicz and Andersson (2006), who estimate that a modern high speed train that travels 150km/h uses between 0.031 kWh and 0.045kWh/seat-km. Converting to seat-miles gives figures of 0.05kWh/seat-mile and 0.07kWh/seat-mile, respectively. It is reasonable to assume that Amtrak will be operating modern trains in 2060 based on the organizations recent purchase of 70 new electric locomotives to be built by Siemens, complete with regenerative braking, which returns electricity back to the grid while the train stops (Amtrak 2010h).

The scenarios for emissions from Amtrak's diesel-electric locomotives depend on varying percentage mixes of biodiesel in the fuel. The BAU scenario figures no mixture of biodiesel and CO_2 emissions from diesel fuel are at 2008 levels, extended trends figures a 10 percent mix and green revolution figures a 20 percent mix. The 20 percent biodiesel figure is based on a current Amtrak pilot project on the Heartland Flyer line in which B20, a 20 percent mixture of biodiesel from rendered beef fat, is being tested for viability (Amtrak, 2010h). Higher mixtures would likely require new testing, new engines and an entire fleet turnover (Amtrak 2010h). Currently, there is no indication that Amtrak intends to test higher biodiesel mixes with new engines.

The CO_2 emissions reduction from biodiesel is assumed to be proportional to the percentage of biodiesel mixture since biodiesel production is assumed to be a closed loop carbon cycle (i.e. emissions are captured in the feed stock annually). The baseline scenario assumes a 30 year average of gCO_2/G diesel, which is estimated by dividing nationwide CO2 emissions from non-aviation transportation diesel use by total gallons of diesel used in non-aviation transportation, and averaging these figures over 30 years (EIA, 2009 and 2010). The 30 year average of CO_2 emissions from non-aviation transportation diesel are estimated to be 10,084 gCO_2/G. Adding a 10 percent and 20 percent mixture of biofuels results in diesel emissions of 9,075 gCO_2/G, and 8,067 gCO_2/G, respectively. Amtrak's gallons of diesel per seat-mile are estimated by dividing the total number of gallons of diesel used by Amtrak in 2008 by the number seat miles traveled outside of the NEC. This method leads to 0.0075G/seat-mile in 2008, which is applied to the analysis as the highest fuel consumption scenario. The extended trends fuel efficiency figure assumes a 10 percent increase in efficiency, resulting in 0.00675G/seat-mile, and the green revolution efficiency scenario assumes a 30 percent increase in efficiency, resulting in 0.00525G/seat-mile.

Subsidization of Intercity Transportation

When looking at transportation from a macro perspective, it has been stated that "the major reason that some modes of transportation are subsidized is that they are perceived as providing social benefits in addition to the benefits provided to passengers using these modes" (BTS, 2004). Three social benefits are measured against the social costs that different modes of transportation accrue. The first relies on the understanding that some modes of transportation produce more environmental pollution than others and use more energy. When modes that produce less of these divert users from the heavy polluters/energy users, social benefits are achieved. The second potential benefit is the reduction in congestion. Depending on the region and the mode described, costs may prove lower when exploring the option of expanding capacity in a non-congested mode as opposed to increasing capacity of an already congested mode. There is the potential that, when a non-congested mode is provided a subsidy, this subsidy motivates passengers to move from the congested mode to a non-congested mode. The final benefit from subsidization is that "subsidies may produce more economically efficient use of a transportation mode" (BTS, 2004). This argues that, without subsidies, modes of transportation would have to charge higher fares in order to cover their fixed costs. These high prices have the potential to discourage usage so far that the current infrastructure would become inefficiently costly and would reduce the overall benefits of that mode of transportation to the user.

Some scholars argue that intercity travel does not need to be subsidized, since users pay the full costs of air, automobile and intercity bus travel (see, e.g. Cox and Vranich, 2008). Backers of HSR use overseas cases to indicate success, but most systems are heavily subsidized. Japan is often cited as the most financially successful high-speed rail in the world, but in the 1980s they wrote down all the debt to zero and are in fact several hundred billion dollars in debt (Smith, 2009). Other opponents acknowledge that HSR provides some of the social benefits mentioned above, but the benefits provided may not outweigh the costs. "High-speed rail is good for society and it is good for the environment, but it is not a profitable business," said Ignacio Barrón de Angioti, the director of high-speed rail for the International Union of Railways. He notes that only two routes in the world — between Tokyo and Osaka, and between Paris and Lyon, France — have broken even (Parker, 2009). The sections below describe the current state of subsidization in each mode, to conclude whether users paying the full cost of their travel would significantly alter their costs.

Highway

Since the 1980s, the Highway Trust Fund has held a steady balance of approximately $10 billion (CBO, 2008). However, the balance began to fall in 2001 as spending started to outpace revenues. Reasons for this shortfall included a continuing trend of increasing disbursements for construction and maintenance of the expanding highway system, along with increased vehicle miles per gallon resulting from efficiency advances in conventional vehicles as well as the addition of larger percentages of hybrid and fully electric vehicles. These effects have already coalesced as is demonstrated by Congress adding funds totaling more than $29 billion to the federal Highway Trust Fund over the past three years (FHWA, 2011a). Since this shortfall is unusual for the trust fund, given the historic trend of steady positive balances in the fund, we do not forecast that shortfalls will persist in 2060.

It is likely, however, that motor fuel taxes will cover a smaller percentage of future highway construction and maintenance costs if left near their current rates. The Government Accountability Office (GAO) and the DOT have already begun to consider new methods of funding (GAO, 2009a). We assume that over the next fifty years the funding mechanism for highway infrastructure will adapt to increasing efficiencies of automobiles and the use of fuels other than gasoline. Under this assumption, highway infrastructure would be paid for by its users, and therefore our model assumes no change in the cost to the user in the scenarios where transportation subsidies are reduced or eliminated.

Air

Airports rely on capital provided by non-travelers to finance $5.1 billion in projects. Bonds possess the largest share, accounting for 60 percent of the full cost total. Combined state and local government assistance represent nearly 30 percent, while private financing sources generate less than five percent of development and maintenance capital.

While most user fees are recycled into the applicable airport, the FAA distributes trust fund revenues differently. As noted previously, this report is concerned mainly with commercial hub operations, but the entire aviation network encompasses an additional 3,200 facilities. Nearly 99 percent of enplanements occur at hub airports, but domestic intercity travel generated only 53 percent of trust fund revenues in 2009. In addition to interest generated by trust fund investments, the remaining revenues come from fees associated with non-hub and cargo activities. Depending on the year, this distribution mechanism leads to misalignment between revenues collected from commercial hub users and actual distributions to associated airports, thus creating a subsidy.

To uncover this dynamic, the FAA Trust Fund revenues were broken down by user generation. Fees flow from domestic and international travelers using commercial hubs, general aviation non-commercial users and cargo and mail carriers. On average, the U.S Treasury also provides nearly 20 percent of the Trust Fund's annual revenues via their General Fund. If a proportional model is used to allocate AIP funds using the percentage of Trust Fund revenues generated by each source, one can compare the amount of AIP distribution commercial hubs should receive versus the amount they actually obtained. Below Table 12 illustrates subsidy analysis.

Table 12: Air Subsidy Analysis (in Millions of Dollars)

	2005	2006	2007	2008	2009
Fees paid by commercial hub users	7,415	7,303	9,002	9,238	7,838
Fees paid by non-hub users	2,955	3,294	1,647	2,004	2,335
Fees paid by cargo/interest	900	962	1,048	951	752
Trust Fund Revenue by users	10,754	10,909	11,941	12,422	10,851
General Funds	2,828	2,619	2,746	2,343	3,804
Total Trust Fund Receipts	13,582	13,528	14,687	14,765	14,655
Total AIP Distributions	3,417	3,411	3,340	3,471	3,385
TF % - hub users	55%	54%	61%	63%	53%
TF % - non hub users	22%	24%	11%	14%	16%
TF % - cargo/interest	7%	7%	7%	6%	5%
TF % - General Funds	21%	19%	19%	16%	26%
Prop. AIP distributions – com. hub	1,866	1,841	2,047	2,172	1,810
Actual AIP distributions – com. hub	1,600	1,881	2,057	2,102	2,254
Subsidy Paid by hub users	**266**			**70**	
Subsidy received by hub users		**-40**	**-10**		**-444**

Source: FAA. (2010). FAA Trust Fund Receipts, 2005-2008 FAA AIP Annual Report of Accomplishments and Congressional Research Service. Retrieved from www.faa.gov

Upon conducting the analysis, yearly variations emerged whereby in 2005 and 2008 commercial hub users overpaid fees, which supported non-commercial travelers. However, this situation reversed in 2006, 2007 and 2009 culminating with over $440 million in subsidies paid by non-commercial users.

To establish the amount of airport infrastructure subsidy, our methodology disaggregates the percentage of Trust Fund receipts paid by commercial hub users, uses the proportional value to establish a target AIP distribution level, and compares this value against actual outlays. The main focus revolves around Trust Fund revenues, in the form of various fees paid by commercial hub users, and their proportional relationship with total Trust Fund receipts including General Funds. For the period between 2005 and 2009, the percentage of Trust Fund receipts varied between 53 and 63 percent. Using this annual proportional value and applying it to AIP distributions provides a level of distribution equating to no subsidy flow within the AIP. When compared to the actual AIP distributions, we arrived at an annual subsidy level, either paid or received by hub users. In our analysis, we used a five year average to smooth variations and determined that commercial hub users received an annual subsidy of $32 million. Assuming non-Trust Fund fees flow directly to collecting airport and therefore do not enable subsidy flows, the calculated levels amount to 0.2 percent of overall infrastructure funding, which averaged around $14 billion per year during the corresponding period. For this reason, we determined the negligible subsidy level did not warrant inclusion in our scenarios where transportation subsidies are cut.

Rail

Baseline Ticket Prices and Full User Prices

The national costs of intercity passenger rail travel were developed from Amtrak's 2008 and 2009 annual reports, which provide data on Amtrak's operations and finances from FY 1999 through FY 2009 (Amtrak, 2008a; 2009a). The reports provide financial data in nominal dollars, so we inflated the pre-2009 values to 2009 dollars using the Consumer Price Index (CPI) (U.S. Department of Labor, 2011).

We estimated the current user ticket price for rail passengers by averaging Amtrak's reported annual ticket revenue per passenger mile from 1999 through 2009. This resulted in an average ticket price of 26.5 cents per passenger mile. We then estimated the full user price of rail, which represents the ticket price users would be forced to pay if there were no state or federal rail subsidies. In order to obtain the full user price, we subtracted Amtrak's alternative sources of revenue, such as freight access fees and food and beverage revenues, from Amtrak's total operations and maintenance (O&M) expense per passenger mile. We assumed that these alternative sources of revenue would continue to exist in the event that government subsidies were eliminated. For example, in 2009, Amtrak's total expenses equaled 62.4 cents per passenger mile, but alternative sources of revenue accounted for 7.23 cents per passenger mile. Therefore, the full user price in 2009 was the difference between these amounts, or 55.17 cents per passenger mile. This represents the current ticket price plus the current amount of government subsidy. We averaged the full user prices from 1999 through

2009, obtaining an average full user price of 58.49 cents per passenger mile. Thus, the current full user price is more than double the current ticket price of 26.5 cents.

This calculation of the full user price is admittedly a simplification of the true economic effects of eliminating government rail subsidies. It is likely that higher ticket prices under a no-subsidy scenario would reduce rail ridership, setting off a cycle in which the low ridership would further increase the ticket prices. We did not consider these interactions between price and demand. Therefore, our full user price is likely an underestimate of the true user price that would result from the elimination of government subsidies. In addition, we considered only O&M expenses and not capital expenses for our current full user prices since we assumed that the initial capital costs of establishing Amtrak are largely sunk at this point in time. However, we did consider capital costs in projecting our 2060 user prices.

2060 Full User Prices

We based our 2060 O&M cost projections on Amtrak's FY 1999 to FY 2009 expenses (Amtrak, 2008a; 2009a). As with the baseline data above, we inflated Amtrak's nominal expenses to 2009 dollars using the CPI (DOL, 2011). In order to forecast 2060 O&M expenses, we assumed that fuel prices would increase according to the fuel price projections outlined earlier in this report, taking into account the percentage of Amtrak passenger miles that are completed with electric power versus diesel power. We assumed that all other expenses, such as salaries and materials, would keep pace with inflation. This resulted in 2060 O&M cost estimates ranging from 57.6 cents per passenger mile on the low end to 63.8 cents per passenger mile on the high end. The range of estimates was narrow because fuel, power, and utilities make up only about 7.35 percent of Amtrak's expenses (Amtrak, 2009a).

We based our 2060 fleet cost projections on Amtrak's *Fleet Strategy* (Amtrak, 2011c). The fleet strategy report includes projected costs of fleet turnover and expansion through 2041. The report projects a diesel locomotive lifespan of approximately 20 years and an electric locomotive lifespan of approximately 22 years. The report also projects an increase in the number of train cars by approximately 50 percent. We forecasted similar fleet spending trends from 2042 through 2060 to obtain our 2060 projected costs. Based on these projections, we calculated average annual fleet replacement costs of approximately $772 million.

We based our 2060 capital replacement and maintenance cost projections on the *Northeast Corridor State of Good Repair Spend Plan* (Amtrak, 2009b). We started with the estimated capital expenditures required to address the backlog of deferred investments in the corridor by 2023. We subtracted from these costs the NEC equipment replacement costs since these were already counted in the costs from the *Fleet Strategy* report as outlined above. We then included the estimated annual expenditures required to complete normalized replacement of equipment and infrastructure in the corridor beyond 2023. Based on the combination of backlogged projects and annual normalized replacements, we calculated an average annual NEC capital cost of approximately $462 million.

For non-NEC corridors, we assumed that track maintenance costs would be incorporated into the fees that Amtrak pays to use freight railroad lines and therefore would be reflected in the O&M expenses. To obtain full capital costs in 2060, we summed the fleet costs and the NEC capital costs and then divided these costs by Amtrak's average annual passenger miles from 1999 to 2009. This resulted in capital costs of approximately 22.1 cents per passenger mile. We assumed that this estimate was on the high end since Amtrak is unlikely to receive sufficient funding to accomplish all of its desired capital investments. Therefore, we calculated our mid-range and low estimates as 75 percent and 50 percent of Amtrak's projected capital costs. This resulted in a mid-range estimate of 16.6 cents per passenger mile and a low estimate of 11.1 cents per passenger mile.

We then combined our O&M cost projections and our capital cost projections to obtain our 2060 full user price projections. We varied these according to different levels of government subsidy, including the status quo level of subsidy. The status quo subsidy corresponds to the current rate of government subsidy, which is approximately 100 percent of capital costs and 55.5 percent of the full user price as calculated in the baseline costs above (total expenses minus those expenses covered through alternative forms of revenue, such as freight access fees and food and beverage revenues).

Chapter VI: National Model

VI. NATIONAL MODEL

Key Factors

Four key factors were used to build the scenarios: fuel prices, subsidy levels, carbon prices, and innovation levels.

Fuel Prices

The medium and high fuel prices were based on the fuel price projections discussed in Chapter V of this report. The low fuel price projections were not modeled because they were not significantly different from the 2009 fuel prices and therefore would not drive any significant departures from the 2009 mode shares. For air, fuel prices were adjusted by applying a multiplier to the taper function. For full details, see Appendix A. For auto, bus, and rail, fuel prices were adjusted by modifying the fuel portions of the full cost calculations.

Subsidy Levels

The subsidy levels were based on the discussion of rail subsidization in Chapter V of this report. The status quo (SQ) level of subsidy represents a 100 percent capital subsidy and a 54.5 percent operations subsidy for rail. The no-subsidy scenarios represent no government subsidization of capital or operating costs for rail. The other modes were assumed to cover the vast majority of their costs through user fees and taxes and therefore were not modeled under different levels of subsidy.

Carbon Prices

The low, medium, and high carbon prices were based on fees of \$25, \$50, and \$100 per ton of CO_2. As explained in Chapter V of this report, these prices were applied to the emissions per passenger mile for each mode, which varied by fuel type and fuel efficiency.

Innovation

Innovation refers to improvements in the fuel efficiency of each mode, as well as reductions in emissions through changes in the raw sources of energy. Examples of innovation include increased fuel efficiency, changes from conventional diesel to biodiesel, and changes in the electricity grid from fossil fuels to non-CO_2 producing energy sources, such as wind, solar, hydropower, and nuclear.

Innovation: Extended Trends (EXT)

Within the category of innovation, extended trends (EXT) refers to the minimum level of innovation that can reasonably be expected to develop between now and 2060 based on past trends of innovation, as well as any innovations currently under commercial development. The justification for all of these innovation gains are detailed in Chapter V of this report.

For air, this represents a 13 percent reduction in fuel consumption. This reduction in fuel consumption was incorporated into the fuel multiplier of the taper function. For full details, see Appendix A.

For auto, extended trends in innovation represent a vehicle fleet that is 85 percent conventional gasoline vehicles and 15 percent hybrid-electric vehicles. The conventional gasoline vehicles are expected to achieve an average of 35 mpg, while the hybrids are expected to achieve an average of 42 mpg. This represents a 40 percent improvement in fleet fuel efficiency by 2060.

For buses, extended trends in innovation represent a bus fleet where 25 percent of buses use B20 biodiesel, and there has been a fuel efficiency improvement in both B20 and pure diesel of 40 percent relative to miles per gallon averages. This translates to a fleet average of 154.2 passenger miles per gallon of fuel.

For the national rail system, extended trends in innovation represent a ten percent biodiesel mix and ten percent efficiency gains. For the California HSR system, it was assumed that the maximum possible efficiencies would be incorporated at the start of the project and that few additional efficiency gains would be achieved by 2060, given the long lifespan of locomotives and other rail capital investments.

Under the extended trends scenarios, the national electricity grid is assumed to shift from 48 percent to 44 percent coal and from 22 percent to 26 percent natural gas. The NEC electricity grid is assumed to shift from 35 percent to 31 percent coal and from 22 percent to 26 percent natural gas. The California electricity grid is assumed to shift from 11 percent to nine percent coal and from 49 percent to 51 percent natural gas.

Innovation: Green Revolution (Green)

Within the category of innovation, green revolution, or simply "green," refers to the highest level of innovation that might plausibly occur between now and 2060 based on the most cutting-edge technologies currently being researched. The justification for all of these innovation gains are detailed in Chapter V of this report.

For air, this represents a 38 percent reduction in fuel consumption. This reduction in fuel consumption was incorporated into the fuel multiplier of the taper function. For full details, see Appendix A. In addition, this level of innovation includes a 20 percent biofuel mix.

For auto, a green revolution represents a vehicle fleet that is 45 percent conventional gasoline vehicles, 35 percent hybrid-electric vehicles, and 20 percent electric vehicles. The conventional gasoline vehicles are expected to achieve an average of 45 mpg, while the hybrids are expected to achieve an average of 54 mpg and the electric vehicles an average of 3 miles per kWh. This represents an 80 percent improvement in fleet fuel efficiency by 2060.

For bus, a green revolution represents an 80 percent improvement in fleet fuel efficiency by 2060 and 100 percent of the fleet using the B20 biodiesel blend.

For rail, a green revolution represents a 20 percent biodiesel mix and 30 percent efficiency gains by 2060. For the California HSR system, it was assumed, once again, that the maximum possible efficiencies would be incorporated at the start of the project and that few additional efficiency gains would be achieved by 2060.

Under the green revolution scenarios, the national electricity grid is expected to shift to 22 percent coal and ten percent natural gas, with the remainder of the electricity generated by non-CO_2 producing sources, such as wind, solar, hydropower, and nuclear. The NEC electricity grid is expected to shift to 17 percent coal and ten percent natural gas. The California electricity grid is assumed to shift to 4.7 percent coal and 24.7 percent natural gas.

National Scenarios

Nine scenarios were considered in the national model (Tables 13 and 14). The first scenario simply represents 2009 conditions, including 2009 fuel prices, the status quo level of subsidy for rail, no carbon price, and the 2009 level of innovation. The second scenario represents the 2009 conditions without any subsidies for rail. Thus, it represents the full cost of rail as opposed to the current user price of rail.

The third scenario represents the 2060 base price, which includes the medium fuel prices, the status quo level of subsidy for rail, no carbon price, and extended trends of innovation. The fourth, fifth, and sixth scenarios represent varying levels of carbon prices added to the 2060 base cost, which is the same as the 2060 base price but without rail subsidies.

The seventh and eighth scenarios represent the 2060 base price and base cost, adjusted for high fuel prices, a high carbon price, and a green revolution in innovation. The ninth scenario represents the most favorable conditions for rail, including high fuel prices, the status quo level of subsidy, a high carbon price, and extended trends of innovation.

Table 13: National leisure model scenarios with corresponding user prices

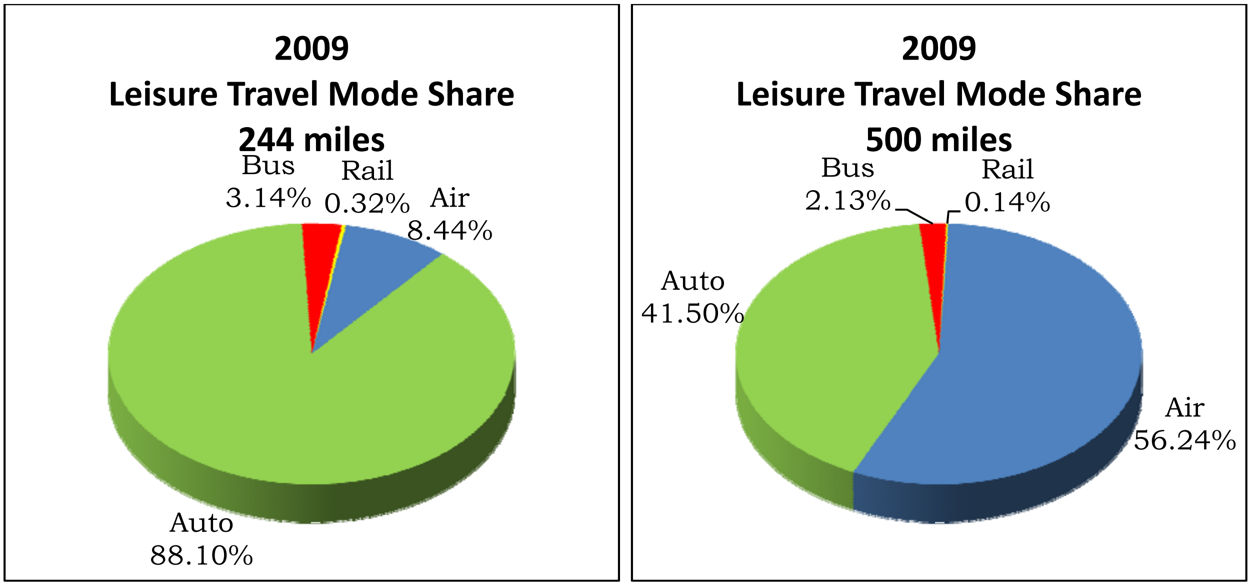
Scenario Number	Fuel Price Level	Rail Subsidy Level	Carbon Price (per tonne)	Innovation Scenario	Mode	Price/PM
1	2009	SQ	none	2009	**Air**	((exp((3.129)-0.695*LN(distance))))
					Auto	0.233
					Bus	0.212
					Rail	0.265
2	2009	none	none	2009	**Air**	((exp((3.129)-0.695*LN(distance))))
					Auto	0.233
					Bus	0.212
					Rail	0.585
3	Medium	SQ	$25	Extended Trends	**Air**	1.339*((exp((3.129)-0.695*LN(distance))))
					Auto	0.229
					Bus	0.227
					Rail	0.274
4	Medium	none	$25	Extended Trends	**Air**	1.339*((exp((3.129)-0.695*LN(distance)))) + 0.004
					Auto	0.232
					Bus	0.229
					Rail	0.767
5	Medium	none	$50	Extended Trends	**Air**	1.339*((exp((3.129)-0.695*LN(distance)))) + 0.008
					Auto	0.234
					Bus	0.230
					Rail	0.767
6	Medium	none	$100	Extended Trends	**Air**	1.339*((exp((3.129)-0.695*LN(distance)))) + 0.0161
					Auto	0.239
					Bus	0.234
					Rail	0.767
7	High	SQ	$100	Green Revolution	**Air**	1.909*((exp((3.129)-0.695*LN(distance)))) + 0.009
					Auto	0.235
					Bus	0.263
					Rail	0.279
8	High	none	$100	Green Revolution	**Air**	1.909*((exp((3.129)-0.695*LN(distance)))) + 0.009
					Auto	0.235
					Bus	0.263
					Rail	0.834
9	High	SQ	$100	Extended Trends	**Air**	1.909*((exp((3.129)-0.695*LN(distance)))) + 0.016
					Auto	0.274
					Bus	0.254
					Rail	0.286

Table 14: National business model scenarios with corresponding user prices

Scenario Number	Fuel Price	Rail Subsidy Level	Carbon Price (per tonne)	Innovation	Mode	Price/PM
1	2009	SQ	None	2009	**Air**	((exp((3.129)-0.695*LN(distance))))
					Auto	0.233
					Bus	0.212
					Rail	0.265
2	2009	none	None	2009	**Air**	((exp((3.129)-0.695*LN(distance))))
					Auto	0.233
					Bus	0.212
					Rail	0.585
3	Medium	SQ	None	Extended Trends	**Air**	1.340*((exp((3.129)-0.69534*LN(distance))))
					Auto	0.229
					Bus	0.227
					Rail	0.274
4	Medium	none	$25	Extended Trends	**Air**	1.339*((exp((3.129)-0.695*LN(distance)))) + 0.004
					Auto	0.232
					Bus	0.229
					Rail	0.767
5	Medium	none	$50	Extended Trends	**Air**	1.339*((exp((3.129)-0.695*LN(distance)))) + 0.008
					Auto	0.234
					Bus	0.231
					Rail	0.767
6	Medium	none	$100	Extended Trends	**Air**	1.339*((exp((3.129)-0.695*LN(distance)))) + 0.016
					Auto	0.239
					Bus	0.234
					Rail	0.767
7	High	SQ	$100	Green Revolution	**Air**	1.909*((exp((3.12918)-0.695*LN(distance)))) + 0.009
					Auto	0.234748
					Bus	0.262803
					Rail	0.27889647
8	High	none	$100	Green Revolution	**Air**	1.909*((exp((3.129)-0.695*LN(distance)))) + 0.008
					Auto	0.234
					Bus	0.263
					Rail	0.834
9* *Most favorable scenario to rail	High	SQ	$100	Extended Trends	**Air**	1.909*((exp((3.129)-0.695*LN(distance)))) + 0.016
					Auto	0.274
					Bus	0.254
					Rail	0.286

National Results

The present day national intercity transportation picture is modeled from the 2009 NHTS. For leisure travelers, under a status quo scenario and an average trip distance of 244 miles auto, is the dominant mode with 88 percent mode share, followed by air with eight percent, bus with three percent, and rail with 0.3 percent.[8] As the trip distance increases to 500 miles, air gains significant mode share, rising to 56 percent. Auto declines to 42 percent, bus to two percent, and rail to 0.1 percent. At the point where the trip distances reaches 1,000 miles, air captures nearly the entire market, rising to 98 percent, with the remainder captured primarily by auto at just below two percent. The 2009 mode share for business travelers closely resembles that of leisure travelers, with the exception that passengers switch to air at shorter distances. This is most clearly evident for the 500 mile trip distance, in which air captures 77 percent of business mode share, in contrast with 56 percent for leisure travelers.


