Building a Diverse Modal Portfolio: Adding High-Speed Rail to the Mix

by

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Abstract

With some exceptions, intercity travelers in the United States have only two viable choices for transportation: air and automobile. This bi-modal system exposes the transportation sector to service interruptions such as earthquakes, oil embargoes and terrorist attacks. Due to the economic and social impacts associated with service disruptions, the position taken in this thesis is that interruptions to intercity travel are too frequent and the consequences are too great. Since each mode of transportation is affected differently by these disruptions, a more diverse intercity transportation system would be less vulnerable. Thus, modal diversification in certain corridors allows for a more flexible system that is better able to accommodate transportation system supply and demand fluctuations.

The outcome of this strategy is a higher level of service and system capacity during disruptions that affect one or more modes of travel; the main benefit is that it reduces the economic losses and social dislocations caused by service interruptions. These diversification benefits are in addition to "conventional" benefits obtained from increased capacity. Concerning high-speed rail, advocates include as "conventional" benefits: enhanced mobility, greater energy efficiency, less dependence on foreign oil, improved air quality, lower greenhouse emissions, and fewer injuries and deaths.

In order to illustrate the benefits of modal diversification, this thesis focuses on a proposed high-speed rail service in California. Since rail can withstand most major transportation disruptions, and can accommodate a substantial number of passengers, it is an effective way to achieve transportation diversification. A scenario-based analysis identifies several service interruptions that have the potential to cause severe economic losses, and estimates the ability of modal diversification to alleviate the impacts of these interruptions.

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Chapter I: Introduction

Main Premise Description

With some exceptions, intercity travelers in the United States have only two viable choices for transportation: air and automobile. This bi-modal system exposes the transportation sector to service interruptions such as earthquakes, oil embargoes and terrorist attacks. A more diverse transportation system (i.e., one with more viable modes) would be less exposed to these disruptions because different modes exhibit different vulnerabilities. A system that offers a multitude of transportation options is more flexible, and better able to accommodate transportation system supply and demand fluctuations. The main benefit of modal diversification is that it reduces economic losses and social dislocations caused by service interruptions.

The benefits gained from modal diversification are in addition to "conventional" benefits obtained from increased capacity. Concerning high-speed rail (HSR), for instance, advocates include as "conventional" benefits: enhanced mobility, greater energy efficiency, less dependence on foreign oil, improved air quality, lower greenhouse gas emissions, and fewer injuries and deaths. The diversification benefits of a new high-speed rail service consist of its ability to reduce the transportation system's exposure to service disruptions such as oil shocks, thereby decreasing economic and social disruptions. Thus, when considering transportation capacity expansions, transportation experts should address not only the "conventional" benefits of a mode during regular operating conditions (i.e., without service interruptions), but also the diversification benefits of an additional mode during service interruptions. (Figure 1)

FIGURE 1

Benefits of a New Mode

	"Conventional" Benefits
+	Modal Diversification Benefits
=	Benefits of a New Mode

The main premise of the following thesis is to explore the benefits of modal diversity for intercity transportation because a multimodal system helps reduce the negative impacts caused by service disruptions. This thesis does not concentrate on the financial feasibility of diversifying the transportation system. Further analysis is needed to consider the cost side of the problem. Other limitations of the thesis pertain to the service interruptions; the thesis computes benefits based on the assumption that disruptions occur meaning that a probability analysis was not performed. Furthermore, the analysis does not cover discounting of cash flow to reflect the time at which modal diversification benefits occur.

Service Interruption Description

The following transportation-related service interruptions are considered in this thesis:

1) Policy changes relating to air quality, energy constraints, and global warming;

2) Natural disasters such as earthquakes, tornadoes, snow storms and floods; and

3) Human-caused disruptions such as terrorist attacks and labor strikes.

These interruptions vary in their impact on the economy, and in their likelihood of occurrence. When calculating the impact of a transportation-related disruption (i.e., its duration and cost), planners should pay close attention to the following potential losses: social dislocations such as increased stress on travelers, and economic disruptions such as the opportunity costs of missed appointments and lost revenues to the restaurant and hotel industries.[1]

The economic impacts of oil shocks and labor strikes are two examples of potential disruptions that negatively affect the transportation system and the economy. For instance, during the 1973/74 oil shock, the growth rate of the real gross national product (GNP) dropped from 5.8 percent in 1973 to - 0.6 percent in 1974 and then another - 1.1 percent in 1975. During the 1979 oil shock, the growth rate of the real GNP dropped from 3.2 percent in 1979 to - 0.2 percent in 1980.[2] Concerning labor strikes, the 1981 Professional Air Traffic Controller Strike caused the air industry to lose an estimated $35 million per day during the first days of the strike while the economic costs to members of the American Hotel and Motel Association were estimated to be between $10 and $15 million per day.[3]

Due to the economic and social impacts associated with oil shocks, labor strikes and other service interruptions, the position taken in this thesis is that disruptions to intercity travel are too frequent and the