2009
Leisure Travel Mode Share
244 miles

2009
Leisure Travel Mode Share
500 miles

Figure 18: 2009 Leisure Mode Shares at Average Trip Distance and 500 Miles

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[8] Note that our analysis in this section will refer to the "mode share" that is captured by each mode of transportation. Our model has predicted the likelihood that an average individual in the United States would take each mode of travel and this output is used as a proxy for overall mode share in the United States.

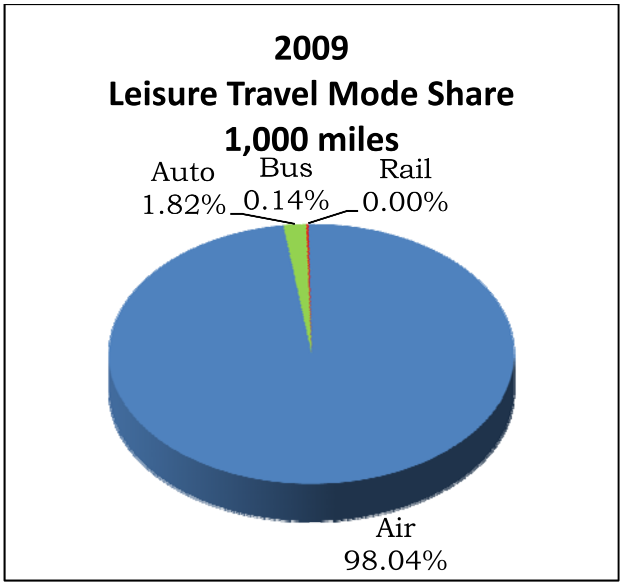
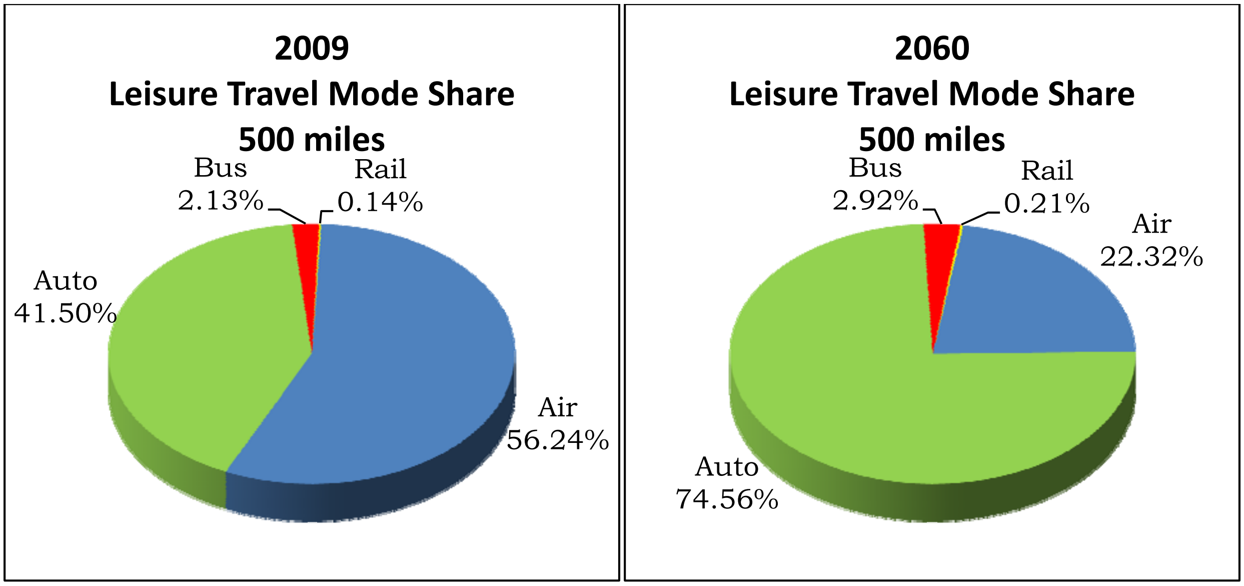


Figure 19: 2009 Leisure Travel Mode Share at 1,000 Miles

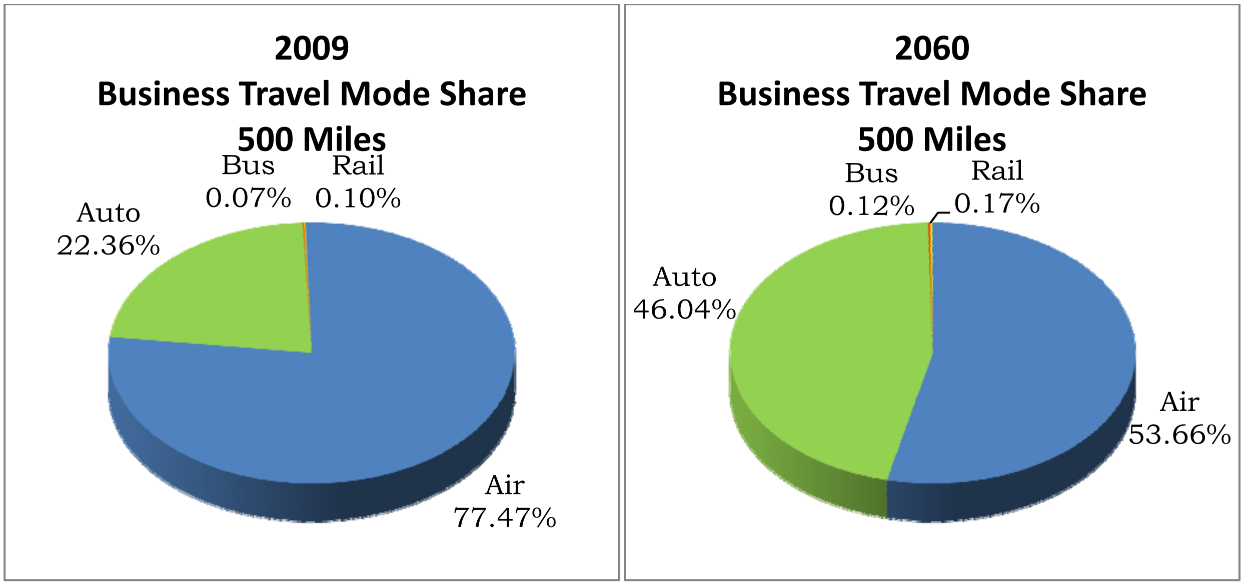
Turning to 2060 mode share projections, a large shift takes place from air to auto modes for 500 mile trips, from 42 percent auto to 75 percent. (Complete 2060 results are presented in Table 15 on page 82). This represents a sizeable shift in mode share from the speedier air mode to the slower auto mode based on projected figures. The shift can likely be attributed to a greater sensitivity of user price for air travel to a slight rise in fuel price. Additionally, autos are projected to experience greater efficiency gains in the next 50 years relative to air (40% compared to 13% improvements), thus softening the impact of higher fuel prices for auto users. This may be due to the potential higher rate of fleet turnover for automobiles than for air. The life of an automobile is much shorter than the life of an aircraft, thus efficiency gains are incorporated into the fleet more quickly, whereas an aircraft manufacturer develops models that last multiple decades. An aircraft commissioned in 2020 may not be replaced in the fleet until 2050 or later, which pushes the potential efficiency increase further into the future than for an automobile that hits the road in 2020. Finally, these results show that travelers place proportionally more emphasis on the monetary cost of travel than on travel time. The major speed advantages for air are not as influential on leisure travel decisions as fuel price and cost increases for 500 mile trips. The 500 mile mode share projection is illustrated below in comparison with the 2009 mode share at this trip distance.


2009 Leisure Travel Mode Share 500 miles

2060 Leisure Travel Mode Share 500 miles

Figure 20: Leisure Travel Mode Share Shift at 500 Miles

Not surprisingly, the shift from air to auto is not as pronounced for business travelers, as travel time is of greater value. However, the shift is still significant, moving from 22 percent to 46 percent for 500 mile trips. Furthermore, even this shift is likely overstated due to the way costs for auto were calculated in the model. To derive costs per passenger mile, the average number of passengers per vehicle, 2.4, was calculated from the NHTS data. Business travelers are more likely to have only one passenger on a trip, which would significantly reduce the cost advantage for auto.


2009 Business Travel Mode Share 500 Miles

2060 Business Travel Mode Share 500 Miles

Figure 21: Business Travel Mode Share Shift at 500 Miles

Assigning a price to carbon does not appear to generate any significant changes in mode share in the national aggregate. A low carbon price moves about 0.5 percent of the mode share from air to auto, while moving from a no carbon price scenario to a very high carbon price of $100/MT CO_2 shifts about 1.5 percent of mode share to autos. The question of carbon pricing is addressed in more detail in the California corridor-specific analysis below.

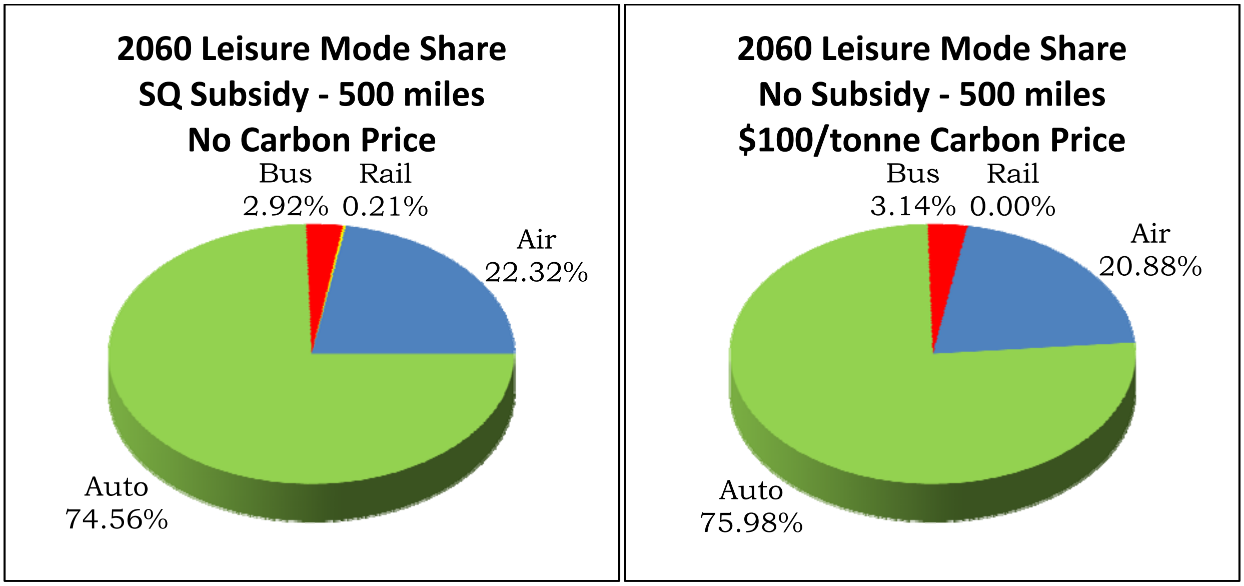


Figure 22: Carbon Price Effect on Leisure Travel Mode Share

When subsidies for rail travel are removed, the present day mode share is expected to remain almost unchanged, except for the share of rail, which essentially falls to zero at distances greater than 100 miles. This demonstrates the magnitude of the current subsidy levels for a national conventional rail system.

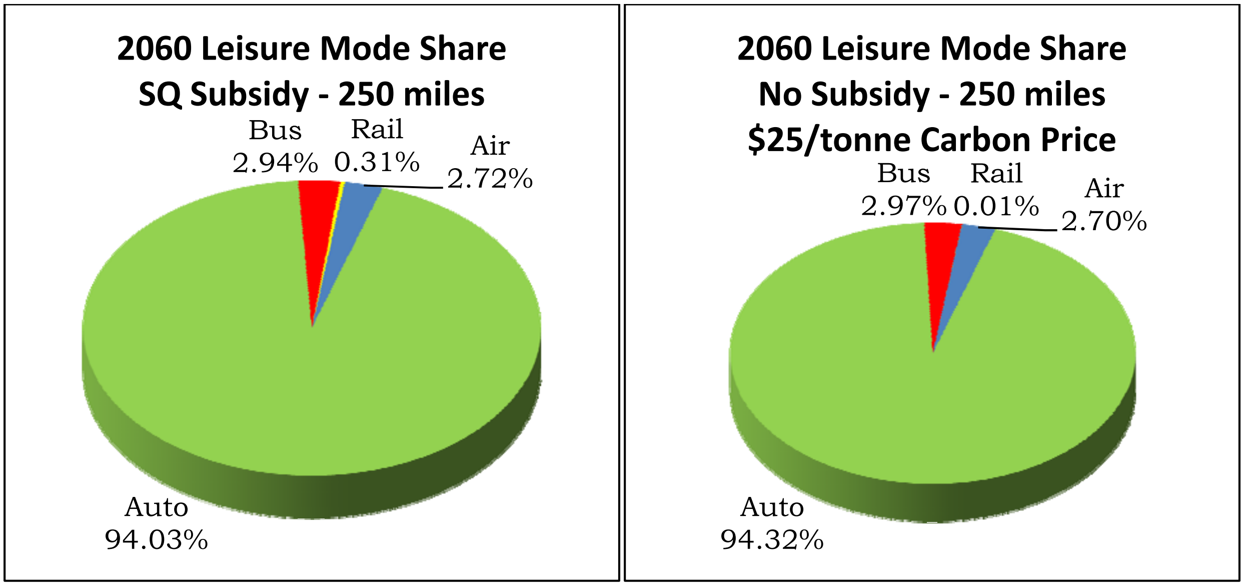


Figure 23: Rail Subsidy Elimination Effect on Leisure Travel Mode Share

Fuel price increases further increase the mode share for auto, due once again to the fuel efficiency advantage relative to air travel. At higher fuel prices, the cost savings from improved efficiency are even greater for travelers.

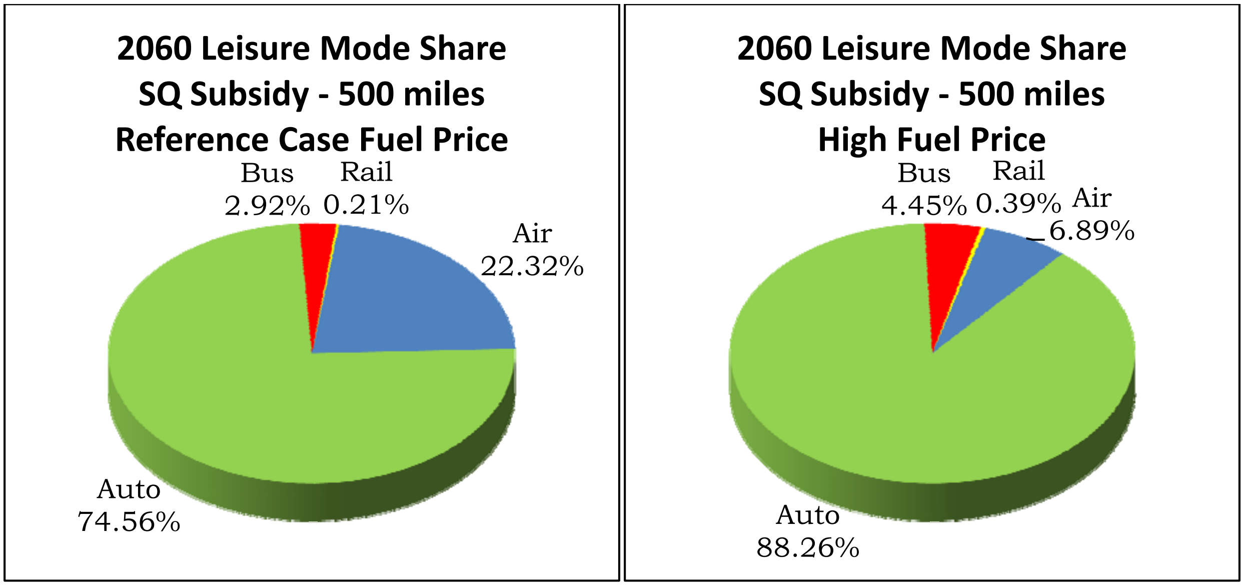


Figure 24: Fuel Price Effect on Leisure Travel Mode Share

The green revolution scenario, which was done as a sensitivity analysis, illustrates that our results regarding mode share are likely to hold true even if the nation adopts alternative technologies at a faster than projected rate (as long as this is done across modes). The mode share does not change significantly between the extended trends and green revolution scenarios.

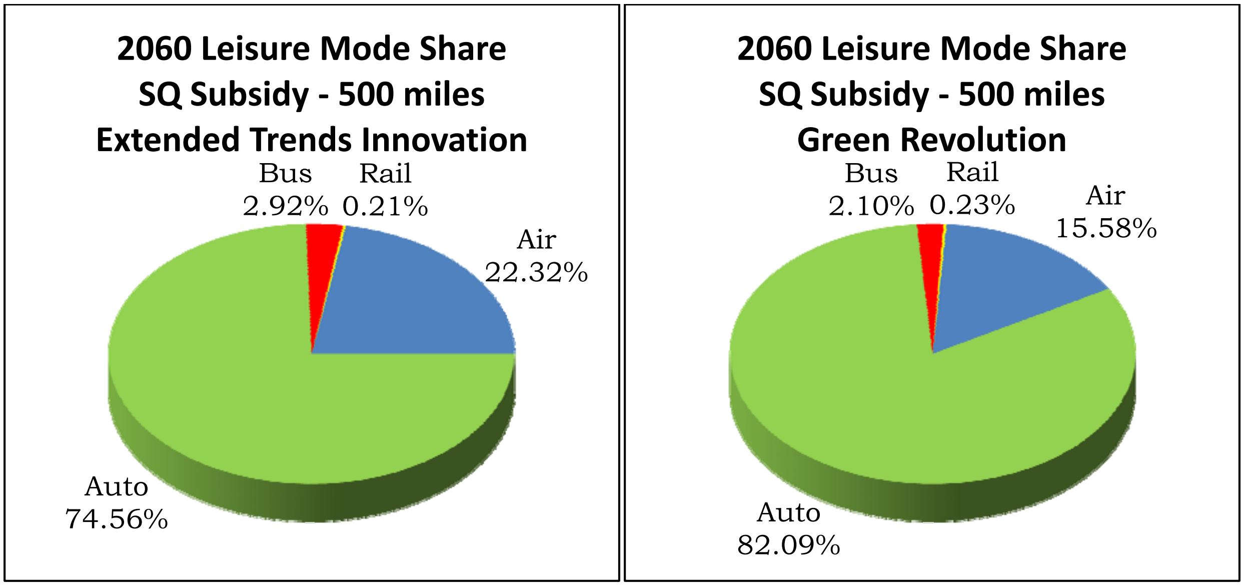


Figure 25: Green Revolution Scenario Effect on Leisure Travel Mode Share

Table 15. National 2060 business and leisure mode share projections and corresponding scenarios.

	National Leisure				National Business			
	Auto	**Bus**	**Rail**	**Air**	**Auto**	**Bus**	**Rail**	**Air**
100 Miles								
Extended Trends Innovation Medium Fuel Price								
No Carbon Price Status Quo Rail Capital Subsidy	97.71%	1.78%	0.26%	0.25%	99.06%	0.11%	0.29%	0.54%
$25/tonne Carbon Price No Rail Subsidy	97.90%	1.79%	0.07%	0.25%	99.24%	0.11%	0.10%	0.54%
$50/tonne Carbon Price No Rail Capital Subsidy	97.89%	1.79%	0.07%	0.25%	99.24%	0.11%	0.11%	0.54%
$100/tonne Carbon Price No Rail Capital Subsidy	97.88%	1.80%	0.07%	0.24%	99.25%	0.11%	0.11%	0.54%
Extended Trends Innovation High Fuel Price								
$100/tonne Carbon Price Status Quo Rail Capital Subsidy	97.74%	1.88%	0.29%	0.09%	99.32%	0.11%	0.31%	0.27%
Green Revolution Innovation High Fuel Price								
$100/tonne Carbon Price Status Quo Rail Capital Subsidy	97.91%	1.64%	0.26%	0.19%	99.16%	0.10%	0.29%	0.45%
$100/tonne Carbon Price No Rail Capital Subsidy	98.11%	1.64%	0.05%	0.19%	99.35%	0.10%	0.09%	0.45%
Average Trip Distance 244 Miles- Leisure, 264 Miles- Business								
Extended Trends Innovation Medium Fuel Price								
No Carbon Price Status Quo Rail Capital Subsidy	94.03%	2.94%	0.31%	2.72%	88.22%	0.19%	0.35%	11.24%
$25/tonne Carbon Price No Rail Subsidy	94.32%	2.97%	0.01%	2.70%	88.59%	0.19%	0.03%	11.20%
$50/tonne Carbon Price No Rail Capital Subsidy	94.33%	2.99%	0.01%	2.67%	88.67%	0.19%	0.03%	11.12%
$100/tonne Carbon Price No Rail Capital Subsidy	94.34%	3.03%	0.01%	2.62%	88.83%	0.19%	0.03%	10.95%
Extended Trends Innovation High Fuel Price								
$100/tonne Carbon Price Status Quo Rail Capital Subsidy	95.40%	3.38%	0.40%	0.82%	94.36%	0.22%	0.45%	4.96%
Green Revolution Innovation High Fuel Price								
$100/tonne Carbon Price Status Quo Rail Capital Subsidy	95.32%	2.42%	0.32%	1.94%	90.58%	0.16%	0.36%	8.89%
$100/tonne Carbon Price No Rail Capital Subsidy	95.62%	2.43%	0.01%	1.95%	90.89%	0.16%	0.02%	8.92%
500 Miles								
Extended Trends Innovation Medium Fuel Price								
No Carbon Price Status Quo Rail Capital Subsidy	74.56%	2.92%	0.21%	22.32%	46.04%	0.12%	0.17%	53.66%
$25/tonne Carbon Price No Rail Subsidy	75.04%	2.98%	0.00%	21.98%	46.50%	0.12%	0.00%	53.37%
$50/tonne Carbon Price No Rail Capital Subsidy	75.35%	3.03%	0.00%	21.61%	46.88%	0.13%	0.00%	52.99%
$100/tonne Carbon Price No Rail Capital Subsidy	75.98%	3.14%	0.00%	20.88%	47.65%	0.13%	0.00%	52.22%
Extended Trends Innovation High Fuel Price								
$100/tonne Carbon Price Status Quo Rail Capital Subsidy	88.26%	4.45%	0.39%	6.89%	68.93%	0.22%	0.36%	30.49%
Green Revolution Innovation High Fuel Price								
$100/tonne Carbon Price Status Quo Rail Capital Subsidy	82.09%	2.10%	0.23%	15.58%	54.20%	0.11%	0.20%	45.49%
$100/tonne Carbon Price No Rail Capital Subsidy	82.28%	2.11%	0.00%	15.62%	54.31%	0.11%	0.00%	45.58%
Table 16 continued on next page.								

	National Leisure				National Business			
	Auto	**Bus**	**Rail**	**Air**	**Auto**	**Bus**	**Rail**	**Air**
1000 Miles								
Extended Trends Innovation Medium Fuel Price								
No Carbon Price Status Quo Rail Capital Subsidy	11.04%	0.49%	0.02%	88.44%	4.18%	0.01%	0.01%	95.79%
$25/tonne Carbon Price No Rail Subsidy	11.47%	0.53%	0.00%	88.00%	4.31%	0.01%	0.00%	95.68%
$50/tonne Carbon Price No Rail Capital Subsidy	11.90%	0.56%	0.00%	87.54%	4.44%	0.01%	0.00%	95.55%
$100/tonne Carbon Price No Rail Capital Subsidy	12.82%	0.64%	0.00%	86.54%	4.71%	0.02%	0.00%	95.28%
Extended Trends Innovation High Fuel Price								
$100/tonne Carbon Price Status Quo Rail Capital Subsidy	31.65%	2.35%	0.13%	65.87%	10.33%	0.05%	0.05%	89.57%
Green Revolution Innovation High Fuel Price								
$100/tonne Carbon Price Status Quo Rail Capital Subsidy	18.43%	0.35%	0.03%	81.19%	6.29%	0.01%	0.02%	93.68%
$100/tonne Carbon Price No Rail Capital Subsidy	18.43%	0.35%	0.00%	81.21%	6.29%	0.01%	0.00%	93.70%
1500 Miles								
Extended Trends Innovation Medium Fuel Price								
No Carbon Price Status Quo Rail Capital Subsidy	0.65%	0.03%	0.00%	99.32%	0.39%	0.00%	0.00%	99.60%
$25/tonne Carbon Price No Rail Subsidy	0.70%	0.03%	0.00%	99.27%	0.41%	0.00%	0.00%	99.59%
$50/tonne Carbon Price No Rail Capital Subsidy	0.74%	0.04%	0.00%	99.22%	0.43%	0.00%	0.00%	99.57%
$100/tonne Carbon Price No Rail Capital Subsidy	0.84%	0.05%	0.00%	99.11%	0.47%	0.00%	0.00%	99.52%
Extended Trends Innovation High Fuel Price								
$100/tonne Carbon Price Status Quo Rail Capital Subsidy	2.18%	0.22%	0.01%	97.59%	0.95%	0.01%	0.00%	99.04%
Green Revolution Innovation High Fuel Price								
$100/tonne Carbon Price Status Quo Rail Capital Subsidy	1.32%	0.02%	0.00%	98.66%	0.66%	0.00%	0.00%	99.34%
$100/tonne Carbon Price No Rail Capital Subsidy	1.32%	0.02%	0.00%	98.66%	0.66%	0.00%	0.00%	99.34%

Chapter VII: High-Speed Rail Analysis

VII. HIGH-SPEED RAIL ANALYSIS

Analysis of HSR's potential mode share is best done on a corridor basis. Below we consider two corridors with potential for HSR development: 1) the Northeast corridor—with high population density and high levels of congestion in other modes, this corridor is the only region where Amtrak revenue currently covers operating costs and 2) California, another area of relatively high population density and relatively high Amtrak ridership, as well as a low electricity and fuel prices that exceed that national average. Ultimately, we determine that California presents a more favorable case for HSR due to lower capital costs. After the corridors are discussed in-depth, we turn to discussing the scenarios developed for the California model and our results.

Northeast Corridor

The northeastern megaregion[9] extends from Washington, D.C. to Boston and is the most densely populated region in the country. New York, Philadelphia, Washington, D.C., and Boston all ranked among the top ten most populous U.S. cities in the 2000 Census (US Census Bureau, 2000). Nearly 50 million people resided in the region in 2000 and that number is projected to grow to more than 58 million by 2025 (US Census Bureau, 2000; Amtrak, 2010a). The Northeast is also vital to the nation's economy. Residents of the region produce more than 20 percent of the nation's total GDP (Amtrak, 2010a). The combination of densely populated urban areas and a robust economy has resulted in the NEC as being one of the most heavily trafficked transportation networks in the United States.

Personal automobiles dominate intercity transportation in the NEC. Amtrak estimates that highway travel accounts for 89 percent of the roughly 160 million intercity trips completed annually in the region (Amtrak, 2010a). Congestion levels on the region's highways are among the highest in the nation, resulting in increased travel times along the roughly 440 miles between Washington, D.C. and Boston.

Air travel accounts for approximately five percent of intercity trips in the NEC (Amtrak, 2010a). More than 70 flights operate between Boston and New York and roughly the same number operate between New York and Washington, D.C. Furthermore, approximately 200 flights depart daily from the three New York metropolitan airports (Newark, La Guardia, and JFK) to other destinations within the NEC (America 2050, 2009; Amtrak, 2010a). High congestion levels and the resulting delays can be a concern at NEC airports. The three major airports in New York as well as the airports in Boston and Philadelphia consistently rank near the bottom of major U.S. airports in terms of percent on-time arrivals (BTS, 2011e). Delays at these major airports can have a ripple effect, slowing down air transportation throughout the nation.

Passenger rail service accounts for six percent of intercity trips within the NEC (Amtrak, 2010a). Thus, in the NEC passenger rail service is competitive with air travel in terms of mode share. In

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[9] America 2050 defines a "megaregion" as a "network of metropolitan regions with shared economies, infrastructure and natural resource systems, stretching over distances of roughly 300 miles – 600 miles in length" (America 2050, 2009).

fact, the NEC is home to the most heavily traveled rail system in the United States. Every year, approximately 10 million people travel on Amtrak's Northeast Regional and Acela Express lines alone. Several million more travelers use the NEC rail infrastructure on commuter lines in the region (Amtrak, 2010d).

Current Challenges

The NEC is unique in that Amtrak owns and operates most of the 457 miles of track on the main line of the NEC (Amtrak Government Affairs, 2010). However, the high volume of rail traffic in the NEC results in infrastructure problems. Intercity and commuter passenger service and freight traffic all share the rail lines in the NEC. Overcrowded and overworked track, coupled with years of backlogged maintenance, has placed strains on the lines in the NEC, hindering the development of a more modern rail system.

Acela Express

In the United States, Amtrak operates the Acela Express, which is the only rail line in the nation to officially hold the distinction of high-speed service. This line operates in the NEC between Boston, New York, Philadelphia, Baltimore, and Washington, D.C. (Gardner, 2010). The Acela Express can reach top speeds of 150 mph but averages less than half that speed due to frequent stops and winding terrain along the route. These logical constraints nullify the Acela Express as a true high-speed service, which typically has minimal stops, consistent speeds, and a dedicated infrastructure not shared by other trains. However, the Acela Express accounts for more than half of Amtrak's total revenues (California Department of Transportation, 2008).

NEC Conclusion

As the home of the most heavily trafficked intercity passenger rail system in the United States, the NEC occupies an important position within the future of rail transportation in this country. However, the rail infrastructure in the NEC suffers from substantial amounts of backlogged maintenance. This deferred maintenance must be addressed if the system is to operate at a level of speed and efficiency that will allow it to provide an attractive mode of intercity passenger transportation in the region. Furthermore, given the projected population increase and economic growth in the region, the capacity of the transportation infrastructure in the NEC must be expanded.

A Vision for High-Speed Rail in the Northeast Corridor

In September of 2010, Amtrak published a report titled, "A Vision for High-Speed Rail in the Northeast Corridor." In this report, Amtrak outlined an ambitious plan to revolutionize intercity passenger rail service in the region. The plan calls for $117 billion through 2040 to construct dedicated, high-speed rail lines in the corridor, modernize stations and equipment, expand capacity, and reduce passenger travel times (Amtrak, 2010a).

In order to reach speeds necessary in the plan, Amtrak proposes the construction of two dedicated HSR lines on a combination of existing and new rights-of-way. Amtrak analyzed a 427-mile possible alignment in order to generate capital costs for the project. A breakdown of the capital costs are as follows: Cost of Track Structure & Stations - $67 billion; Soft Costs - $21 billion; Obtaining right-of-way - $13 billion; Contingencies (Unallocated) - $13 billion (Amtrak, 2010a). Construction would be completed in phases over a 30-year time frame.

Table 16: Projected Annual O & M and Capital Renewal Costs (million $2010)

	Next-Gen HSR Express	Next-Gen Super Express	Keystone Express	Shoreline Express	Next-Gen Total Costs
Train Operations	74	34	9	40	156
On-Board Services	66	30	10	33	139
Maintenance-of-way	59	29	9	26	122
Electric Traction Power	89	43	7	38	178
Equipment Maintenance	154	75	12	66	307
Station Services	79	38	11	33	161
Sales and Marketing	96	47	9	41	194
Total Operating Expenses	616	296	67	278	1,275
Capital Renewal Costs (Maintenance Of Way and Rolling Stock)	172	84	19	74	349
Total Operating and Capital Renewal	**788**	**380**	**86**	**352**	**1,605**

Projections based on following source: Amtrak. (2009b). *Northeast Corridor State of Good Repair Spend Plan*. Retrieved from http://www.amtrak.com/servlet/ContentServer/Page/1241245669222/1237608345018

California Corridor

In response to the success of the Amtrak Acela Express and to growing concerns about the emissions from auto and air transportation, 54 rail projects in 23 different states across the United States are currently under exploration by the FRA state planners, private think tanks, and other organizations for implementation of a dedicated high-speed rail service. In 2010, the federal government allocated more than $10 billion to these potential projects as part of the American Reinvestment and Recovery Act of 2009 (Lombardi, 2010). States have the option to accept or reject the federal funding. If the funding is rejected, which has occurred in some states including Wisconsin and Florida, it will then be available for other state governments (Kunz, 2011).

California has a history of consistent ridership on its Amtrak lines. In this section, three of Amtrak-California's most highly traveled lines are analyzed: the Pacific Surfliner route (San Luis Obispo - Santa Barbara - Los Angeles - San Diego), the San Joaquin route (San Francisco Bay Area/Sacramento - Bakersfield/Southern California), and the Capital Corridor route (Auburn - Sacramento – Emeryville/San Francisco - Oakland - San Jose) (Amtrak, 2011).

The Pacific Surfliner route has experienced a growth in revenue of approximately 134 percent from 1997 to 2007. In FY 2010, total revenue for the line was about $49.5 million (Amtrak, 2010b). The Pacific Surfliner is Amtrak's third-busiest line. The line carried approximately 2.6 million passengers in FY 2010 (Amtrak, 2010d). During the busier summer months, the line sometimes carries more passengers than the Acela Express --- Amtrak's busiest line (Gardner, 2010). In addition, the line is similar to other Amtrak lines in the United States because it receives the majority of its funding ---70 percent --- through state and federal subsidies, and 30 percent of its funding from Amtrak (California DOT, 2008). The entire Pacific Surfliner route totals 350 miles, which translates to a ride time of eight hours and 15 minutes (Amtrak, 2010d).

The San Joaquin route experiences the lowest ridership among the three lines discussed here. This is primarily due to its inland location in the Central Valley where the population density is relatively low. However, the line has seen steady growth in ridership, revenue, and on-time performance in recent years. Specifically, since 2006, these areas have increased 84 percent, 86 percent and 18 percent, respectively (California DOT, 2008). In 2010, ridership totaled almost one million passengers, and revenues topped $31 million. Distance traveled for the entire San Joaquin route totals 315 miles (Amtrak, 2010d).

The Capital Corridor route is the shortest among these three lines, running only 186 miles. However, it serves two of California's top five municipal regions, plus Sacramento and San Francisco. This has caused ridership on the route to triple between 1998 and 2005. As a result of this high ridership, the line runs 32 trains daily, 16 in each direction (Amtrak, 2010d). In addition to steady ridership growth, revenues for this line have increased 158 percent from 1999 to 2009. The line experienced revenues of $9 million per year beginning in 1999; this figure grew to over $24 million per year in 2009 (Amtrak, 2010d).

Currently, the state of California is the most serious candidate to invest in the nation's first dedicated HSR infrastructure. A study released by America 2050, a developmental research organization backed by the Rockefeller and Ford Foundations, analyzes each potential HSR region using six criteria, including metropolitan size, travel distance, connectivity to inner city transit systems, economic productivity of the region, highway and airport congestion, and population density (Hagler and Todorovich, 2009). Each criterion was used to create an index that ranked city pairs based on potential market demand for HSR service. City pairs that ranked the highest overall fell within California, the Northeast, and the Midwest. In addition, according to the report the high growth rates in the region, especially the Southwest, create an opportunity for growth to spur new rail infrastructure (Hagler and Todorovich, 2009).

As of late March 2011, California has applied to receive $2.4 billion in additional funds for HSR projects to be made available by the DOT. This funding became available via a bidding process after the Obama Administration offer was rejected by the governor of Florida (Doyle, 2011.) Support for a high-speed rail line in California is ongoing, and arguments of unsustainable high costs and low ridership are countered by justifications of economic development and job creation. According to Roelef van Ark, CEO of California's High-Speed Rail Authority, "Additional funding may allow California to extend next year's construction segment and operate initial high-speed rail passenger service. California's high-speed rail system will be profitable, will attract private investment, and will create tens of thousands of jobs in the state at a time when they are needed most" (Amtrak, 2010e).

Planners are considering an 800 mile system in the Central Valley linking the San Francisco Bay Area and Sacramento to Los Angeles and San Diego via the San Joaquin Valley. Initially, the state is allocating $9 billion in general obligation bond funds to the project, with more funding expected from the federal government as a result of the bid process. The remaining cost balance to build the entire line was originally estimated at $54.3 billion, but some estimates are as high as $81 billion (Cox and Vranich, 2008). This disparity can be attributed to the sources which they originate. The Reason Foundation (a nonprofit policy think tank), Howard Jarvis Taxpayers Association, and Citizens Against Government Waste collaborated to publish "The California High Speed Rail Proposal: A Due Diligence Report" in 2008. This report was responsible for issuing the higher cost projection, and provides evidence that a high speed rail line in California would be unsustainable. In addition to the higher cost, the report also cites a low ridership estimate: 25 million riders per year by 2030 (Cox and Vranich, 2008). Conversely, the California High-Speed Rail Authority (CHSRA) projects the lower cost estimation mentioned above, in addition to a higher ridership projection of 65-95 million riders per year by 2030 (Cox and Vranich, 2008).

CASE STUDY 2: JAPAN SHINKANSEN HIGH-SPEED RAIL

Historical Context

Japan consists of four main islands: Honshu, Hokkaido, Kyushu, and Shikoku as well as 6,800 small islands. Japan is an Organization for Economic Co-operation and Development (OECD) country with a GDP per capita of $32,477 (OECD, 2009). The Japanese archipelago is located in a zone of relatively recent tectonic activity and about 75 percent of its land area is mountainous. Although Japan's land area is slightly smaller than California's its population density of 886 persons per square mile is ten times greater than that of the United States (Statistics Bureau, Ministry of Internal Affairs and Communication, Japan, 2010). Consequently, railways, passing tunnels and bridges are very important transportation routes between cities of the northern and southern islands.

Japan is undeniably the world's pioneer of HSR. Demand for mass rapid transportation rose alongside the increasing movement of people and goods due to high economic growth during 1950s and coincided with the Tokyo Olympics in 1964. In response to this demand, a high-speed railway, known as Shinkansen, was introduced in 1964 with a 320-mile route between Tokyo and Osaka. Travel time between the two cities was cut from 6.5 hours of conventional rail trip to about 4 hours on Shinkansen.

As of 2009, Shinkansen covers 1,352 intercity miles with maximum speeds ranging from 163 miles per hour to 186 miles per hour (Ministry of Land, Infrastructure, Transport, and Tourism, Japan, 2011). In 2008, Shinkansen generated about $19 billion in revenues and has created additional economic benefits by stimulating growth in the manufacturing, real estate, and restaurant industries around the rail stations (MLIT, 2008).

Public-Private Partnership

Prior to 1987, railway transportation in Japan had been developed, owned and operated by a public company known as Japan National Railway (JNR). The construction cost of the first four Shinkansen networks, Tokaido, Sanyo, Tohoku, and Joetsu, were mainly financed by Japanese Government funds and loans. For Tokaido Shinkansen, about 7.5 percent of costs (28.8 billion yen) were covered by the World Bank – International Bank for Reconstruction and Development (IBRD) - Loan (Tanemura, 2011). In 1987 due to JNR's financial crisis, the government divided and privatized JNR to a freight rail company and six regional passenger railway companies, better known as Japan Railway Companies (JR). After privatization, construction and operation-maintenance have been managed by different parties through a public-private partnership scheme. The construction is funded by the public budget, including 66 percent from the central government, and the remainder is funded by the local government. The Japan Railway Construction, Transport and Technology Agency (JRTT), as a public company leases infrastructure facilities to the JRs. Operators of Shinkansen, JR, collect revenue from tickets and pay a leasing fee to the JRTT for using infrastructure facilities.

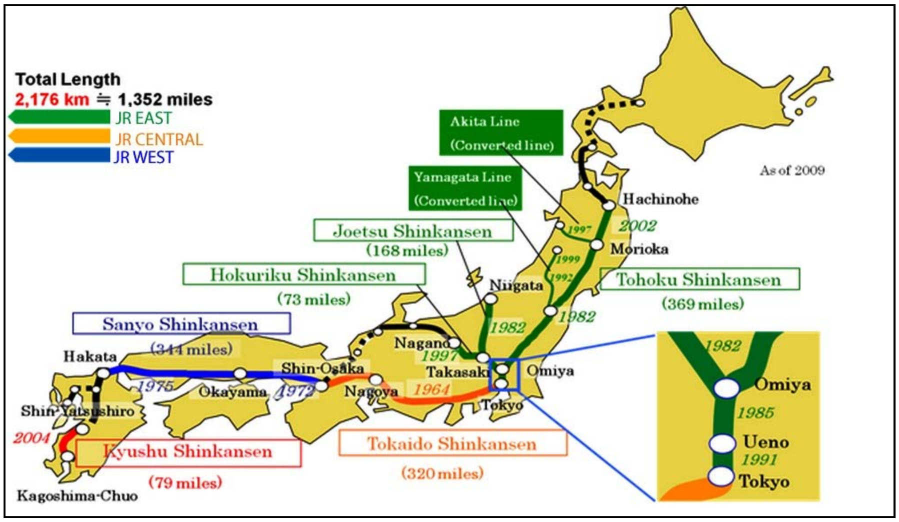


Figure 1: Shinkansen Networks in Japan
Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan. (2011). Shinkansen Japanese high-speed rail. Retrieved from www.mlit.go.jp

Shinkansen Costs

Construction costs in the Shinkansen network are different for each line. Various factors such as infrastructure type, land price, environmental restriction, and technology contribute to different construction costs. Topography is a significant factor affecting infrastructure costs due to the increased costs associated with bridges and tunnels to navigate about mountains or seas. The differences in construction costs for various lines are presented in Table 1 while the proportion of various infrastructures to the overall network length is presented in Figure 2.

On the Sanyo line, more than 50 percent of the network consists of tunnels. The biggest proportion of construction costs for the Sanyo line is 58 percent for infrastructure while the cost proportion of land, electricity equipment, and track are 25.8 percent, 10.9 percent, and 5.1 percent, respectively (Taniguchi, 1992). Construction costs per mile on the Joetsu line and Tohoku (Omiya-Morioka) line are more expensive than the other lines due to environmental laws which impose additional costs. However, in the same construction time, construction cost per mile of the Joetsu line is about 44 percent more expensive than the Tohoku (Omiya-Morioka) line. It was affected by the price of land in Joetsu and the Joetsu line has a longer tunnel than the Tohoku. By contrast, the cost of construction of the Kyushu line is cheaper than the Joetsu and Tohoku lines even though a majority of the line (69 percent) is tunnel. Improvement of construction technology has played a significant role in reducing construction costs.

Table 1: Construction Costs of Various Shinkansen Lines

Line	Year Completed	Length (mile)	Cost/mile (current price) (billion yen)
Tokaido (Tokyo - Osaka)	1964	320	4.97
Sanyo (Okayama - Hakata)	1975	360	4.80
Joetsu (Omiya - Nigata)	1982	129	15.60
Tohoku Shinkansen (Omiya - Morioka)	1982	289	10.88
Kyushu	2004	79	8.10

Source: Hood, C. P. (2006). *Shinkansen.* New York: Routledge.

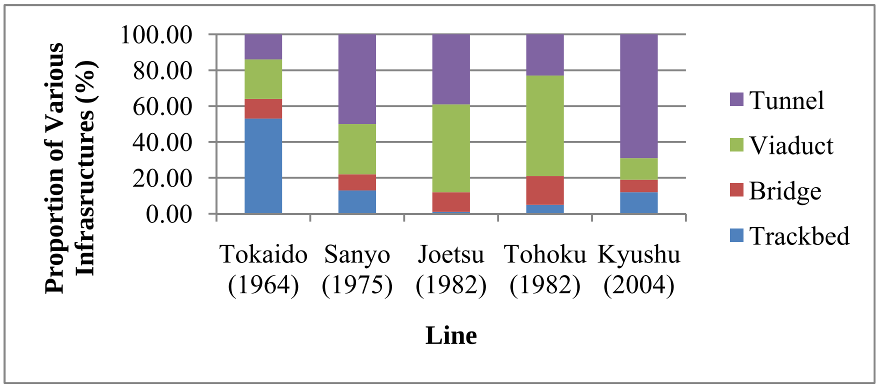


Figure 2: Proportions of Infrastructure Types on Shinkansen Lines.
Source: Takatsu. (2007). The history and future high-speed railways in Japan. *Japan Railway & Transport Review, 48(6).*

Competitiveness

Competitiveness among transportation modes, presented in Figure 3, is influenced by travel distance or travel time. Intercity transportation in Japan is dominated by Shinkansen for distances of 300 to 450 miles or two to four hour trips. For longer trips, air travel is more competitive. On the other hand, automobiles have a larger share than Shinkansen for distances less than 200 miles, although congestion problems are prevalent. For long distance travel, automobiles are not competitive because highway travelers in Japan are subject to tolls and roads have insufficient capacity. Moreover, the price of fuel in Japan is very expensive (about twice the price of U.S. fuel). Figure 4 presents a comparison of gasoline prices between the United States and Japan.

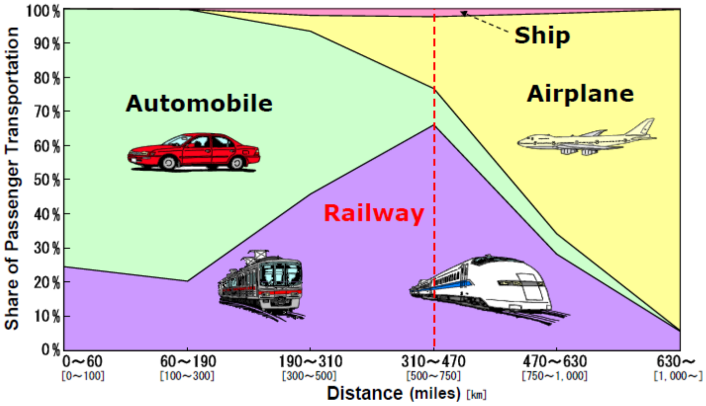


Figure 3: Market Share Among Transportation Modes in Japan.
Source: Tanemura. (2010). Shinkansen: the high-speed rail system in Japan. *US-Japan Business Forum.*

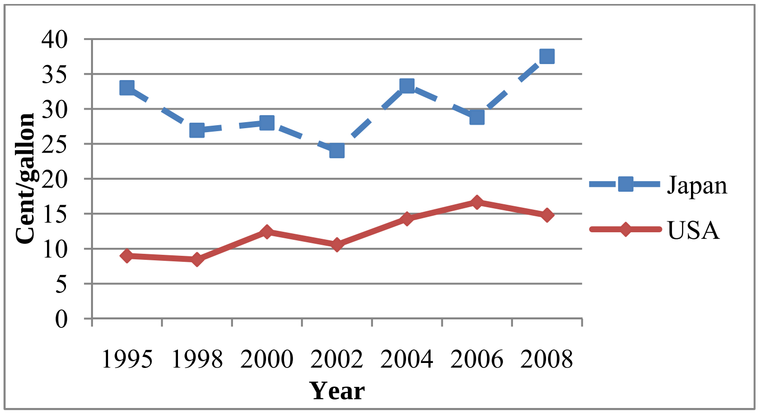


Figure 4: Time-Series Comparison of Super Gasoline Prices between the United States and Japan.
Source: GTZ. (2009). International fuel prices 2009. Eschborn: Deutshe Gesellschaft fur Technische Zuammenarbeit.

Passenger vehicle ownership in Japan is lower than in the United States. In 2007, the ratio of total passenger vehicles in Japan was 325 versus 451 in the United States per 1000 people (Latipop, Alexeev, and Lych, 2009). Car ownership in Japan is presented in Figure 5. In line with population growth, passenger car ownership has increased two-fold from 0.451 units per household in 1975 to 0.959 units per household in 1995. Household growth has continued to increase from 40.77 million households in 1995 to 48.01 million households in 2009 (Statistics Bureau Ministry of Internal Affairs and Communication, 2010). By contrast, car ownership has decreased by 12 percent in the same period and it reached 0.842 units per household in 2009. Based on a survey conducted by the Japan Automobile Manufacturers Association (JAMA) in 2009, this decline is the result of economic factors on a nationwide basis and demographic factors on a regional basis. Demographic factors affecting the decline in passenger car ownership are the increase in single-person households within the greater Tokyo region and the increase in two-person households in Japan's non-urban areas. On the other hand, declining household incomes is perceived to be an economic factor contributing to the decline in car ownership.

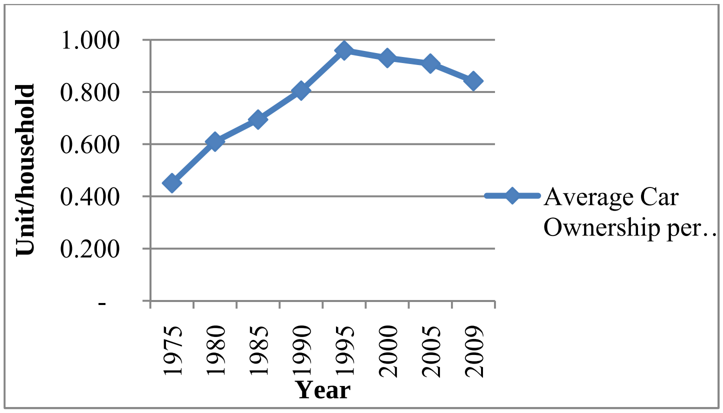


Figure 5: Average Car Ownership Per Household in Japan
Source: Statistical Bureau, Ministry of Internal Affairs and Communication. (2010). Monthly statistical report on motor vehicle transport. Retrieved from http://www.mlit.go.jp

Compared to air travel, Shinkansen has comparative advantages due to travel time, more frequent operation, stations located in central locations of cities, reliability of schedules (average delay time is less than one minute) and safety (no passenger fatalities since 1964). Shinkansen allows travel between Tokyo and Osaka in two hours and twenty-five minutes. The same trip by air takes one hour. However, the travel time of taking an airplane is almost the same as Shinkansen when transfer and access time from the city center to the airport is taken into account. Between these two cities, there are 251 departures per day on Shinkansen while there are only 102 departures by air (Central Japan Railway Company, 2010).

Ridership

Ridership of Shinkansen has increased significantly since 1964, with an average ridership growth of about eight percent per year. It reached 352 million passengers per year in 2008 (MLIT, 2010). Shinkansen has been successful in attracting passengers. In the first six months of operation of the Tokaido line, about 3.6 million passengers, equivalent to 14 percent of the Tokyo – Osaka air transport market, shifted to rail. However, this growth of ridership is subject to the economic situation. The ridership of Shinkansen declined in 1976 and remained stagnant until 1981. Apart from the oil crisis of 1973 and the exchange reform of 1971, it has also been impacted by the financial crisis of the JNR due to a huge financial deficit. During this time, investment, maintenance, and operation costs were basically self-managed by the JNR. The situation has deteriorated as a result of increased motorization in urban and regional transport, which has impeded the expansion of the railway network in rural areas. To resolve this financial problem, the government and JNR increased fares from 2,480 Yen to 2,050 Yen by 1974 and reached 10,800 Yen by 1981 (Yamaguchi and Yamasaki, 2009). Ridership trends for the three Shinkansen companies after JNR privatization is presented in Figure 6.

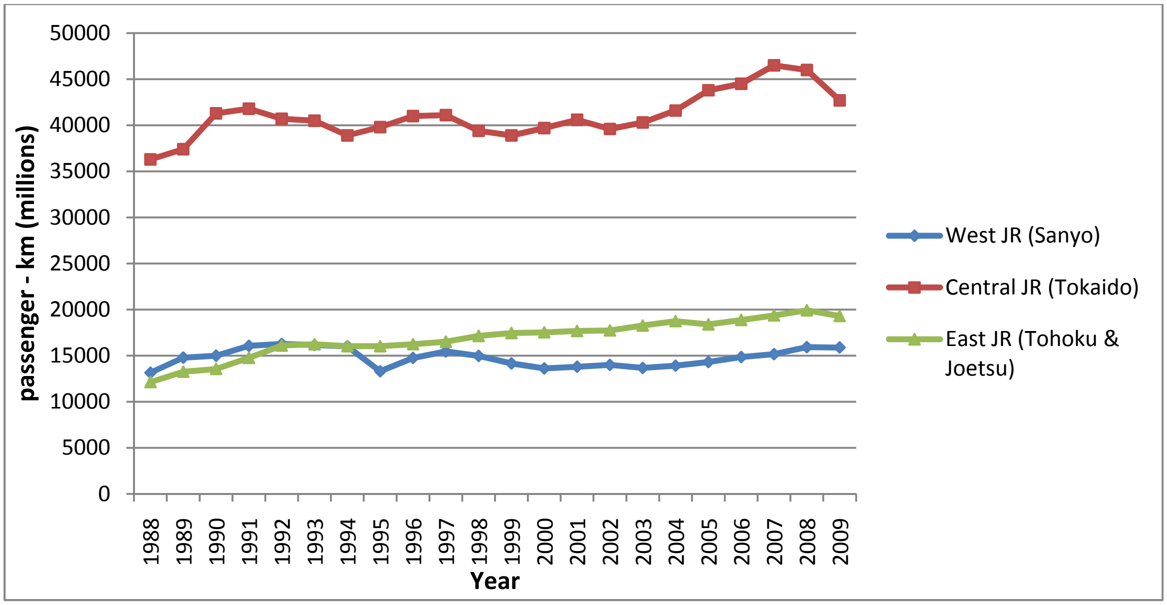


Figure 6: Ridership of Shinkansen in the Three Companies

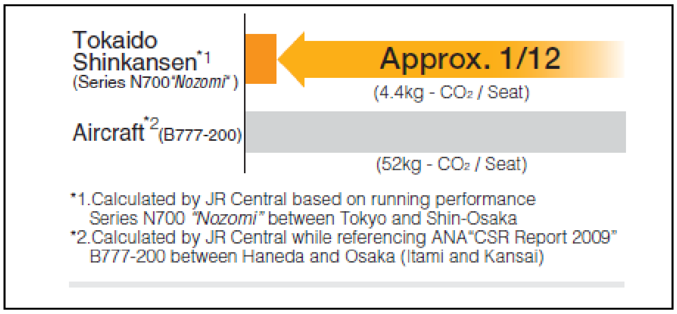
Source: Central Japan Railway Company. (2010). Central Japan Railway Company annual report 2010. Retrieved from english.jr-central.co.jp/; East Japan Railway Company. (2010). 2010 factsheet East Japan Railway Company. Retrieved from http://www.jreast.co.jp/e/;West Japan Railway Company. (2010). West Japan Railway Company fact sheet 2010. Retrieved from http://www.westjr.co.jp/english/

Tokaido Shinkansen (Tokyo - Osaka), operated by Central Japan Railway Company, has the highest ridership compared to the other lines. This line contributed to about 49 percent of total Shinkansen ridership in 2008. This company serves central Japan, which accounts for 23.7 percent of Japan's land area, 59.2 percent of Japan's population, and 64.5 percent of Japan's GDP. Technology has improved the speed of Shinkansen and reduced the travel time between Tokyo and Osaka from four hours (1964) to approximately two hours and 25 minutes (2010). It has increased the number of trains per day from 60 (1964) to 323 (2010) and the ridership per day has increased from 61,000 passengers to 378,000 passengers, respectively (Central Japan Railway Company, 2010).

Energy and Environmental Issues

HSR can be identified as an environmentally friendly transportation mode that produces lower CO_2 emissions per passenger-km than other transportation modes. It is an environmentally friendly option for those in the transportation sector concerned about global warming. The Shinkansen system has been developed through balancing environmental protection and business interests. Several environmental targets have been created to evaluate the environmental impacts such as the reduction in CO_2 emissions, energy-efficiency in railcar utilization rate, waste recycle, and the reduction of noise to 75dB or less.

For the Tokaido line (Tokyo – Osaka), Shinkansen (N700 series) produces 12 times fewer CO_2 emissions (7.9 kg/seat/km) than a Boeing B777-200 (94 gram/seat/km). The comparison is presented in Figure 7. Improving technology increases the energy efficiency of Shinkansen. The speed of Shinkansen's N700 is 270 km/h and higher than the zero series (220 km/h), but the energy consumption is 32 percent lower. The commitment to energy efficiency has been implemented by the Central Japan Railway Company by implementing new energy-saving technology. In 2010, this company operated 49 units of Shinkansen's Series N700, which is the newest energy-saving model, which also operates at the highest speed. By contrast, usage of the older N 300 series has been decreased from 61 units (2005) to 25 units (2010).



*1.Calculated by JR Central based on running performance Series N700 "*Nozomi*" between Tokyo and Shin-Osaka

*2.Calculated by JR Central while referencing ANA "CSR Report 2009" B777-200 between Haneda and Osaka (Itami and Kansai)

Figure 7: Comparison of CO_2 Emissions from Operation between Tokyo and Osaka per Seat
Source: Central Japan Railway Company. (2010). Central Japan Railway Company annual report 2010. Retrieved from english.jr-central.co.jp/

Conclusion

HSR is a viable choice for intercity transportation due to high capacity, shorter travel time, and the fact that it is an environmentally friendly option. Japan is suitable for HSR due to its mountainous and archipelago topographies, long and narrow geography, high population density, and the linear location of its major cities. HSR might be optimal for intercity transportation within states or among states in parts of the United States that have high population densities and integrated economic activities. This system would help increase energy efficency and reduce CO_2 emissions, but the cost of construction would be a debatable issue in terms of economics and politics. The construction costs in the United States would likely be lower than in Japan because of fewer topographic obstacles in areas such as the Central Valley area in California. In this region, tunnel and bridge usage, the most expensive components of construction cost in Japan, would not be as prevalent as in Japan.

However, it is impossible to develop HSR without public investment. Experience from Japan shows that HSR has been succesful as a result of the public-private partnership scheme in which both central and local governments provide financial support. Another key point in HSR's success in Japan has been competitiveness between HSR and other modes. Moreover, inter-city HSR would require integrated access and transit systems within metropolitan areas that are served by HSR. Apart from the short-term cost-benefit issues, the HSR system can also be perceived as an opportunity to stimulate regional development and to generate multiplier effects and other social and economic benefits.

CORRIDOR CHOICES

The most frequently discussed possibilities for other HSR corridors include the NEC and Midwest from Cleveland to Minneapolis via Chicago. Weaknesses for HSR in the NEC are primarily related to construction feasibility. High-speed rail construction in the NEC would require entirely new track alignment with exceedingly high right-of-way costs. While the NEC certainly has an advantage with respect to many high density city pairs, this analysis assumes that the advantage is not significant enough to overcome the major increased cost concerns, with capital estimated to run at least $117 billion in 2010 dollars. The Midwest system's costs would not likely run nearly as high as the NEC, and potentially not as high as California, the region lacks the frequency of high density city pairs needed to achieve justifiable load factors. Without enough station stops in high density cities to gain passengers along the Midwest route, the necessary public subsidy to support the mode is likely to be very high. It is the assumption of this study that the San Diego-Los Angeles-San Francisco corridor is the most feasible HSR route proposed, and that if the analysis showed that a California HSR system captured significant mode share under reasonable scenarios, then other corridors should be assessed for HSR feasibility. However, if a California HSR system cannot be expected to capture mode share, then there is not compelling enough evidence that HSR would be feasible elsewhere without major public subsidy.

Corridor Mapping

High-speed rail attracts riders in dense, highly populated corridors (GAO 2009b; Amtrak, 2008b). Drawing from 11 "Corridor Success Elements from Amtrak Interviews" in a 2008 Amtrak report, the following maps illustrate two key factors—population density and city pair distance. According to the 2008 Amtrak report, the FAA considers corridors 75 to 500 miles to be most competitive to short-haul air travel. Although the model does not include population density as a key variable in the development of high-speed rail, this section includes a geospatial analysis that fulfills that gap for two key corridors—California and the Northeast. 2060 population projections are extrapolated from population data retrieved from the U.S. Census Bureau (USCB).

Figure 26 illustrates the theoretical California corridor that was modeled in this report, with unofficial corridor data geo-referenced from a map made available by the California High-Speed Rail Authority (CHSRA). The corridor reaches from Sacramento in the north to San Diego in the south, with San Francisco and Los Angeles as two main hubs. Projected 2060 population density is shown according to county boundaries.

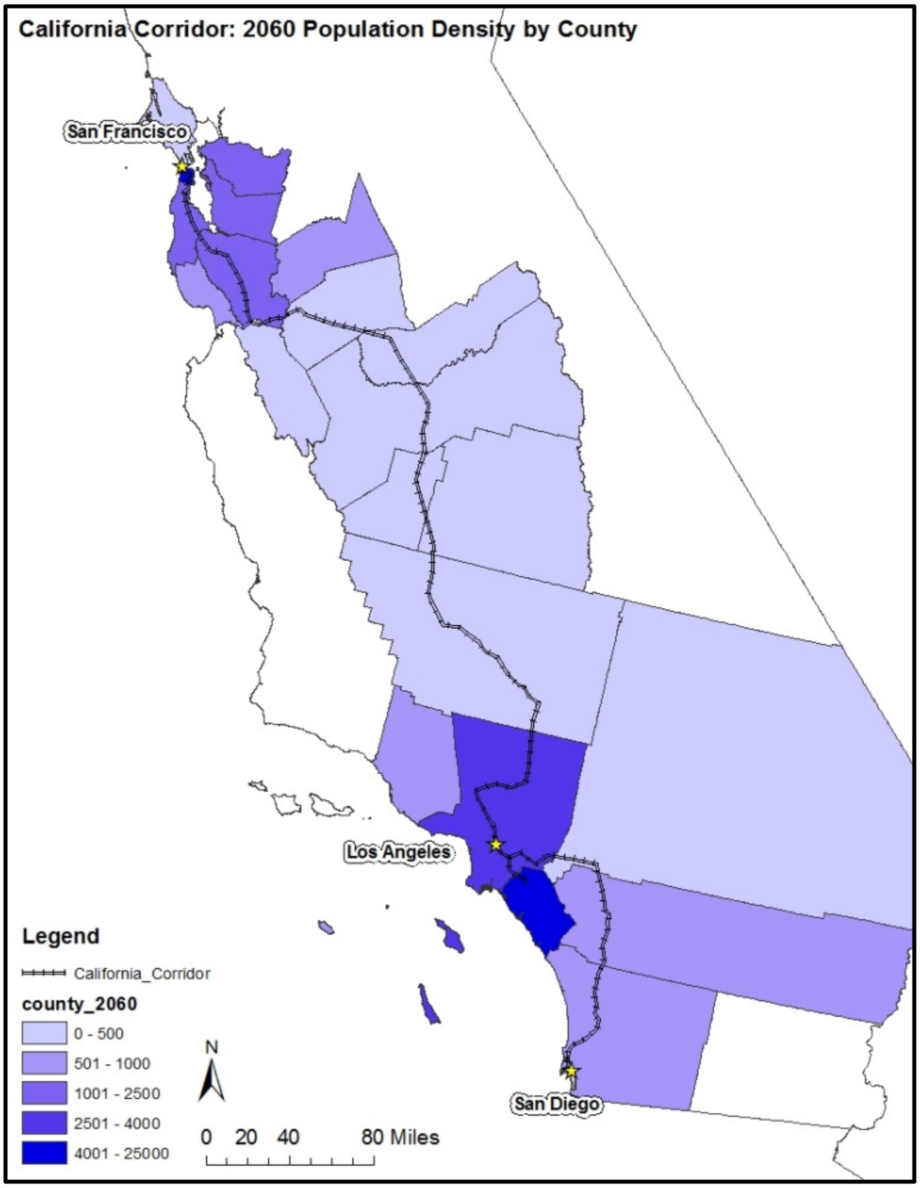


Figure 26: California Corridor

Figure 27 shows the current Northeast corridor with unofficial corridor data geo-referenced from maps made available by the FRA. The current corridor runs from Boston to Washington D.C., passing through four major cities. Projected 2060 population density is shown according to county boundaries.

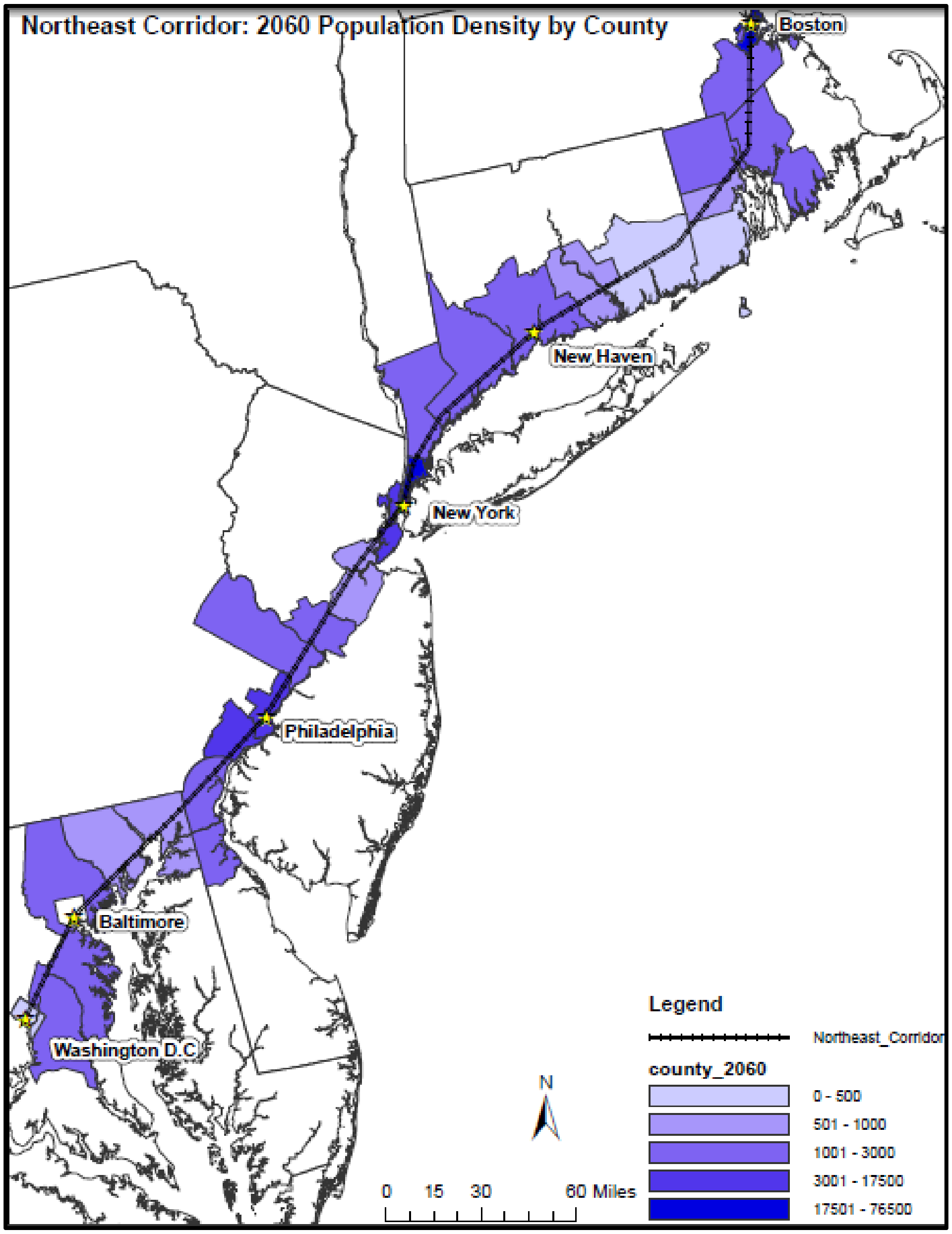


Figure 17: Northeast Corridor

CASE STUDY 3: FRANCE Train à Grande Vitesse (TGV) HIGH-SPEED RAIL

TGV Facts	
Miles of High-Speed Rail	1246
Number of Lines	7 domestic 2 international
Date of First Line	September 22, 1981
Average Load Factor	0.71
Average Infrastructure Cost per km	$3,380,000 (in 1994 USD)
Capital Investment	€9.8 billion (cumulative through 31 December 2009)
Speed	Maximum speed of 186 mph
Sources: Briginshaw, D. (2007). Three drivers for HS rail success. *International Railway Journal.* Retrieved from **http://www.highbeam.com/doc/1G1-160925565.html** Center for Clean Air Policy and Center for Neighborhood Technology (2006). High speed rail and greenhouse gas emissions in the U.S. Retrieved from *www.cnt.org/repository/HighSpeedRail Emissions.pdf* Levinson, D., Mathieu, J.M., Gillen D., Kanafani A. (1997). The Full Cost of High Speed Rail: An Engineering Approach. The Annals of Regional Science. 31:2 189-215. Retrieved from http://nexus.umn.edu/Papers/HighSpeedRail.pdf Meunier, J. (2002). *On the fast track: French railway mondernization and the origins of the TGV, 1944-1983.* Westport, CT: Praeger. Reseau Ferre de France. (2009). A network for a world on the move. Retrieved from *www.rff.fr/IMG/RFF_RA%202009_GB_WEB.pdf.*	

Potential Lessons for the United States

1. European countries have higher population densities that the United States, allowing them to capture high ridership (World Resources Institute, 2008). For example, France's population density is approximately 262.75 people per square mile, while the US population density is 82. 56 people per square mile (Factbook, 2010). To obtain comparable ridership rates in the U.S., a high-speed rail system would either have to increase its number of stops or decrease passenger fares, relative to European averages. However, there are drawbacks of these approaches to consider; increasing the number of stops would lead to decreased speed and increased travel time; reducing HSR attractiveness. Also, decreasing passenger fares will require additional federal subsidies to cover the losses in revenue.
2. Cost overruns are a common occurrence for high-speed rail in Europe (Albalate, 2010). The United States must invest ample resources to accurately assess capital costs and investments, operations and management costs and overrun scenarios prior to any implementation of HSR construction.
3. Construction costs of new high-speed rail tracks in densely population city limits may be prohibitive to high-speed rail development. To avoid these high right of way acquisition costs, the United States may link high-speed rail tracks to existing conventional rail tracks within city limits. France employed this connection to existing tracks in many metropolitan areas reduce construction costs (Albalate, 2010).

CORRIDOR- SPECIFIC SCENARIOS

High-Speed Rail User Prices

We developed California 2060 full user prices based on the implementation of a HSR system from San Diego to San Francisco with a stop in Los Angeles. Our initial cost estimates were based on those of the CHSRA as detailed in its 2009 report to the California legislature (California High-Speed Rail Authority, 2009). However, since CHSRA's projected costs have been criticized as underestimates of the true costs of HSR, we set their costs as our lowest estimate. We then multiplied CHSRA's costs by 30 percent and by 60 percent to achieve our mid-range and high cost estimates. These percentage increases were based on the results of a due diligence study of the California HSR proposal (Cox and Vranich, 2008). As with the national data above, we used the CPI to inflate or deflate CHSRA's estimates as necessary to achieve cost estimates in 2009 dollars (DOL, 2011).

CHSRA's projected total capital costs for the 520-mile section of rail from San Francisco to Anaheim, including both the rail infrastructure and the vehicles, amounted to approximately $35.7 billion. Since full operations of the HSR line are slated to begin in 2020, we divided the initial capital costs by 40 years, assuming that all of the initial capital investments would be paid off by 2060 and that all of the users between 2020 and 2060 would pay an equal portion of those costs. This resulted in an average annual cost estimate of approximately $892 million.

We then added the forecasted 2060 capital replacement costs to this initial capital cost estimate. The CHSRA report projected capital replacement costs out to 2045. We followed their trend of a four percent annual growth rate in capital replacement costs to obtain projections out to 2060. This resulted in a 2060 capital replacement cost of approximately $358 million. Summing the initial capital costs and the capital replacements costs, we obtained a total 2060 capital cost of approximately $1.25 billion.

We then divided this cost by 520 miles, the route length used to develop CHSRA's cost estimates, to obtain a 2060 capital cost of approximately $2.4 million per route mile. We multiplied this figure by 616 miles, the length of the entire San Francisco to San Diego route, to obtain a total 2060 capital cost of approximately $1.48 billion. In doing so, we assumed that the cost per route mile would be roughly the same from Anaheim to San Diego as from San Francisco to Anaheim.

CHSRA projects O&M costs for the 520-mile section of rail from San Francisco to Anaheim out to 2035. We followed their trend of a 0.5 percent annual growth rate in O&M costs to obtain projections out to 2060. This resulted in a 2060 O&M cost of approximately $1.2 billion. We then divided this cost by 520 miles, the route length used to develop CHSRA's cost estimates, to obtain a 2060 O&M cost of approximately $2.3 million per route mile. We multiplied this by 616 miles, the length of the entire San Francisco to San Diego route, to obtain a total 2060 O&M cost of $1.48

billion. In doing so, we assumed that the O&M cost per route mile would be roughly the same from Anaheim to San Diego as from San Francisco to Anaheim.

Finally, we divided the total expense of the California HSR line, including the capital costs and the O&M costs, by the projected number of passenger miles. CHSRA's ridership intensity figures (passenger miles per route miles) were deemed unreasonably high because they were approximately 50 percent to 100 percent greater than those achieved by France's TGV and Japan's Bullet Train (Cox and Vranich, 2008). As a result, we developed our own estimates of annual passenger miles based on the calculations in Table 17.

Table 17. Annual passenger mile projections for the California HSR system.

Seats per train	Seats/day (30, 50, 100 trains/day)	Seat miles/day (616 miles)	Seat miles/year (365 days/year)	Passenger miles per year (65% load factor)
650	19,500	12,012,000	4,384,380,000	2,849,847,000
650	32,500	20,020,000	7,307,300,000	4,749,745,000
650	65,000	40,040,000	14,614,600,000	9,499,490,000

The number of seats per train was based on the average number of seats on HSR trains in Europe and Asia, which ranges from 400 to 650 (CHSRA, 2009). The number of trains per day was based on reasonable expectations of how many trains would depart from each end of the route per day. For example, the low estimate of 30 trains per day corresponds to one train departure per hour in either direction between 5 a.m. and 8 p.m. The high estimate of 100 trains per day corresponds to three train departures per hour in either direction between 5 a.m. and 9 p.m., as well as two train departures per hour in either direction between 9 p.m. and 10 p.m. We assumed these departure rates for 365 days per year and that each departure would run the entire 616 mile route. Finally, we assumed a 65 percent load factor. This figure is in line with the load factors achieved by the Acela Express in the NEC, which has the highest load factor of any intercity train in the United States (Amtrak, 2009b; 2010d). Our projected annual passenger miles of 2.8 billion, 4.7 billion, and 9.5 billion would require ridership intensities of roughly three times, six times, and 13 times the ridership intensity achieved on the Acela Express (Cox and Vranich, 2008). Therefore, we believe these figures are still relatively optimistic projections, although they fall far below those of the CHSRA.

Ridership Caveats

Before evaluating the projected HSR mode share in the California corridor, it is important to understand the primary assumption that is constant throughout this analysis. In order to be able to evaluate how varying circumstances affect HSR mode share, the user price must first be competitive with other modes. Since HSR has very high capital and O&M costs, user prices that are competitive with other modes depends on very high load factors and subsequent ridership figures. The CHSRA has projected 25 billion passenger miles per year, a figure this analysis views with serious skepticism. However, just to make HSR user prices competitive, this analysis assumes a ridership figure we still consider to be highly unlikely. Table 18 below outlines the assumptions applied to the ridership figures used here. To make comparisons and compare mode shares based on varying scenarios like carbon prices and high fuel prices, this analysis applies the upper range – 9.5 billion passenger miles per year – to each mode share projection that will follow.

Table 18: California HSR Corridor Projected Ridership Figures

Departures per day	Seats per train	Route miles	Load factor*	Passenger miles per year	CA Corridor Ridership Multiples of Acela Express Ridership
30	650	616	65%	2.8 billion	3x
50	650	616	65%	4.7 billion	6x
100	650	616	65%	9.5 billion	13x

Since user prices are estimated ex ante from projected ridership figures, a bit of circular logic is injected into model interpretations. For instance, high load factor projections are estimated here in order to assess whether HSR can be competitive with other modes. However, the model projects the likelihood that an average person will choose a particular mode of transportation for intercity travel based in part on the user price. Thus, HSR mode share probabilities are estimated from the model, but the user prices are estimated with a load factor figure already expressed. Therefore, if user prices based on high projected ridership still result in low projected mode share, it is not likely that the low mode share probability will achieve the level of ridership necessary to bring user prices down to a level that is competitive with other modes, unless it is covered by additional subsidies. The consequence of low mode shares that will not achieve the ridership figures assumed in the user prices used in the model is that the ridership deficit will need to be made up by additional O&M subsidies. For instance, if user prices used in modeling mode share projections are based on 9.5 billion passenger-miles per year, but the projected mode share only results in 4.5 billion passenger miles per year, the five billion passenger-mile deficit will need to be covered by additional subsidies in order to keep the user price at a level that will achieve the projected mode share. Table 19 below illustrates the approximate O&M subsidy level that would be necessary in the case of low ridership figures.

Table 19: Estimated O&M Subsidy Necessary to Preserve Competitive User Price

Passenger miles per year (billions)	O&M Subsidy
9.5	0%
4.7	51%
2.8	71%

Additionally, high-speed rail ridership is dependent on stops in high density areas in order to achieve high load factors. Another important assumption of this analysis is that there are no intermediate stops outside of San Diego, Los Angeles, and San Francisco. This allows the HSR system to experience a competitive advantage over auto with regard to trip time, but will likely not result in ridership necessary to avoid large O&M subsidies. The difficulty with the California corridor, as well as most other potential high speed rail corridors in the U.S. outside of the NEC is that there are not a large number of high density population centers within relatively short distances. The figure below compares three rail corridors: Japan, the Acela Express in the NEC, and the California corridor.

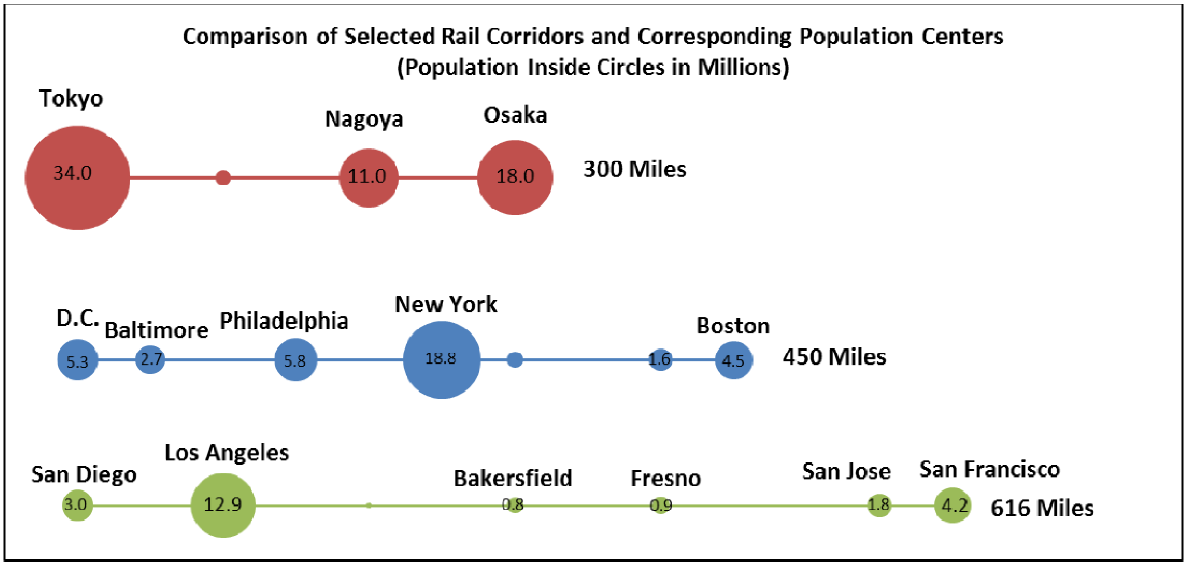


Figure 28: Population and distance comparison of selected rail corridors. Source: GAO, 2009.

The above figure illustrates that the California corridor does not have the advantage of high population density along relatively short distances, particularly on the 500+ mile line haul from Los Angeles to San Francisco. This comparison illustrates the catch-22 for HSR systems outside of very dense population centers. As outlined above, the user prices used to project mode share in the California corridor are based on unlikely ridership figures. To achieve those figures, an HSR system must make enough stops in population centers to draw riders. However, as more stops are added the average speed between stations is decreased and the overall trip time is lengthened. When there are only medium- to low-density areas in which to stop, more stops must be made to achieve ridership, resulting in even longer trip time. As trip time increases, HSR loses its competitive advantage on speed and travelers begin switching back to autos, thus decreasing HSR mode share. The Acela Express in the NEC has six population centers over one million people in which to stop, achieving load factors of 60 percent, but still only drawing about six percent mode share. The question should be asked, can we expect higher load factors than the Acela Express in the California corridor even with many more daily departures, a disadvantage in corridor population density, and a marginal maximum speed advantage? It is important to recall these caveats in consideration of mode share projections below. High-speed rail mode shares are likely to be overstated due to user prices based on overly optimistic load factors, and a trip time based on no intermediate stops between population centers.

High-Speed Rail Subsidies

In addition to this range of estimates for annual passenger miles, we considered a range of government subsidies, including a 50 percent capital subsidy, a 75 percent capital subsidy, and a 100 percent capital subsidy. Furthermore, as mentioned above, we set CHSRA's cost figures as the lowest total cost estimate and created mid-range and high cost estimates that were 30 percent and 60 percent higher, respectively.

Altogether, we developed 36 separate estimates of the California 2060 full user prices based on our range of annual passenger mile projections, capital and O&M expense estimates, and government subsidy levels. The lowest estimate was 15.1 cents per passenger mile and was based on CHSRA's cost projections, a full government subsidy for all capital costs, and the highest ridership rate (9.5 billion passenger miles per year). The highest estimate was 163.8 cents per passenger mile and was based on cost projections 60 percent greater than CHSRA's estimates, no government subsidies, and the lowest ridership rate (2.8 billion passenger miles per year).

High-Speed Rail Emissions

It is important to note that in determining the full external environmental cost to HSR, only operations, and not infrastructure, were analyzed. Three different scenarios were investigated: a business as usual scenario, in which no changes occur from present day expected emissions per unit of energy to 2060; an extended trends scenario, in which current trends in energy generation leading to emissions are applied through 2060 with modest efficiency gains; and a green revolution scenario in which by 2060 fossil fuel usage has greatly decreased.

In order to determine the environmental costs from HSR operation, we focus on CO_2 emissions because other pollutants are already highly regulated, and since HSR results in no point source emissions, the contribution is realized from emissions due to electricity generation.

The baseline scenario applies the 2008 percentage mix of fossil fuels used in electricity generation from the electric power industry in California. It should be noted that California only produces around 74 percent of its entire electricity supply with the rest of the production covered by the U.S. Pacific Northwest (PNW) supply (about eight percent) and the U.S. Southwest (USW) supply (about 18 percent). In 2008, California's mix was 1.1 percent coal, 58 percent natural gas and 0.8 percent oil; the PNW mix was seven percent coal, 16 percent natural gas and no oil; the USW mix was 52 percent coal, 31 percent natural gas and no oil.

Weighted by each state/region's percentage of the CA supply, the 2008 emissions from electricity in CA was 320gCO_2/kWh (U.S. Department of Energy 2009; Tanaka, Thompson, Kosinski, Schipper, and Deakin, 2011). The "extended trends" scenario follows the EIA's projection of a two percent reduction of coal in the electricity mix by 2035, extrapolated out to 2060 as a four percent reduction (which brings CA to zero, PNW to three percent, and USW to 48 percent); additionally, following the EIA's projection of a two percent increase of natural gas in the electricity mix, this figure is extrapolated out to 2060 as a four percent increase (bringing CA to 59 percent because it picks up only the share of coal removed from the mix, PNW to 20 percent and USW to 35 percent). The extended trends scenario also assumes a five percent efficiency gain in primary energy to electricity (consistent with historical progress), leading to emissions of 289 gCO_2/kWh (US DoE 2010; Tanaka, et. al 2011). For the "green revolution" scenario, the fossil fuel inputs are reduced by half in each region (zero coal in PNW), with 15 percent efficiency gains in production and delivery resulting in emissions of 129gCO_2/kWh(EIA 2009b; Tanaka, et. al 2011).

Using these scenarios for emissions and sensitivity analysis for energy consumption and load factor, a high value of 0.00006 tonnes CO_2/pm (under the business as usual trend with high energy consumption and low load factor), and a low value of 0.0000089 tonnes CO_2/pm (under the green revolution scenario with low energy consumption and high load factor) were derived.

California Fuel Price Projections

We used EIA weekly data on retail historical gasoline prices from January 2, 1995 through April 4, 2011 to calculate the average percent difference between California gasoline prices and national gasoline prices (EIA, 2011b). We found that on average California's gasoline prices were 7.3 percent higher than the national gasoline prices. We used this percent difference to adjust our 2060 motor gasoline price forecasts for California, resulting in a high estimate of $8.72, a mid-range estimate of $5.45, and a low estimate of $2.18. Using the same method, we determined that we needed to adjust our 2060 California diesel price forecasts by 9.57 percent relative to the national diesel price forecasts, resulting in a high estimate of $9.20, a mid-range estimate of $5.75, and a low estimate of $2.30.

Summary of California Scenarios

Twelve scenarios were considered in the California model (Tables 16 and 17). All of the scenarios included the highest ridership estimates for rail. At lower ridership levels, rail remained significantly more expensive than the other modes and therefore gained little additional mode share relative to the national scenarios. As a result, the most informative results emerged from the highest ridership estimates. The limitations of these ridership estimates are discussed in Chapter IV and below.

The first four scenarios include no cost overruns for rail. In other words, they match the capital and operating costs projected by the CHSRA (CHSRA, 2009). These scenarios also include medium fuel prices, extended trends of innovation, and varying levels of carbon prices for all modes. Finally, they include varying levels of rail subsidies, with the increase in subsidies mirroring the increase in carbon prices. This represents an assumption that carbon prices and rail subsidization would emerge together as part of a comprehensive political response to energy and environmental concerns.

The fifth through eighth scenarios include 30 percent cost overruns for rail. In other words, they include costs that are 30 percent greater than those projected by the CHSRA. In all other respects, these four scenarios match the first four scenarios.

The ninth through 12th scenarios include the green revolution assumptions while applying no cost overruns and 30 percent cost overruns. The 13th and 14th scenarios apply extended trends innovation and reference case and high fuel prices, respectively. The 15th and 16th scenarios include 60 percent cost overruns for rail. In other words, they include costs that are 60 percent greater than those projected by the CHSRA. They also include high fuel prices and a green revolution in innovation. Finally, they include the highest and lowest levels of rail subsidies and carbon prices.

The 16th scenario is the "most favorable to rail." It includes no cost overruns for rail. In other words, it includes costs that match those projected by the CHSRA. It also includes high fuel prices, a high carbon price, and extended trends of innovation.

Table 20: California corridor leisure scenarios with corresponding user prices

HSR Cost Scenario	Fuel Price Level	HSR Subsidy Level	Carbon Price (per tonne)	Innovation Scenario	Mode	Price/PM
No cost overruns	Medium	none	none	Extended	**Air**	1.339*((exp((3.129)-0.695*LN(distance))))
				Trends	**Auto**	0.233
					Bus	0.229
					Rail	0.307
No cost overruns	Medium	50% of capital	$25	Extended	**Air**	1.339*((exp((3.129)-0.695*LN(distance)))) + 0.004
				Trends	**Auto**	0.236
					Bus	0.230
					Rail	0.229
No Cost Overruns	Medium	75% of capital	$50	Extended	**Air**	1.339*((exp((3.129)-0.695*LN(distance)))) + 0.008
				Trends	**Auto**	0.239
					Bus	0.232
					Rail	0.190
No cost overruns	Medium	100% of capital	$100	Extended	**Air**	1.339*((exp((3.129)-0.695*LN(distance)))) + 0.016
				Trends	**Auto**	0.244
					Bus	0.235
					Rail	0.151
30% cost overruns	Medium	none	none	Extended	**Air**	1.339*((exp((3.129)-0.695*LN(distance)))) + 0.004
				Trends	**Auto**	0.234
					Bus	0.229
					Rail	0.399
30% cost overruns	Medium	50% of capital	$25	Extended	**Air**	1.339*((exp((3.129)-0.695*LN(distance)))) + 0.004
				Trends	**Auto**	0.236125386
					Bus	0.230356
					Rail	0.2979
30% cost overruns	Medium	75% of capital	$50	Extended	**Air**	1.339*((exp((3.129)-0.695*LN(distance)))) + 0.008
				Trends	**Auto**	0.239
					Bus	0.232
					Rail	0.247
30% cost overruns	Medium	100% of capital	$100	Extended	**Air**	1.339*((exp((3.129)-0.695*LN(distance)))) + 0.016
				Trends	**Auto**	0.244
					Bus	0.235
					Rail	0.197
No cost overruns	High	100%	None	Green	**Air**	1.434*((EXP((3.129)-0.695*LN(tripmiles))))
				Revolution	**Auto**	0.229
					Bus	0.261
					Rail	0.151
No cost overruns	High	100%	$100	Green	**Air**	1.434*((exp((3.130)-0.695*LN(distance)))) + 0.009
				Revolution	**Auto**	0.240
					Bus	0.267
					Rail	0.151
30% Cost Overruns	High	100%	None	Green	**Air**	1.434*((EXP((3.129)-0.695*LN(tripmiles))))
				Revolution	**Auto**	0.215
					Bus	0.261
					Rail	0.197
30% Cost Overruns	High	100%	$100	Green	**Air**	1.434*((exp((3.129)-0.695*LN(distance)))) + 0.009
				Revolution	**Auto**	0.240
					Bus	0.267
					Rail	0.197

Table 20 continued on next page.

Table 20: California corridor leisure scenarios with corresponding user prices

HSR Cost Scenario	Fuel Price Level	HSR Subsidy Level	Carbon Price (per tonne)	Innovation Scenario	Mode	Price/PM
30% Cost Overruns	Medium	100%	None	Extended Trends	**Air**	1.339*((exp((3.129)-0.695*LN(distance)))) + 0.008
					Auto	0.234
					Bus	0.229
					Rail	0.197
30% cost overrun	High	100%	None	Extended Trends	**Air**	1.747*((exp((3.129)-0.695*LN(distance)))) + 0.016
					Auto	0.281
					Bus	0.252
					Rail	0.197
60% cost overruns	High	100% of capital	$25	Green Revolution	**Air**	1.434*((EXP((3.129)-0.695*LN(distance)))) + 0.002
					Auto	0.235
					Bus	0.262
					Rail	0.242
60% cost overruns	High	100% of capital	$100	Green Revolution	**Air**	1.434*((exp((3.129)-0.695*LN(distance)))) + 0.009
					Auto	0.240
					Bus	0.267
					Rail	0.2418
No cost overruns	High	100% of capital	$100	Extended Trends	**Air**	1.747*((exp((3.129)-0.695*LN(distance)))) + 0.016
					Auto	0.281
					Bus	0.258
					Rail	0.151

Table 21: California corridor business scenarios with corresponding user prices

HSR Cost Scenario	Fuel Price	Subsidy Level	Carbon Price (per tonne)	Innovation	Mode	Price/PM
No cost overruns	Medium	none	none	Extended Trends	**Air**	1.339*((exp((3.129)-0.695*LN(distance))))
					Auto	0.234
					Bus	0.229
					Rail	0.307
No cost overruns	Medium	50% of capital	$25	Extended Trends	**Air**	1.339*((exp((3.129)-0.695*LN(distance)))) + 0.004
					Auto	0.236
					Bus	0.230
					Rail	0.229
No cost overruns	Medium	75% of capital	$50	Extended Trends	**Air**	1.339*((exp((3.129)-0.695*LN(distance)))) + 0.008
					Auto	0.239
					Bus	0.232
					Rail	0.190
No cost overruns	Medium	100% of capital	$100	Extended Trends	**Air**	1.339*((exp((3.129)-0.695*LN(distance)))) + 0.016
					Auto	0.243
					Bus	0.235
					Rail	0.151
30% cost overruns	Medium	none	none	Extended Trends	**Air**	1.339*((exp((3.129)-0.695*LN(distance))))
					Auto	0.233
					Bus	0.229
					Rail	0.399
30% cost overruns	Medium	50% of capital	$25	Extended Trends	**Air**	1.339*((exp((3.129)-0.695*LN(distance)))) + 0.004
					Auto	0.236
					Bus	0.230
					Rail	0.298
30% cost overruns	Medium	75% of capital	$50	Extended Trends	**Air**	1.339*((exp((3.129)-0.695*LN(distance)))) + 0.008
					Auto	0.239
					Bus	0.232
					Rail	0.247
30% cost overruns	Medium	100% of capital	$100	Extended Trends	**Air**	1.339*((exp((3.129)-0.695*LN(distance)))) + 0.016
					Auto	0.243693303
					Bus	0.235142
					Rail	0.1965
No cost overruns	High	100%	none	Green Revolution	**Air**	1.434*((EXP((3.129)-0.695*LN(tripmiles))))
					Auto	0.229
					Bus	0.260
					Rail	0.151
No cost overruns	High	100%	$100	Green Revolution	**Air**	1.434*((exp((3.129)-0.695*LN(distance)))) + 0.009
					Auto	0.240
					Bus	0.267
					Rail	0.151
30% cost overruns	High	100%	None	Green Revolution	**Air**	1.434*((EXP((3.129)-0.695*LN(tripmiles))))
					Auto	0.215
					Bus	0.261
					Rail	0.197
30% cost overruns	High	100%	$100	Green Revolution	**Air**	1.434*((exp((3.129)-0.695*LN(distance)))) + 0.008
					Auto	0.240
					Bus	0.267
					Rail	0.197

Table 21 continued on next page.

Table 21: California corridor business scenarios with corresponding user prices

HSR Cost Scenario	Fuel Price	Subsidy Level	Carbon Price (per tonne)	Innovation	Mode	Price/PM
30% cost overruns	Medium	100%	None	Extended	**Air**	1.339*((exp((3.129)-0.695*LN(distance)))) + 0.008
				Trends	**Auto**	0.234
					Bus	0.229
					Rail	0.197
30% cost overruns	High	100%	None	Extended	**Air**	1.747*((exp((3.129)-0.695*LN(distance)))) + 0.0161
				Trends	**Auto**	0.281
					Bus	0.252
					Rail	0.197
60% cost overruns	High	100% of capital	$25	Green	**Air**	1.434*((EXP((3.129)-0.695*LN(tripmiles)))) + 0.002
				Revolution	**Auto**	0.235
					Bus	0.262
					Rail	0.242
60% cost overruns	High	100% of capital	$100	Green	**Air**	1.434*((exp((3.129)-0.695*LN(distance)))) + 0.009
				Revolution	**Auto**	0.240
					Bus	0.267
					Rail	0.242
No cost overruns*	High	100% of capital	$100	Extended	**Air**	1.747*((exp((3.129)-0.695*LN(distance)))) + 0.016
***Most favorable scenario to HSR**				Trends	**Auto**	0.281
					Bus	0.258
					Rail	0.151

California Results

To assess the viability of a national HSR network, this analysis focuses on the proposed HSR corridor in California. As it was outlined in the previous section, the focus on the California corridor serves as a proxy for other potential HSR corridors in the United States. The analysis assumes that if HSR does not capture significant mode share under a variety of conditions in California, then it will not do so in other corridors that are suited to HSR networks. This analysis has estimated an HSR mode share range between 0.31 percent and 37 percent. The lower range indicates the projected HSR mode share if it were treated the same as other modes – i.e. no subsidies. The upper range is the estimated HSR mode share based on very favorable conditions considered by this analysis to be extremely unlikely, including no cost overruns, a 100 percent capital subsidy, high fuel prices and a user price based on 9.5 billion passenger-miles each year. The mode shares falling between this lower and upper range are highly dependent on varying circumstances, which will be the focus of this section. We estimate HSR mode share in the context of cost overruns, a subsidy effect, a carbon price effect, and a high fuel price effect. Based on the estimated projected mode shares for HSR in this analysis, we draw three primary conclusions: 1) HSR will require very large subsidies in order to capture sizeable mode share, 2) a carbon price will have little impact on HSR mode share, and 3) high fuel prices will benefit HSR and auto mode shares.

Turning first to the issue of cost overruns, it is evident that HSR mode share is highly sensitive to cost overruns, so long as those overruns are passed through to the user prices. If capital were to be subsidized 100 percent and the HSR system were to experience 30 percent O&M cost overruns and the additional costs are absorbed by users, HSR mode share falls from 22 percent with no overruns, to 11 percent. The cost overrun effect is illustrated in the figures below.

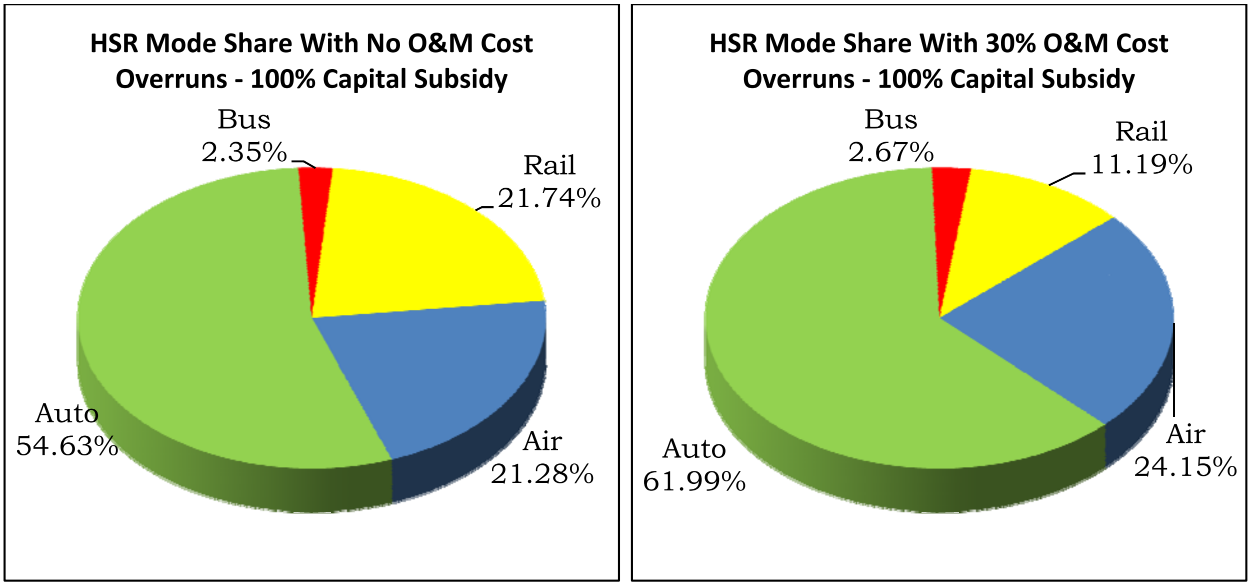


Figure 29. Demonstration of cost overrun effect. Left, mode share with no HSR cost overruns beyond CHSRA estimates; right, mode share with 30 percent O&M cost overruns beyond CHSRA estimates.

The same issue can be demonstrated with both capital and O&M cost overruns. We make the same comparison as above assuming no cost overruns and 30 percent overruns, but this time only providing a 50 percent subsidy for capital so that capital overruns are captured in projected mode share, and the resulting disparity is six percent HSR mode share with no cost overruns and two percent with 30 percent overruns, illustrated in the tables below. It is also important to note that most of this shift is drawn from auto mode share.

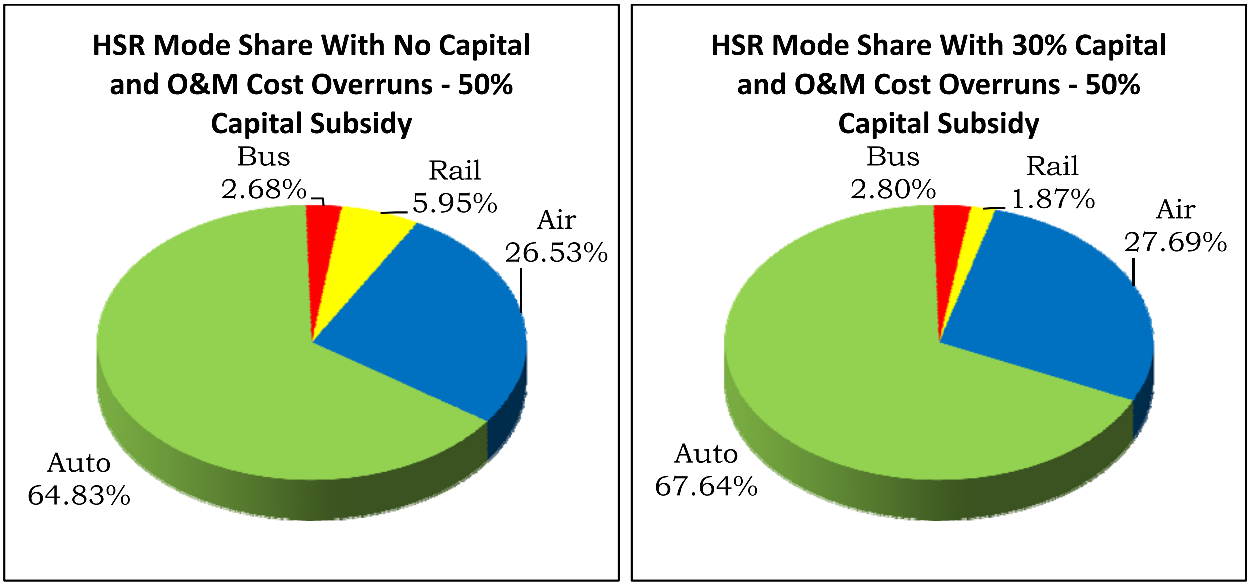


Figure 30. Demonstration of capital and O&M cost overruns. Left, no capital or O&M overruns beyond CHSRA estimates; right, 30 percent capital and O&M cost overruns beyond CHSRA estimates.

Turning next to the subsidy effect, it is evident that an HSR system will draw very limited mode share without very high subsidies and it remains unclear how high the subsidy level would have to be in order to capture sizeable mode share. Under a no subsidy approach, using 30 percent cost overruns beyond the CAHSRA cost projections, the most mode share drawn by the HSR system is 0.3 percent of intercity passengers. Not surprisingly, as the capital subsidy increases, as well as the carbon price, mode share for HSR increases. Under a 100 percent capital subsidy scheme with CO_2 priced at $100/tonne and 30 percent cost overruns, HSR achieves about 11 percent of mode share, a sizeable share relative to past rail experience in the U.S., but still well below that of auto and air. This effect is illustrated in the figures below.

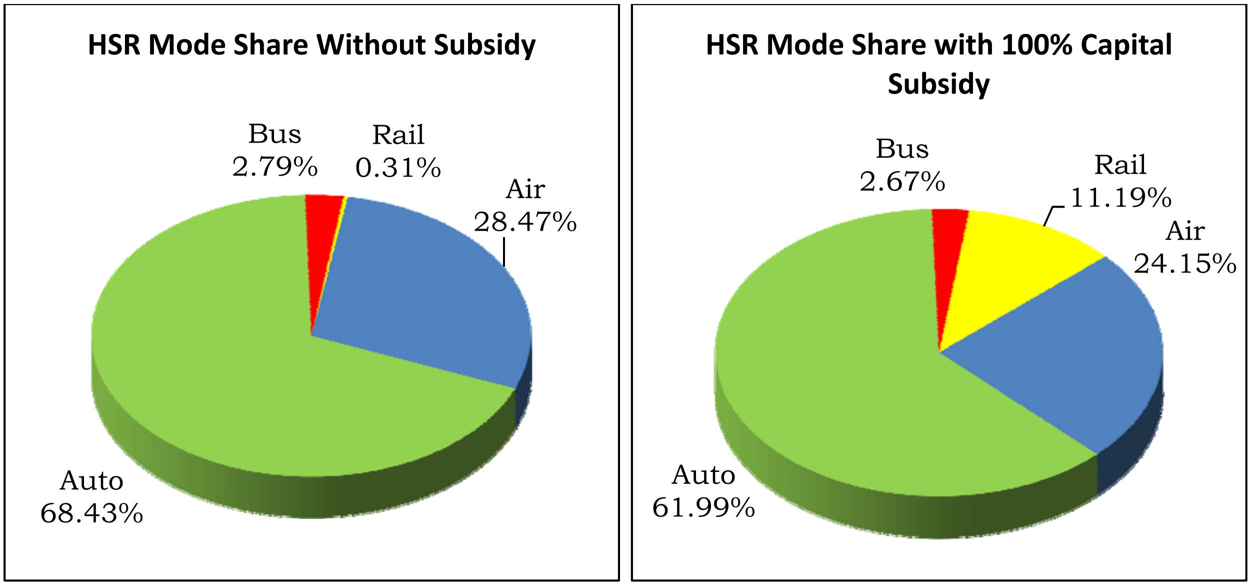


Figure 31. Demonstration of subsidy effect. Left, mode share without HSR subsidy; right, mode share with 100 percent HSR capital subsidy.

The above effect is due almost entirely to the subsidy level and not the carbon price. High-speed rail is frequently cited as a way to reduce transportation CO_2 emissions because of its emissions advantage over other modes. It is not in dispute here that HSR produces far less emissions than auto and air – under extended trends assumptions HSR emits 0.000013 tonnes CO_2/PM, while auto emits about 0.0001 tonnes CO_2/PM. However, it turns out that HSR's emissions advantage is not large enough to result in mode shift when CO_2 emissions externalities are internalized. One of the only ways to actually determine the extent of environmental advantages of HSR is to internalize the social cost of emissions for all modes. If HSR does in fact hold a advantage over other modes in regard to CO_2 emissions, then internalizing those costs should theoretically shift intercity travelers to the HSR system because its user price should be less when one factors in the environmental damage from travel. The tables below show the share of emissions costs in the user price for each mode at the \$25/tonne and \$100/tonne level, as well as the total cost added to a trip in the corridor when CO_2 emissions costs are internalized.

Table 22: Carbon emissions share of total user price and estimated additional cost for a trip in corridor at \$25/tonne CO_2

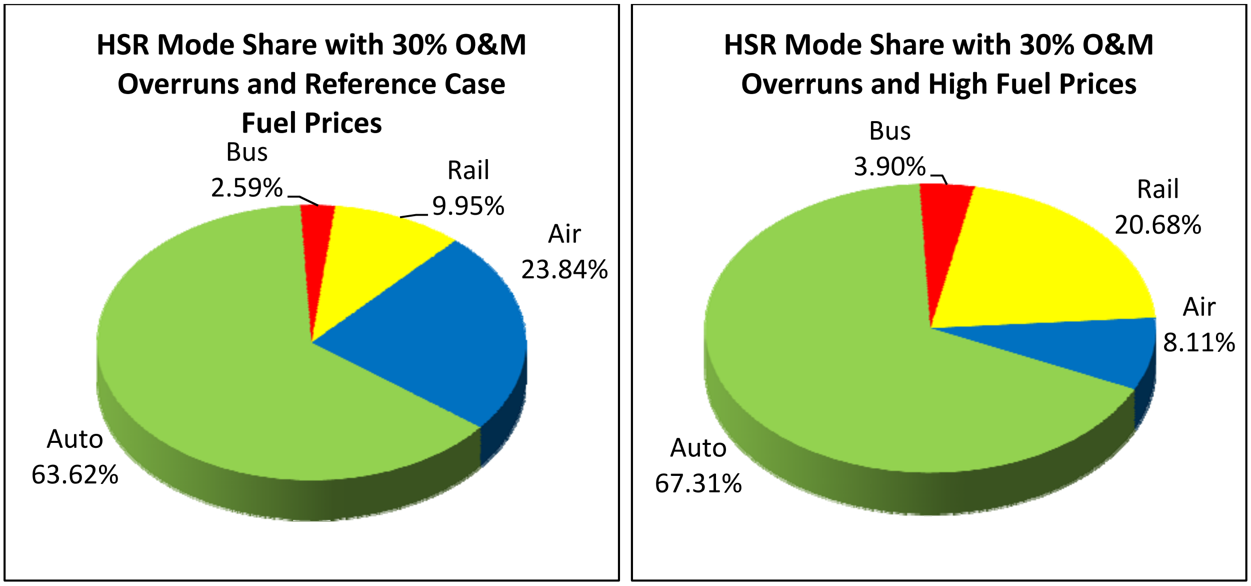
Mode	Emissions Cost % of User Price	\$ for trip in corridor
Auto	1.06%	\$1.25
Air	0.97%	\$2.00
Bus	0.65%	\$0.75
HSR	0.11%	\$0.21

Table 23: Carbon emissions share of total user price and estimated additional cost for a trip in corridor at $100/tonne CO_2

Mode	Emissions Cost % of User Price	$ for trip in corridor
Auto	4.14%	$5.05
Air	3.81%	$8.05
Bus	2.68%	$3.15
HSR	0.20%	$0.37

It is evident that a carbon price at any level is not likely to add enough of a cost to the user price that would result in any sizeable mode share shift. The relatively small impact of a carbon price on mode share in transportation, even with the highly efficient HSR system is added to the mix indicates that the potential to reduce CO_2 emissions in transportation under a carbon pricing scheme may be overstated in the public discourse. It may also be an indication that a carbon price may not be the most effective method by which to reduce CO_2 emissions in the intercity passenger transportation sector. If under a carbon pricing scenario automobiles continue to draw a bulk of the mode share, then a more effective strategy may be to focus efforts on automobile CO_2 reduction, rather than adding another costly mode to the mix. If HSR does not capture a sizeable mode share, not only will the cost to the public be high, but CO_2 emissions will not be significantly reduced. It should be noted that this analysis does not forecast overall trip demand within the corridor, so it is not possible to determine the magnitude of CO_2 emission reduction based on mode shares. However, it can be said that low HSR mode share figures are not likely to lead to large overall emissions reductions. Since automobiles retain a large portion of mode share under any scenario, the largest potential for emissions reductions will remain with that mode.

To demonstrate the fuel price effect on mode share, we compare two scenarios, one using the reference case fuel prices, and the other using high projected fuel prices. Fuel efficiency innovation is held constant across each of these scenarios in order to isolate the effect of high fuel prices. However, with a long term fuel price increase, we would expect fuel efficiency innovation to be accelerated over time, and considering the potential advantage automobiles have for innovation, the share of auto in this scenario is likely understated. Each scenario also assumes a 100 percent capital subsidy and 30 percent cost overruns for HSR. The fuel price effect is illustrated by the figures below.


HSR Mode Share with 30% O&M Overruns and Reference Case Fuel Prices

HSR Mode Share with 30% O&M Overruns and High Fuel Prices

Figure 32. Demonstration of fuel price effect. Left, mode share with reference case fuel prices; right, mode share with high fuel prices.

This is a sizeable mode share capture for HSR, and demonstrates that one of the most significant factors for achieving higher HSR mode shares can be highly volatile in the short term, difficult to predict, and largely out of the control of policy makers. Very large fuel taxes are likely the only method for policy makers to achieve these high fuel prices, and the political feasibility of such an action is probably near zero. The implication here is that gasoline prices around $8.75/gallon and jet fuel prices about the same will shift travelers mostly away from air toward HSR and automobiles. It is interesting that the auto mode share actually grows under these circumstances. This scenario highlights just how large of a portion of an air traveler's ticket price is influenced by the amount of fuel used on a trip. If fuel efficiency innovation was to be accelerated, we would expect auto to have the advantage over air, which would likely result in an even large mode share for auto.

The next area of attention is business travel. Not surprisingly, business travelers in the California corridor choose air travel as the dominant mode, given its speed advantage and this group's higher time valuation. Business travelers are also more likely than leisure travelers to choose HSR on the 616 mile distance between San Diego and San Francisco, presumably due again to the speed advantage with no intermediate stops. The effects on HSR business travel from cost overruns, subsidies, carbon prices, and high fuel prices are quite consistent with leisure travelers, so here we only illustrate the slightly larger HSR mode share for business travelers relative to leisure travelers. The figures below illustrate this difference with 30 percent O&M cost overruns and 100 percent capital subsidies.

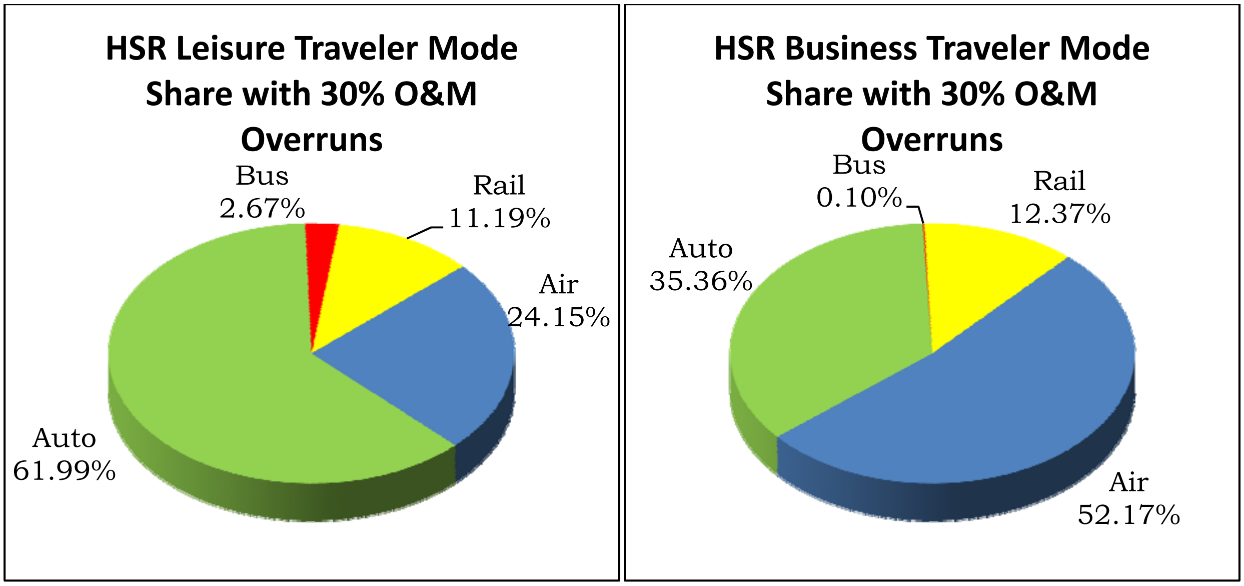


Figure 33. Demonstration of business mode share in corridor. Left, leisure mode share with 30 percent O&M cost overruns and 100 percent capital subsidy; right, business mode share with same assumptions applied.

Note the significantly larger air travel mode share for business travelers, and a slightly larger HSR mode share. These projections reflect the relative speed advantages of HSR and air in this analysis, but recall that HSR is assumed to make no intermediate stops. As more intermediate stops were added, we could expect auto's mode share to increase.

Another point of interest in this analysis considers the impact on future mode share under a scenario in which all modes experience a green revolution. From the results in the model and based on the projections of this study, it is clear that the auto mode is the beneficiary of a high innovation scenario, while the HSR mode share would depend in part on the price of electricity. Assuming that there will be no further large-scale hydroelectric dams built in California, reducing natural gas electricity production would need to be met with huge increases in renewable electricity generation, and likely some type of breakthrough in energy storage technology. The set of figures below illustrates a green revolution scenario in which HSR experiences just 30 percent O&M cost overruns.

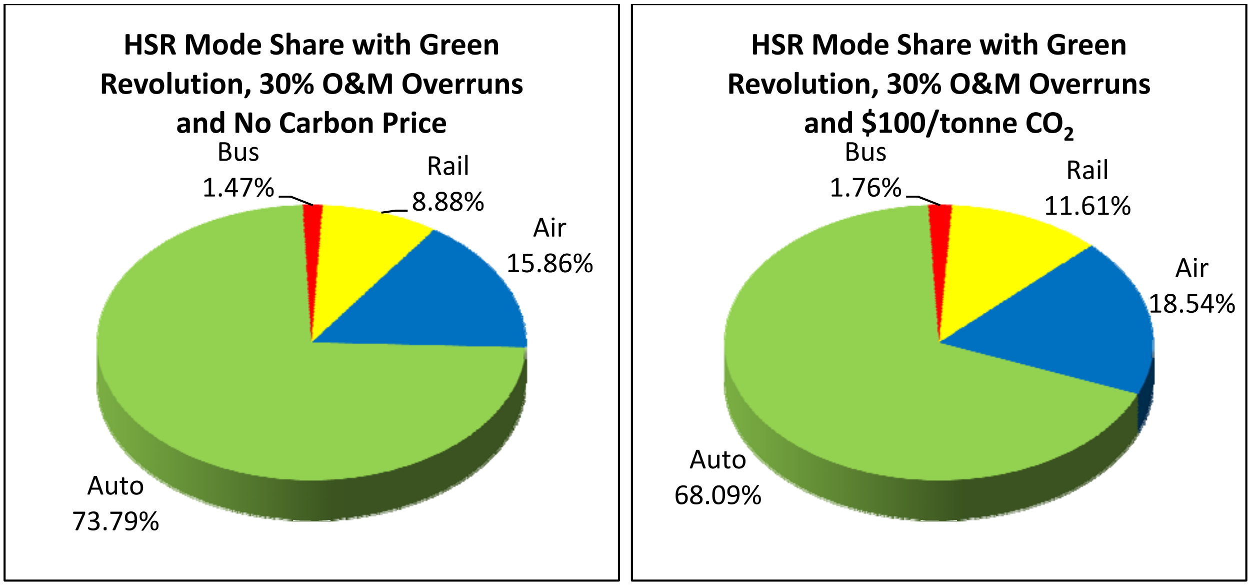


Figure 34. Demonstration of green revolution effect. Left, mode share under green revolution with 30 percent O&M cost overruns and no carbon price; right, mode share with same assumptions applied and $100/tonne carbon price.

The next set of figures below demonstrate the effect of large O&M cost overruns as a result of very high electricity prices from the large expansion of renewable energy sources in the generation mix.

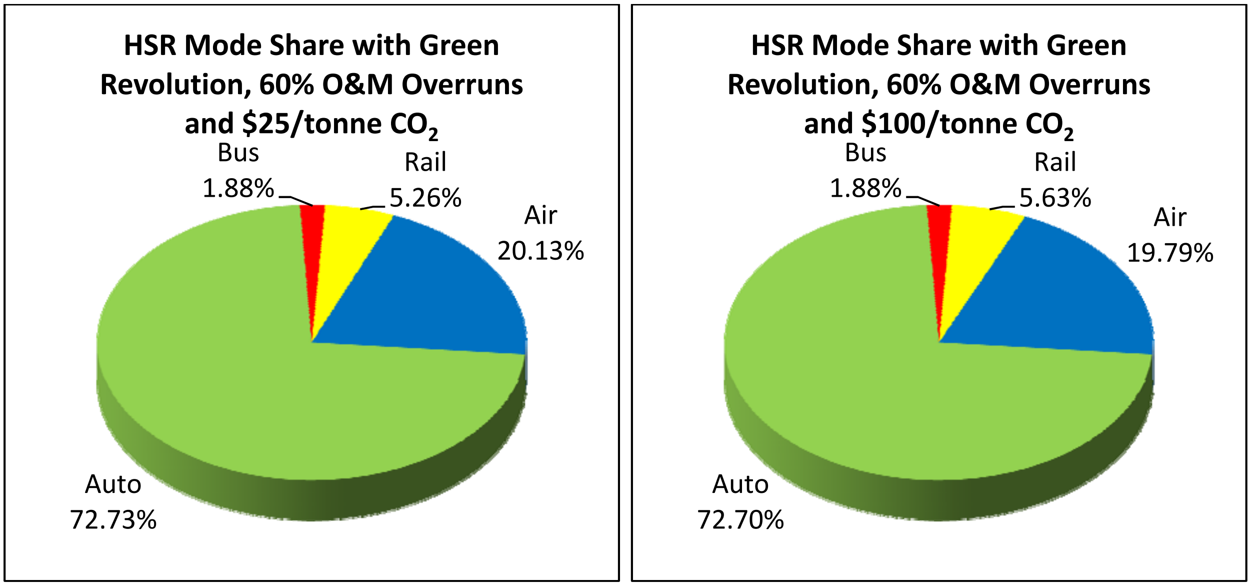


Figure 35. Demonstration of green revolution with large O&M cost overruns due to high electricity prices. Left, mode share with 60 percent O&M cost overruns and $25/tonne carbon price; right, mode share with same assumptions applied and $100/tonne carbon price.

A driving factor behind these changes can be attributed to the relative innovation scenarios of auto to air. It should be noted, however, that through a flaw of this analysis, high electricity prices are not applied to electric automobiles, which are assumed to have 20 percent market share under the green revolution scenario. This would increase the cost of driving electric automobiles and would likely reduce the mode share of automobiles, to some extent shifting those travelers to HSR. Essentially, this model expresses the relative advantage or disadvantage of each mode to the others. As innovation is varied, air loses mode share because its efficiency and innovation gains are projected to be less over time, relative to auto. A key argument in favor of establishing an HSR network has consistently been that HSR is much more energy efficient and less carbon intensive. While this was shown to be the case in the previous section, it will never be true in practice unless HSR can draw significant mode share away from the more carbon intensive modes. While HSR currently has an advantage over other modes with regard to energy consumption, it is demonstrated here that HSR is most sensitive to capital costs, subsidy levels, and high fuel prices. Marginal efficiency increases over time are not likely to bring down the cost of HSR travel enough relative to other modes so as to result in any major mode share shifts. Likely the greatest opportunity for innovation in HSR is during the construction phase. Process and operational innovations in construction that could bring down the capital costs have important implications for HSR mode share.

Policy Implications

Decisions about whether to invest in HSR and alter the mode choices of travelers ultimately become public transportation policy issues taking account of economic factors that influence mode choice. The primary policy focuses of this report with regard to HSR are taxpayer subsidies of capital and O&M costs and the potential effects of internalizing CO_2 emissions costs. We also evaluated the potential economic effects on mode share of roughly a 100 percent real fuel price increase over 50 years. Our conclusions listed above have various implications for policymakers the debate over establishing HSR networks carries on.

On the issue of taxpayer subsidies to finance HSR construction and O&M, we determine that HSR will not achieve user prices necessary to capture sizeable mode share without very high capital and O&M subsidies. This finding points to the need for a very accurate accounting of costs and projected ridership. As demonstrated above, the consequences of over projecting ridership and subsequently not achieving that ridership will result in further subsidies beyond a level already necessary to make user prices competitive with other modes (likely a 100 percent capital subsidy). The O&M costs estimated in this analysis came out to about $1.5 billion per year on the lower bound, so additional O&M subsidies will be sizeable and much of it likely to be absorbed by the state of California (Connell & Weikel, 2010). Without accurate accounting of costs and ridership, the accuracy of potential subsidies cannot be understood, and this may have serious fiscal implications for state budgets. Additionally, we demonstrated that cost overruns that are passed through into user prices have a sizeable negative effect on mode share. The implication of these cost overruns is that, in order to capture more sizeable mode share, the overruns will need to be covered by additional taxpayer subsidies. Prior to constructing an HSR network, the public and policy makers should be fully aware of these implications, and be provided with the most accurate and realistic information regarding costs and ridership. In the event that costs and ridership are accounted accurately and realistically, taxpayer subsidies for HSR should be strongly justified with potential public benefits given the magnitude of the potential subsidies.

High-speed rail is frequently cited as a strategy for reducing CO_2 emissions from intercity transportation. While it is not in dispute here that HSR is much less carbon intensive than other modes, particularly auto and air, this analysis concludes that a CO_2 price will not noticeably affect mode share. The reason for the small effect is that the relative emissions advantage of HSR is not large enough for a carbon price to create enough a user price advantage that would result in travelers shifting modes. This analysis does not forecast aggregate travel demand, but we conclude that the mode shares projected to occur under realistic circumstances will not be high enough to generate large declines in CO_2 emissions from current levels. This leads to the possibility that building an HSR system may not be the most effective method of drastically reducing CO_2 emissions. Given that autos are projected to capture a large majority of mode share under most circumstances, the most effective policy focus to greatly reduce CO_2 emissions from intercity travel may be to achieve further improvements in auto fuel efficiency, or switch to less carbon intensive fuels such as cellulosic ethanol.

Lastly, this analysis finds that large increases in fuel prices have the potential to generate sizeable mode share shifts to HSR. This finding may provide some justification for constructing HSR as an alternative mode choice in the event that fuel prices rise in the long term. However, justification is needed for investing large amounts of capital and taxpayer subsidies into a transportation system in order to create a hedge against an economic factor that is highly uncertain and largely outside the influence of public policy. In the event that fuel prices remain at current levels or even slightly rise, HSR is not likely to capture sizeable mode share, so ridership deficits that would likely result would need to be covered by taxpayer subsidies. Additionally, as outlined in the previous subsection, large long-term fuel price increases would likely result in accelerated fuel efficiency innovation, which would benefit auto mode share, thus creating a smaller fuel effect than is projected in this analysis.

This study is not a benefit-cost analysis. It is certainly possible that an HSR network could result in public benefits not considered here. An HSR system could spur economic development along the line, foster increased economic and social collaboration between city pairs, provide benefits by offering diversity in transportation mode choice in the case of short term fuel price spikes, and provide longer term benefits by using domestic energy sources rather than foreign sources of petroleum. On the other hand, the analysis also does not consider additional public costs such as noise, nuisance or changes in land use that could reduce net public benefits. Assessing accurate net benefits for HSR projects, however, will still require realistic estimates of potential ridership, user prices, and costs.

Table 24: California corridor mode share projections and corresponding scenarios.

	California Leisure				California Business			
	Auto	**Bus**	**Rail**	**Air**	**Auto**	**Bus**	**Rail**	**Air**
No HSR Cost Overruns								
Extended Trends Innovation Medium Fuel Price								
No Carbon Price No Subsidy	67.59%	2.76%	1.54%	28.12%	38.05%	0.10%	2.99%	58.86%
$25/tonne Carbon Price 50% Rail Capital Subsidy	64.83%	2.68%	5.95%	26.53%	36.41%	0.10%	7.82%	55.67%
$50/tonne Carbon Price 75% Rail Capital Subsidy	61.25%	2.57%	11.51%	24.67%	34.79%	0.10%	12.53%	52.58%
$100/tonne Carbon Price 100% Rail Capital Subsidy	54.63%	2.35%	21.74%	21.28%	32.29%	0.09%	19.98%	47.64%
Extended Trends Innovation High Fuel Price								
$100/tonne Carbon Price 100% Rail Capital Subsidy	54.04%	2.86%	36.58%	6.51%	39.31%	0.13%	35.68%	24.87%
Green Revolution Innovation High Fuel Price								
No Carbon Price 100% Rail Capital Subsidy	62.22%	1.51%	20.04%	16.23%	37.91%	0.07%	20.13%	41.88%
$100/tonne Carbon Price 100% Rail Capital Subsidy	59.74%	1.54%	22.45%	16.27%	36.56%	0.07%	21.71%	41.66%
30% HSR Cost Overruns								
Extended Trends Innovation Medium Fuel Price								
No Carbon Price No Subsidy	68.43%	2.79%	0.31%	28.47%	38.84%	0.11%	0.96%	60.10%
No Carbon Price 100% Rail Capital Subsidy	63.62%	2.59%	9.95%	23.84%	36.33%	0.10%	11.46%	52.11%
$25/tonne Carbon Price 50% Rail Capital Subsidy	67.64%	2.80%	1.87%	27.69%	67.64%	2.80%	1.87%	27.69%
$50/tonne Carbon Price 75% Rail Capital Subsidy	66.05%	2.77%	4.59%	26.60%	37.18%	0.10%	6.53%	56.18%
$100/tonne Carbon Price 100% Rail Capital Subsidy	61.99%	2.67%	11.19%	24.15%	35.36%	0.10%	12.37%	52.17%
Extended Trends Innovation High Fuel Price								
No Carbon Price 100% Rail Capital Subsidy	67.31%	3.90%	20.68%	8.11%	46.52%	0.16%	23.88%	29.43%
Green Revolution Innovation High Fuel Price								
No Carbon Price 100% Rail Capital Subsidy	73.79%	1.47%	8.88%	15.86%	44.97%	0.07%	11.75%	43.21%
$100/tonne Carbon Price 100% Rail Capital Subsidy	68.09%	1.76%	11.61%	18.54%	40.37%	0.08%	13.56%	46.00%
60% HSR Cost Overruns								
Green Revolution Innovation High Fuel Price								
$100/tonne Carbon Price No Subsidy	76.98%	1.99%	0.08%	20.96%	46.52%	0.09%	0.38%	53.01%
$25/tonne Carbon Price 100% Rail Capital Subsidy	72.73%	1.88%	5.26%	20.13%	42.81%	0.08%	*7.74%*	49.36%
$100/tonne Carbon Price 100% Rail Capital Subsidy	72.70%	1.88%	5.63%	19.79%	42.89%	0.08%	8.15%	48.88%

Chapter VIII: Conclusions

VIII. CONCLUSIONS

The national outlook for intercity passenger transportation includes continued dominance of the air and auto modes even in the presence of high fuel prices and a high carbon price. In particular, the auto mode is expected to maintain its dominance over short distances and gain greater mode share over intermediate distances of approximately 500 miles. In short, commercial airplanes and personal automobiles will not disappear from the U.S. travel landscape during the next 50 years. As a result, any policies aimed at reducing the greenhouse gas intensity of passenger transportation will need to focus on improving technology in these modes, not simply on switching to less carbon-intensive modes.

Even in the rail-friendly corridor of San Diego to San Francisco, high-speed rail is not expected to achieve a large mode share without significant subsidies. This raises the question of whether high-speed rail has sufficient external benefits to merit the payment of subsidies by non-riders. In essence, should people who never set foot on a train pay a significant portion of the costs for those who regularly ride the rails? This report does not attempt to quantify the external benefits of rail. Therefore, additional research is necessary to answer this question.

It is important to stress that this report considers only intercity transportation. The study does not address whether trains, buses, bicycles, and other alternative forms of transportation will gain greater mode share within cities. An entirely new study would be necessary to examine the urban transportation outlook. Furthermore, additional research is necessary to examine the linkages between urban and intercity transportation networks. Ultimately, it is hoped that this report will spur greater research into comprehensive, cross-modal assessments of passenger transportation.

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Appendix A: Model Technical Details

DESCRIPTION OF THE MODEL PARAMETERS AND DIAGNOSTICS

A conditional logit model was estimated with Stata software using National Household Travel Survey (NHTS) 2009 data (BTS, 2011c) and the variables described below (see Figure 1). Both the business and leisure models were statistically significant (χ^2 values with p <0.001) and had a high pseudo R^2, meaning that variation among the independent variables (time, user cost, and other constants) explained a large amount of the variation in the dependent variable (mode choice). Summary statistics of the two models are presented in Table 1.

Figure 1: Estimated Conditional Logit Equation

$$Y_{ij} = \alpha_{ij} + \beta_{1ij}(\mathrm{Ln(Time)}) + \beta_{2ij}(\mathrm{User\ Cost})$$

Table 1: Summary Statistics of Conditional Logit Models:

Model	Pseudo R-Squared	Log Likelihood Ratio	Chi-squared (p-value)
Business	0.9233	-448.82223	10808.23 (<0.0001)
Leisure	0.8812	-2857.0574	42395.84 (<0.0001)

BUSINESS MODEL

Business Model Parameter Estimates

Table 2: Business Model Parameter Estimates

	Coefficient (s.d.)	Z-statistic (p-value)	Odds Ratio (s.d.)	Z-statistic (p-value)
User cost (tavcost5)	-.0204234 (.0029342)	-6.96 (<0.001)	.9797838 .0028749	-6.96 (<0.001)
Ln of Time (logtim)	-3.876752 (.244403)	-15.86 (<0.001)	020718 (.0050635)	-15.86 (<0.001)
Constant: Bus-income interaction (busxinc)	-.0000761 (6.69e-06)	-11.38 (<0.001)	.9999239 (6.69e-06)	-11.38 (<0.001)
Constant: Rail-income interaction (trainxinc)	-.0000475 (5.74e-06)	-8.27 (<0.001)	.9999525 (5.74e-06)	-8.27 (<0.001)
Constant: Air-income interaction (trainxinc)	-.0000206 (2.66e-06)	-7.73 (<0.001)	.9999794 (2.66e-06)	-7.73 (<0.001)

The business model parameters are all significant, with p-values of <0.001, as shown above in Table 2 with additional model information found in Table 3 below. All coefficient signs are negative, corresponding to theory:

- As the **log of trip time** increases on a given mode, the probability of taking that given mode decreases.
- As the **user cost** increases on a given mode, the probability of taking that given mode decreases.
- The **constants** demonstrate that, compared to the default mode of auto, individuals are less disposed to choose bus, rail, and air. The constants pick up much of the variation in the model that is not accounted for in the other independent variables. The constants are interaction terms with income, indicating that individuals of different income levels respond differently to the four modes.

Table 3: Business Model Output

Conditional (fixed-effects) logistic regression Number of obs = 16888C

LR χ^2 (5) = 10808.23

Prob > χ^2 = 0.0000

Log likelihood = -448.822 Pseudo R^2 = 0.9233

choice	Coef	Std. Err.	z	P>|z|	[95% Conf. Interval]	
tavcost5	-0.0204234	0.029342	-0.696	0.000	-0.0261743	-0.0146724
logtim	-3.876752	0.244403	-15.86	0.000	-4.355773	-3.397731
busxinc	-0.0000761	6.69E-06	-11.38	0.000	-0.0000893	-0.000063
trainxinc	-0.0000475	5.74E-06	-8.27	0.000	-0.0000588	-0.0000362
airxinc	-0.0000206	2.66E-06	-7.73	0.000	-0.0000258	-0.0000154

choice	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf. Interval]	
tavcost5	0.9797838	0.0028749	-0.696	0.000	0.9741652	0.9854347
logtim	0.020718	0.0050635	-15.86	0.000	0.0128325	0.0334491
busxinc	0.9999239	6.69E-06	-11.38	0.000	0.9999107	0.999937
trainxinc	0.9999525	5.74E-06	-8.27	0.000	0.9999412	0.9999638

Figure 2: 2009 Business Predicted Probabilities Distribution as a Function of Trip Miles

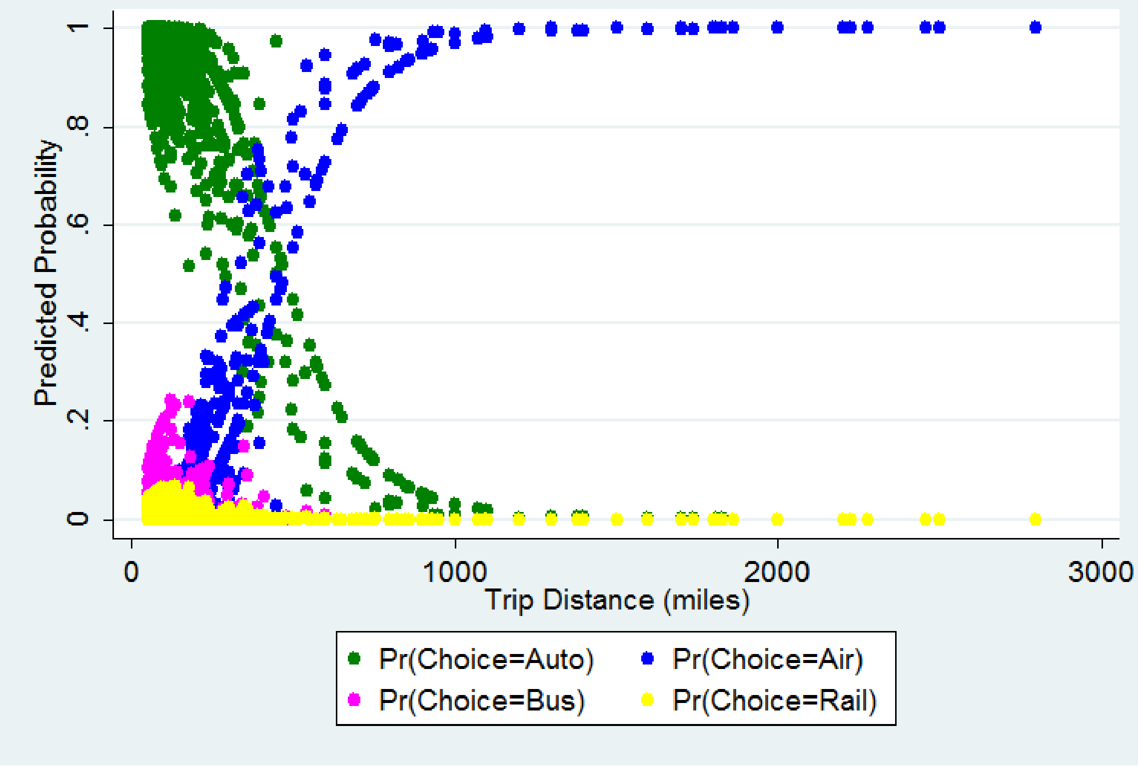

Figure 2 shows the probability distribution predicted by applying the model to the NHTS data, plotted against trip distance for business mode share. It demonstrates the baseline for the future model scenarios – under different scenarios of user cost and time, the probability distribution will shift.

LEISURE MODEL

Leisure Model Parameter Estimates

Table 4: Leisure Model Parameter Estimates

	Coefficient (s.d.)	Z-statistic (p-value)	Odds Ratio (s.d.)	Z-statistic (p-value)
User cost (tavcost5)	-.0141584 (.0006449)	-21.95 (<0.001)	.9859413 .0006359	-21.95 (<0.001)
Ln of Time (logtim)	-3.348757 (.1118898)	-29.93 (<0.001)	.035128 .0039305	-29.93 (<0.001)
Constant: Bus-income interaction (busxinc)	-.0000608 (1.76e-06)	-34.50 (<0.001)	.9999392 1.76e-06	-34.50 (<0.001)
Constant: Rail-income interaction (trainxinc)	-.0000776 (4.55e-06)	-17.03 (<0.001)	.9999224 4.55e-06	-17.03 (<0.001)
Constant: Air-income interaction (trainxinc)	-.0000344 (1.38e-06)	-24.89 (<0.001)	.9999656 1.38e-06	-24.89 (<0.001)

The business model parameters are all significant, with p-values of <0.001, as shown in Table 4 with supplemental leisure model information in Table 5. All coefficient signs are negative, corresponding to theory:

- As the **log of trip time** increases on a given mode, the probability of taking that given mode decreases.
- As the **user cost** increases on a given mode, the probability of taking that given mode decreases.
- The **constants** demonstrate that, compared to the default mode of auto, individuals are less disposed to choose bus, rail, and air. The constants pick up much of the variation in the model that is not accounted for in the other independent variables. The constants are interaction terms with income, indicating that individuals of different income levels respond differently to the four modes.

Table 5: Leisure Model Output

Conditional (fixed-effects) logistic regression Number of obs = 69408

LR χ^2 (5) = 42395.84

Prob > χ^2 = 0.0000

Log likelihood = -2857.0574 Pseudo R2 = 0.8812

choice	Coef	Std. Err.	z	P>|z|	[95% Conf.	Interval]
tavcost5	-0.0141584	0.0006449	-21.95	0.000	-0.0154225	-0.0128944
logtim	-3.348757	0.1118898	-29.93	0.000	-3.568057	-3.129457
busxinc	-0.0000608	1.76E-06	-34.5	0.000	-0.0000643	-0.0000574
trainxinc	-0.0000776	4.55E-06	-17.03	0.000	-0.0000865	-0.0000687
airxinc	-0.0000344	1.38E-06	-24.89	0.000	-0.0000371	-0.0000317

choice	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
tavcost5	0.9859413	0.0006359	-21.95	0.000	0.9846959	0.9871884
logtim	0.035128	0.0039305	-29.93	0.000	0.0282106	0.0437415
busxinc	0.9999392	1.76E-06	-34.50	0.000	0.9999357	0.9999427
trainxinc	0.9999224	4.55E-06	-17.03	0.000	0.9999135	0.9999314
airxinc	0.9999656	1.38E-06	-24.89	0.000	0.9999629	0.9999683

Figure 3: 2009 Leisure Predicted Probabilities Distribution as a Function of Trip Miles

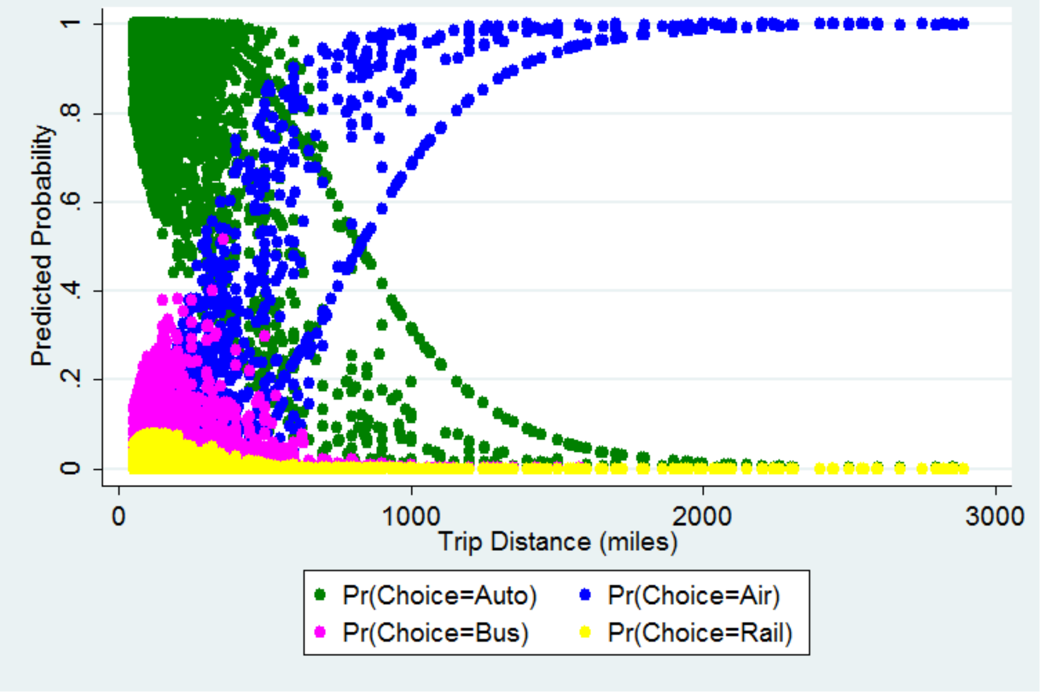

Figure 3 shows the probability distribution predicted by applying the model to the NHTS data, plotted against trip distance for leisure mode share. It demonstrates the baseline for the future model scenarios – under different scenarios of user cost and time, the probability distribution will shift.

CALCULATED VARIABLES IN BUSINESS AND LEISURE MODELS

Derivations of Time Spent on Trip

To derive an estimate of the time spent traveling between cities, we used the best available sources and assumptions to find average speeds by mode. For both automobiles and buses, we assumed an average speed of 66.11 miles per hour, based on the average maximum speed limit on U.S. interstates. Recent studies have found that in general, average highway speed closely matched interstate speed limits (BTS, 2008b; Shunk, 2010). We determined that typical national rail speeds were 46.17 miles per hour based on train travel times (FRA, n.d.), and that average passenger air speeds were 511 miles per hour based on the typical speeds of airliners (FAA, 2010b). For the California scenarios, we assumed the trains would have the same speed as the TGV in France – an average of 173 miles per hour and up to 200 miles per hour on longer track lengths (Taylor, 2007). We added additional trip time for non-automobile modes in consideration of the following factors: average delays where applicable (five minutes), travel to transit hubs (30 minutes), and early arrival at airports (90 minutes). We assumed that delays were already incorporated into national rail travel times. The California HSR scenario included an extra 15 minutes for the stop in Los Angeles. We calculated the travel times for each segment of the California HSR scenario separately and added these times together. These calculations by mode resulted in the paneled variable "trpminutes" (in minutes). The specific equations used for each mode are shown below, including the California HSR calculations. The HSR trip time calculations did not vary between scenarios, since we assumed only one stop between cities and one route for all of the simulations.

Automobile: $trpmiles\ (miles) \cdot \frac{60\ minutes/hour}{66.11\ miles\ per\ hour}$

Bus: $trpmiles\ (miles) \cdot \frac{60 \frac{minutes}{hour}}{66.11\ miles\ per\ hour} + 30\ minutes$

Rail: $trpmiles\ (miles) \cdot \frac{60 \frac{minutes}{hour}}{46.17\ miles\ per\ hour} + 30\ minues$

Air: $trpmiles\ (miles) \cdot \frac{60 \frac{minutes}{hour}}{511\ miles\ per\ hour} + 30\ minutes + 5\ minutes + 90\ minutes$

HSR, San Diego to Los Angeles: $116\ miles \cdot \frac{60 \frac{minutes}{hr}}{173\ miles\ per\ hour} = 40.23\ minutes$

HSR, Los Angeles to San Francisco:

$$100\ miles \cdot \frac{60 \frac{minutes}{hr}}{173\ miles\ per\ hour} + 400\ miles \cdot \frac{60 \frac{minutes}{hr}}{200\ miles\ per\ hour} = 154.68\ minutes$$

HSR Total:

$$30\ minutes + 40.23\ minutes + 15\ minutes + 154.68\ minutes = 239.91\ minute$$

Derivation of the Airfare Function

We obtained airfare data for the top 1000 US passenger airline markets in the third quarter of 2010 from the Office of Aviation Analysis, along with the distances along these routes. After deriving the fare per mile for each market in Excel, we regressed airfare per mile against market distance (in miles) using several alternative specifications - linear, logarithmic-linear, linear-logarithmic, and logarithmic-logarithmic. The F-statistic in every regression was significant, as were the t-statistics for the beta coefficients in all of the regressions. However, the logarithmic-logarithmic specification had the highest R^2 value (Table 6). The final equation, $\ln\left(\frac{airfare}{distance}\right) = 3.12918 - 0.69534 \cdot \ln(distance)$, indicates that every 0.695 percent increase in distance traveled from the baseline corresponds to a one percent decrease in airfare per mile, *ceteris paribus*.

Table 6:

Specification	**F-Statistic**	**R^2**	**Adjusted R^2**	**t-statistics**	
				Intercept	**Distance Coefficient**
Linear	958.99	0.4898	0.4893	64.83	-30.97
Logarithmic-Linear	2128.74	0.6806	0.6803	-51.82	-46.14
Linear-Logarithmic	2194.58	0.6872	0.6869	55.65	-46.85
Logarithmic-Logarithmic	4133.17	0.8053	0.8052	42.40	-64.29

Source: Office of Aviation Analysis. (2010). Domestic airline fares consumer report. Third Quarter, 2010. Retrieved from http://ostpxweb.dot.gov/aviation/X-50%20Role_files/consumerairfarereport.htm

Appendix B: 2060 Emissions Cost Projection Methodologies and Definitions

AUTO

The baseline illustrates the current amount of carbon emissions per passenger mile. In order to arrive at this figure, pounds of carbon dioxide per gallon is divided by vehicle average miles per gallon for highway travel and average number of passengers per vehicle, which differs for business and leisure travel (1.39 and 2.63, respectively) (BTS, 2011c). Pounds of carbon dioxide emitted per gallon were taken from the EPA Emission Fact Sheet that was developed to serve as a standard value for annual GHG emissions from a passenger vehicle. This standard value of 19.4 pounds of carbon dioxide per gallon of gasoline was generated to maintain consistency when comparing GHG emissions among federal programs. Values were taken from the Code of Federal Regulations at 40 CFR 600.113-78 to determine this standard. Assumed values include 2,421 grams of carbon per gallon of gasoline and an oxidation factor of 0.99. This standard includes emissions from the vehicle only, not lifecycle carbon dioxide emissions (EPA, 2005a).

Table 1:			
Gas/Vehicle Type	**1990 Tg (CO_2 Eq.)**	**2008 Tg (CO_2 Eq.)**	**Overall % Change**
Passenger Cars	**657.3**	**632.1**	**-3.8%**
CO_2	629.2	597.5	-5.0%
CH_4	2.6	0.8	-69.2%
N_2O	25.4	11.7	-53.9%
HFCs	+	22.1	1909.1%
Light-Duty Trucks	**336.5**	**552.4**	**64.2%**
CO_2	321	513.7	60.0%
CH_4	1.4	0.6	-57.1%
N_2O	14.1	9.5	-32.6%
HFCs	+	28.6	2283.3%
Medium- and Heavy-Duty Trucks	**231.1**	**401.2**	**73.6%**
CO_2	230.1	388.6	68.9%
CH_4	0.2	0.1	-50.0%
N2O	0.8	1	25.0%
HFCs	+	11.6	5700.0%
Buses	**8.4**	**12.1**	**44.0%**
CO_2	8.4	11.7	39.3%
CH_4	+	+	N/A
N_2O	+	+	N/A
HFCs	+	0.4	300.0%
Motorcycles	**1.8**	**2.2**	**22.2%**
CO_2	1.7	2.1	23.5%
CH_4	+	+	N/A
N_2O	+	+	N/A
TOTAL HIGHWAY	**1235.1**	**1600.0**	**29.5%**
Source: Environmental Protection Agency (2010, April 15). Inventory of US Greenhouse Gas Emissions & Sinks: 1990-2008. EPA 430-R-10-006.			

AIR

$$(\mathit{Fuel\ Consumption})\times\left(\frac{\mathit{Domestic, Scheduled, Revenue\ Aircraft\ Miles}}{\mathit{Domestic\ CFR}\,121\ \mathit{and\ CFR}\,135\ \mathit{Aircraft\ Miles}}\right)\times\left(\frac{9.57\ kg\ CO_2}{\mathit{gallon\ Jet\ A}}\right)\times\left(\frac{10^3\ g}{kg}\right)\times\left(\frac{1}{\mathit{Domestic, Scheduled, Revenue\ Passenger\ Miles}}\right)$$

Methodology

1. *Remove fuel consumption from aircraft outside the scope of this study:* multiply fuel usage figure by the fraction of domestic, scheduled, revenue aircraft miles within the 14 CFR 121 and 14 CFR 135 total domestic aircraft miles

2. *Figure Carbon Dioxide emissions:* multiply fuel consumption for the domestic, scheduled, revenue passenger carriers by the Carbon Dioxide emission factor of 9.57 kg of CO_2 per gallon of Jet A Fuel, derived from the EIA (2005).

3. *Determine average grams of CO_2 per passenger mile:* divide carbon dioxide emissions by the domestic, scheduled, revenue passenger miles

4. *Create Regression Model:* calculations performed on 1996 to 2009 data and create exponential regression model

Regression Model Results: R^2 : 0.76797

The model predicts an 11.3 percent reduction in CO_2 from 2009 levels by 2060, assuming no carbon tax. The exponential function of the model was chosen because the substantial reductions in emissions per passenger mile (2.9 percent average annual decrease) can largely be attributed to load factors, which have increased from 68.0 percent in 1996 to 80.7 percent in 2009 (BTS, 2011a). In the future, lower rates of fuel efficiency gains will result because load factors will be unable to continue increasing at the same rate due to capacity issues, and the exponential design of the model accounts for these decreased rates.

Definitions

14 CFR 121: Major commercial or cargo aircraft, or aircraft with 10 or more seats (NTSB, 1998).

14 CFR 135: Scheduled service on aircraft with less than 10 seats or non-scheduled commercial or cargo aircraft (NTSB, 1998).

Variables

Fuel usage: Table 4-8 of the BTS National Transportation Statistics, 14 CFR 121/135 (BTS, 2011d).

Revenue aircraft miles: BTS U.S. Air Carrier Traffic Statistics (2011d) *Aircraft miles:* for 14 CFR 121 and 14 CFR 135 were obtained from Table 4-21 of the BTS National Transportation Statistics (2011d).

GHG Emissions: Greenhouse gas emissions absorb and emit radiation within the thermal infrared range. This process is the fundamental cause of the greenhouse effect. The primary greenhouse gases in the Earth's atmosphere are water vapor, carbon dioxide, methane, nitrous oxide, and ozone. (EPA, 2006).

Direct Emissions: Direct emissions occur during the operation and maintenance of vehicles (EPA, 2006).

Upstream Fuel Cycle: Upstream emissions are those that occur before a product is used, including extraction of raw materials, processing, manufacturing, and assembly. Sources of upstream emissions include any fuel combustion associated with these processes, as well as "fugitive" emissions, such as venting and/or flaring of natural gas from oil wells or natural gas plants. (EPA, 2006).

RAIL

Assumptions for CO_2 tonne/pm

Carbon dioxide emissions for rail assume emissions from actual train operations, not life cycle emissions of raw materials and construction. We used the national average emissions per kWh from the net generation of electricity from fossil fuel use in the electric power sector (EIA). High speed rail energy intensity was assumed from the energy requirement of the Shinkansen in Japan. The most recent equipment (Nozomi 700N) uses 0.037 kWh/seat km at 220km/hr (136.7mph), and 0.049kWh/seat km at 270km/hr (167.8mph) (Noda, 2009). Emissions for high speed rail use the estimated gCO_2/kWh based on California's electricity generation mix. This is slightly complicated by the fact that California consumes more electricity than it produces, so electricity production from the pacific northwest is included and weighted by its percentage contribution to California's electricity (about 8%), as well as electricity production from the U.S. southwest and weighted by its percentage contribution (about 18%).

Emissions from electricity generation in the US in 2008 were near 580gCO2/kWh including loses in transmission and distribution (EIA, 2010f). In 2008, the share of fossil fuels used in energy production was 48% coal, 1% oil, and 21% natural gas (EIA, 2010f). The 2050 "extended trends" scenario assumes shares of 44% coal, 0% oil, and 26% natural gas, along with a 5% decline in primary energy to electricity (consistent with historical progress, resulting in 520gCO_2/kWh (EIA, 2010f). CO_2 intensities for electricity production were extrapolated to 2060 using US EIA 2035 projections, from the EIA's Annual Energy Outlook (2010f). For the "green revolution" scenario, the fossil fuel inputs were reduced by half, leading to shares of 22% coal, 0% oil, 10% natural gas, with losses from production and delivery declining 15%, resulting in 222gCO_2/kWh, consistent with EIA's 2030 low case scenario of 237 gCO2/kWh (EIA, 2010f). The same methods are applied to California and the U.S. northeast electricity mix in order to estimate emissions from high speed rail and electrified Amtrak routes, respectively. California emissions in 2008 were found to be

320gCO_2/kWh, extended trends 289 gCO_2/kWh, and green revolution 129gCO_2/kWh. Northeast corridor electricity emissions were found to be 449 gCO_2/kWh in 2008, extended trends 395 gCO_2/kWh, and green revolution 183 gCO_2/kWh.

Load factors for high speed rail and Amtrak have been assumed to be 65% and 50%, respectively. Amtrak load factors are borrowed from Amtrak September Montly Performance Reports (end of FY).

High Speed Rail - California

To calculate final environmental cost per passenger kilometer the following equation is applied:

Cost/pm= [EC/LF]*[EM/10^6]*[CP]

Where EC is the energy consumption of the rolling stock in kWh/seat-mile, LF is the estimated load factor (passenger-mile/seat-mile), EM is emissions (in gCO_2/kWh), and CP is the estimated carbon price.

Energy consumption was assumed from the energy requirement of the Shinkansen in Japan. The most recent equipment (Nozomi 700N) uses 0.037 kWh/seat km at 220km/hr (136.7mph), and 0.049kWh/seat km at 270km/hr (167.8mph) (Noda, 2009). Keeping these comparative energy intensities in mind, three values of energy consumption were used for sensitivity analysis, a low value of .03kWh/seat km, a medium value of .04kWh/seat km, and a high value of .05 kWh/seat km. Load factors from CE Delft (2003) data regarding TGV ridership estimate loads of 67 percent in the moderately populated French Paris to Lyons corridor. Sensitivity analysis is applied to load factors.

Emissions values are presented in gCO2/kWh, and are based on national average CO_2 emissions per kWh generated by the electric power sector for each fossil fuel primary energy source. The national average electricity generation mix from fossil fuels is estimated using the EIA's State Electricity Profile figures for net kWh generation from the electric power industry by primary energy source, including coal, natural gas, petroleum, other gases, nuclear, hydroelectric, other renewables, and other (EIA, 2010e). The national average gCO_2/kWh by fossil fuel source is multiplied by the percentage of each fossil fuel generation energy source in the mix to arrive at gCO_2/kWh from each respective source (EIA, 2010d):

EM_s=EM*10^6/kWh*MS

Where EM_s is CO_2 emissions in grams per kWh from coal, natural gas or petroleum, and MS is the percent share of that particular primary energy source in the generation mix.

Each source outside of coal, natural gas and petroleum is assumed to have negligible or no CO_2 emissions. In 2008, each kWh generated from the electric power industry in the U.S. is estimated to emit 79 gCO_2 from coal, 89 gCO_2 from natural gas, and 10 gCO_2 from petroleum for a total of 578 gCO_2/kWh.

Appendix C: Major Data Assumptions and Definitions

National Household Travel Survey

The National Household Travel Survey (NHTS) conducted by the Bureau of Transportation Statistics was a central data set necessary for future predictions. A more exhaustive technical appendix, codebook, and user manual is available at www.bts.gov. The following appendix details definitions and manipulations relative to the report (BTS, 2011c).

Weighted v. Unweighted

Weighted values are utilized in the NHTS in order to correct for sampling error and bias in the data set. The weighted values correct for a variety of confounding variables such as nonresponse households, time of survey, geographical location of phone number, travel dates, ethnicities, etc. A variety of weights were applied to the NHTS data in order to account for the bias created through sampling strata. For a detailed explanation of the weighting process utilized in the NHTS refer to the 2009 NHTS User Guide (BTS, 2011c).

Different weights were created depending on the file, household, personal, vehicle, or travel day trip. For this report, the travel day trip dataset and its corresponding sampling weight were utilized for the statistical modeling. While the weighted value attempts to control for sample bias, in some cases the unweighted value is also useful. In many sections of the report both the weighted and unweighted values are reported.

Definitions

Long-distance trip: a trip of 50 miles or more away from home

Business: includes trips taken to attend conferences and meetings or for any other business purpose other than commuting to and from work. Trips are classified as business so long as business is the primary purpose, even though the traveler may have done some sightseeing or other pleasure activities

Pleasure: includes vacations, sightseeing excursions, as well as trips taken for the purposes of rest and relaxation, visiting friends and family or outdoor recreation"

Personal and family business: "includes medical visits, shopping trips, and trips to attend weddings funerals, etc."

Work: "trips to and from work, commonly referred to as commuting trips"

Variables

The following variables were utilized from the NHTS day trip dataset.

HHFAMINC: Derived total household income
Response Options: Eighteen income range options, I don't know, Refused, Not ascertained

NUMONTRP: Count of total people on trip
Response Options: 1-16 people

TRPMILES: Calculated Trip distance converted into miles
Response Options: Not ascertained, Don't know, Refused (Data coded with additional option: Appropriate Skip)

TRPTRANS: Transportation mode used on trip
Response Options: Refused, Don't know, Not Ascertained, Car, Van, SUV, Pickup Truck, Other Truck, RV, Motorcycle, Golf Cart, Local Public Bus, Commuter Bus, School Bus, Charter/Tour Bus, City-to-city Bus, Shuttle Bus, Amtrak/Intercity train, Commuter Train, Subway/Elevated Train, Street Car/Trolley, Taxicab, Ferry, Airplane, Bicycle, Walk

WHYTRP90: 1990 Trip Purpose
Response Options: To/From Work, Work-related business, Shopping, Other Family/Personal Business, School/Church, Medical/Dental, Vacation, Visit Friends/Relatives, Other Social/Recreational, Other, N/A, Refused

AUTO

Costs of owning and operating a vehicle (which we refer to as user price, the out of pocket expense a user sees for driving) are taken from BTS's use of American Automobile Association (AAA) statistics on the average costs of owning and operating an automobile (BTS, 2010d; AAA, 2011). The AAA data assumes 15,000 vehicle miles drive per year in stop-and-go travel, and is not limited to intercity travel. We accepted this assumption because personal vehicles are not used solely for intercity travel. Stop and go conditions will overestimate the price of driving on intercity trips if we assume that intercity travel requires a more fuel-efficient average speed, and less stop and go driving. Even with this overestimate of cost, auto travel still gains mode share in most scenarios in 2060.

The AAA data, after 1985, assumes insurance figures based on a "full coverage policy for a married 47-year-old male with a good driving record, living in a small city and community three to ten miles daily to work" (BTS, 2010d). AAA figures are found by a composite of three current model vehicles with standard and optional features, such as automatic transmission, air conditioning, anti-lock breaks, air bags, and others (BTS, 2010d).

BUS

Bus user prices were derived using data from 1990-2001, when the most recent bus revenue information was collected (Eno Transportation Foundation, Inc., 2002). These data do not reflect the most recent trends in bus prices because no data were collected. These data do not consider modern changes to the American intercity bus system—including curbside intercity bus carriers such as Mega Bus and Bolt Bus, which began operation after 2001. The exclusion of these low-cost carriers could overestimate the per passenger mile user price and thus underestimate the mode share of bus in our final model. We assume that revenue per passenger mile translates to out-of-pocket user price per mile.

AIR

Air user costs are taken from the Depart of Transportation *TransStats* report. The average fair pace is $309. Majority of capital costs, such as infrastructure and security are paid for by user chargers and fees. Information regarding these projected capital and user fees are taken from FAA, ACI, and Congressional research reports. Understanding the relative amount of government subsidy compare to other modes is a key component of the model.

Definitions

Operating Revenue: Revenues from the performance of air transportation and related incidental services includes: 1) transportation revenues from the carriage of all classes of Traffic in scheduled and nonscheduled services, and 2) non-transportation revenues consisting of federal subsidies (where applicable) and services related to air transportation (Key Transportation Indicators, 2011f).

International Revenues: The data recorded does not include Foreign point-to-point flights. We chose to exclude these revenues since we are focusing on domestic inter-city travel. International data is included because many times inter-city travel occurs to before international travel, and domestic airlines are affected by this travel (Key Transportation Indicators, 2011f).

Itinerary Fare: Average fares are based on domestic itinerary fares, round-trip or one-way for which no return is purchased. Fares are based on the total ticket value which consists of the price charged by the airlines plus any additional taxes and fees levied by an outside entity at the time of purchase. Fares include only the price paid at the time of the ticket purchase and do not include other fees, such as baggage fees, paid at the airport or onboard the aircraft. Averages do not include frequent-flyer or 'zero fares' or a few abnormally high reported fares (TranStats, 2010c).

Passenger Revenue: Revenues from the transport of passengers by air (BTS, 2009c).

Enplanements: The total number of passengers boarding aircraft includes both originating and connecting passengers (BTS, 2009c).

Total Passenger Miles: The BTS receives monthly, quarterly, and annual reports from certified airline carriers documenting information about the airline's activities, including passenger information, flight operations, and distances between airports. Certification for the reporting carriers is defined under the U.S. Code 41102 as any carrier representing at least one percent of domestic passenger revenues on an annual basis. Documentation procedures and required statistics are outlined in CFR 234 and 241, and include number of passengers per flight that are not crewmembers and flight distance, from airport to airport in statute miles, or 5280 feet (T-100 Domestic Segment (U.S. Carriers). This information is used to determine total passenger miles, which is calculated by multiplying the number of passengers per flight and the flight distance, and summing this product for all flights performed by the carrier. BTS has used this information to supply quarterly reports to the public since 1990 in the form of the T-100 Segment Data (BTS, 2011d).

Committed Financing: projects with secured or expected funding, (Airport Council International, 2009).

Airport Improvement Program: provides grants to public agencies — and, in some cases, to private owners and entities -- for the planning and development of public-use airports that are included in the National Plan of Integrated Airport Systems (NPIAS), (Airport Council International, 2009).

AMTRAK

The data supplied in the Amtrak Annual and Performance Reports applies only to Amtrak, and not to other rail systems in the United States. Passenger related revenue was calculated to contain ticket revenue, as well as state contribution revenue associated with service requested by Amtrak, beyond basic route service. These revenues are counted as operating revenues, while passenger related revenue listed in the report excludes 403(b) service revenue. 403(b) service is additional service requested and partially funded by states (Amtrak, 2009a). It should also be noted that passenger miles do not include contract commuter passenger miles.

Variables

The following are variables used from Amtrak, 2009a:

Operating Ratio:* calculated as Total Operating Expenses / Total Operating Revenue.

On-Time Performance: (At the endpoint)—The increase is primarily due to increases in schedule adherence fees (incentive payments) to host railroads to achieve better on-time performance.

Passenger Miles (Commuter Included-millions): Per year-to-date average; do not include contract commuter passengers.

Train Miles in millions: About 70 percent of the train-miles traveled by Amtrak trains are on tracks owned by freight and commuter railroads. In FY 2009, Amtrak paid host railroads for reimbursed costs and incentives to travel 26 million train-miles; Amtrak also depends on host railroads for the dispatching and timely movement of its trains. Based on annual train-miles traveled by Amtrak, the seven largest host railroads are BNSF Railway, Union Pacific Railroad, CSX Transportation, Norfolk Southern, CN Railway, Metro-North Railroad and Canadian Pacific Railway.

Passenger Miles per train mile: do not include contract commuter passengers.

Ticket Yield (Tic Rev divided by Passenger Mile): do not include contract commuter passengers.

Yield (pax rel rev per pax mile): do not include contract commuter passengers; passenger related revenue excludes state 403(b) service revenue.

Total Revenue per Seat Mile: Federal payments received related to grants and TRA funds, state capital payments received, plus investment income earned ($34.6M, $23.1M, $12.1M, $2.9M and $0.7M in FY98-02, respectively) on TRA funds drawn are excluded from the operating ratio, and applicable revenue-based operating statistics.

Total Expense per Seat Mile: Total revenues decreased $100.0 million, or 4.1%, to $2,352.8 million in 2009 compared to $2,452.8 million in 2008. The decrease is primarily due to a decrease in passenger-related revenue as a result of decreased ridership. Total expenses increased $97.6 million, or 2.9%, to $3,507.2 million in 2009 compared to $3,409.6 million in 2008. The increase is largely due to an increase in salaries, wages, and benefits and depreciation.

Core Revenue per Seat Mile: This is calculated as Total Core Revenue divided by Total Train Miles (Amtrak, 2011c). Core revenues include passenger related, 403(b) service revenue, mail and express, and certain other revenues (specifically: commuter fees, freight railroad access fees and miscellaneous other). Mail and Express operations were discontinued in FY'04. Core revenues and expenses exclude Mail and Express operations beginning in FY'03.

Core Expense per Seat Mile: This is calculated as Total Core Expense less Depreciation and non-cash OPEB's divided by Total Train Miles (Amtrak, 2011c). Mail and Express operations were discontinued in FY'04. Core revenues and expenses exclude Mail & Express operations beginning in FY'03.

System wide Ridership in Millions: While ridership in FY 2009 was down from the all-time record of 28.7 million in FY 2008, it was up 5 percent over FY 2007, continuing a long-term trend of rising ridership since FY 2002 when 21.6 million passengers rode Amtrak. Rising gasoline prices and higher airline fares led to Amtrak's record ridership and revenue in 2008. Gasoline prices and airfares decreased in 2009 making alternative modes of transportation more competitive.

Stations Served by Amtrak: Thanks to state and local support, new or renovated stations were opened in FY 2009 in communities across the country, including Durham, N.C., Picayune, Miss., and Leavenworth, Wash., a new stop along the route of the Empire Builder.

HIGH SPEED RAIL

Operation and maintenance costs for California's High Speed Rail line are based on existing geographic alignment of current train stations and lines in California, as well as estimations based on maintenance frequency drawn from other high speed rail lines in other parts of the world. Specifically, operating costs are not incurred until 2017, when construction of the line is complete and expected to be in full-time service. The California High Speed Rail Authority projects these costs out to 2035. Operating costs ramp up sharply from 2017 to 2023, an increase of about $990 million over that time period, then plateau significantly, maintained at about 1.1 billion per year until 2060. Also, the CHSRA assumes that ridership will be significantly lower during the 2017-2023 time period, but will increase steadily during that time and taper off in 2024. The Authority claims that this will affect operating costs since ticket revenues are used to cover the costs. After 2024, operational costs increase at a rate of approximately 1% per year until 2035, as ridership projections become more consistent (CHSRA, 2009).

The fastest TGV train completes an approximately 100-mile trip at an average speed of 173 mph (Taylor, 2007). This speed was used to calculate the trip time of the San Diego to Los Angeles portion of the HSR line. The following calculation resulted in a trip time of 40 minutes from San Diego to Los Angeles: (116 miles / 173 mph) * (60 min/hr).

The model assumes that the average speed of 173 mph will account for the acceleration and deceleration on either end of the Los Angeles to San Francisco trip (i.e., for 100 miles out of that entire trip). We then assumed a top cruising speed of 200 mph for the middle 400 miles of the Los Angeles to San Francisco trip. This speed was based on the top cruising speed of the fastest TGV train. The following calculation resulted in a trip time of 155 minutes from Los Angeles to San Francisco: [(100 miles /173 mph) * (60 min/hr)] + [(400 miles /200 mph) * (60 min/hr)].

Further, the model includes 30 minutes to reach the train station and a 15-minute stop time in Los Angeles, the entire trip time from San Diego to San Francisco was approximately 240 minutes.

California HSR User Cost Methodology Outline

Methodology

1. *Column C: O&M User Costs (cents) per PM (2009$)*: divide 2060 O&M costs (D105) by passenger miles per year (using a .6 load factor)
2. *Project low, medium, high passenger miles*: blue, red, green (derived from cells K29, K30, K31); 2060 medium and high O&M Costs (B3, B4) – found by taking 130% and 160% of 2060 Low O&M costs, respectively
3. *Calculate passenger miles/year*: multiply seat miles/year by a load factor .6 (Column K)
   - Seat miles/year: multiply seat miles/day by 365
   - Seat miles/day: multiply seats/day by 500 (total route miles for the most common average Cal route)
   - Seats/day: found by multiplying max seat capacity (per train) by number of departures per day (low 30, med 60, high 75)
4. *Cap Costs per PM (Column D):* divide total capital 2009$ (F44) by passenger miles/year (J29)
   - Total Capital 2009$ - sum 2060 Capital Replacement Cost (F43) by Average Annual Capital Cost (F42)
     - Average Annual Capital Cost (F42) – divide Initial Capital Cost by 50 (time periods)
     - Initial Capital Costs – see Section Cost Update table

- low, medium high Cap Costs per pm: same methodology as 1.
- 50%, 75%, 100% subsidy – found by multiplying initial cap costs per PM by each subsidy rate

5. *2060 Full User Cost (cents per PM 2009$) (Column H)* – sum User Costs per PM with Cap costs per PM

Appendix D: Additional Mode Information

Fatality and Injury Rate Methodology

The Federal Highway Administration provides fatality data broken down by "functional system," or the type of roadway where the fatal accident occurred. These categories are: Rural Interstate, Rural Principal Arterial, Rural Minor Arterial, Rural Major Collector, Rural Minor Collector, Rural Local, Urban Interstate, Urban Freeway or Expressway, Urban Major Arterial, Urban Minor Arterial, Urban Collector, and Urban Local. The following categories were considered to constitute "intercity" travel: 1) Rural Interstate 2) Rural Principal Arterial 3) Urban Interstate and 4) Urban Freeway or Expressway in our estimates of intercity travel fatalities. This is an imperfect measure, as all these roadways will inevitably see some traffic of both intra- and inter-city travel, but the authors estimated that these 4 "functional systems" were the most likely to have a significant percentage of intercity travelers.

Injury data is not broken into functional systems, however, except for in years 1995 and 1996. We used the relationship between fatalities, injuries, and serious injuries in these years to estimate the injury and serious injury rates for the other years in the table below (61.73 times more total injuries than fatalities, 6 times more serious injuries than fatalities. "Moderate" injuries in the table above reflect is total injuries minus serious injuries). Of course, the relationship may have changed over the years, so these are only estimates and should not be considered to be exact figures. For the years when VMT disaggregated by functional system was available, these results are provided along with fatality rates (since injuries are calculated as a function of fatalities, the injury rate would be proportional to the fatality rate).

Table 1: Intercity Fatalities and Injuries: Historical Trends

Year	Total Fatalities	Serious Injuries (est.)	Moderate Injuries (est)	VMT (Millions)	Fatality Rate per 100M VMT
1980	12784	76704	712452.3		
1981	13231	79386	737363.6		
1982	10127	60762	564377.7		
1983	9819	58914	547212.9		
1984	10217	61302	569393.4		
1985	10032	60192	559083.4		
1986	10686	64116	595530.8		
1987	11409	68454	635823.6		
1988	11615	69690	647304		
1989	11193	67158	623785.9		
1990	10869	65214	605729.4		
1991	10206	61236	568780.4		
1992	9604	57624	535230.9	841,163	1.1418
1993	10331	61986	575746.6		
1994	11851	71106	660456.2	1,451,788	0.8163
1995	11324	67944	631086.5	932,017	1.2150
1996	12034	72204	670654.8	963,152	1.2494
1997	12022	72132	669986.1	989,976	1.2144
1998	12048	72288	671435	1,029,478	1.1703
1999	12253	73518	682859.7	1,058,703	1.1574
2000	11954	71724	666196.4	1,088,368	1.0983
2001	12103	72618	674500.2	1,109,349	1.0910
2002	12180	73080	678791.4	1,135,801	1.0724
2003	12277	73662	684197.2	1,101,819	1.1142
2004	12669	76014	706043.4	1,170,356	1.0825
2005	12538	75228	698742.7	1,175,586	1.0665
2006	11794	70764	657279.6	1,184,128	0.9960
2007	11417	68502	636269.4		
2008	10538	63228	587282.7		

Source: **Federal Highway Administration. (2008).** ***Our Nation's Highways 2008*** **(FHWA-PL-08-021). Washington, DC: Government Printing Office.**

Average Time Delay

Originally, to calculate average delay time for rail, Amtrak data found in the Monthly Performance Reports were used. The problem with using this data was two-fold. First, the aggregate total skews rail to have longer delays, as the long-distance trips have many more minutes of delay than the short trips or the North East corridor data. Second, the delay time was assumed to be minutes of delay per train rather than per passenger, which could not be accurately divided per passenger mile; again skewing the results.

In the end, the model used the assumption that delay costs are embedded in the full-cost price and represent some portion of the user-cost or subsidy. Overall, Amtrak –related delays represent less than half of the delays experienced by rail consumers. Delays stemming from the host railroad or other third parties may be reduced through contract negotiation, but the real area for Amtrak to see improved efficiencies is in Amtrak-related delays. See definitions below in Table 2. If Amtrak can lower cost and minimize delays this would make rail more attractive to users.

Table 2: Delay Time Definitions

Host Railroad	
Description	**Explanation**
Freight Train Interference	Delays for meeting or following All Other passenger trains
Passenger Train Interfere	Delays for meeting or following All Other passenger trains
Commuter Train Interfere	Delays for meeting or following commuter trains
Slow Order Delays	Temporary slow orders, except heat or cold orders
Signal Delays	Signal failure or All Other signal delays, wayside defect-detector false-alarms,defective road crossing protection, efficiency tests, drawbridge stuck open
Debris	Debris strikes
Routing	Routing-dispatching delays including diversions, late track bulletins, etc.
Maintenance of Way	Maintenance of Way delays including holds for track repairs or MW foreman to clear
Detour Delays	Delays from detours
Amtrak-Related	
Description	**Explanation**
ADA Passenger Related	All delays related to disabled passengers, wheel chair lifts, guide dogs, etc.
HLD Passenger Related	All delays related to passengers, checked-baggage, large groups, etc.
Crew & System	Delays related to crews including lateness, lone-engineer delays
Locomotive Failures	Mechanical failure on engines
Cab Car Failure	Mechanical failure on Cab Cars
Car Failure	Mechanical failure on all types of cars
Servicing	All switching and servicing delays
Hold for Connection	Holding for connections from All Other trains or buses.
Initial Terminal Delay	Delay at initial terminal due to late arriving inbound trains causing late release of equipment.
Injury Delay	Delay due to injured passengers or employees.
Miscelaneous Delays	Lost-on-run, heavy trains, unable to make normal speed, etc.
Other Third Party Delays	
Description	**Explanation**
Unused Recovery Time	Time Waiting for scheduled departure time at a station
Customs	U.S. and Canadian customs delays; Immigration-related delays
Police-Related	Police/fire department holds on right-of-way or on-board trains
Trespassers	Trespasser incidents including road crossing accidents, trespasser / animal strikes, vehicle stuck on track ahead, bridge strikes
Drawbridge Openings	Movable bridge openings for marine traffic where no bridge failure is involved
Weather-Related	All severe-weather delays, landslides or washouts, earthquake-related delays, heat or cold orders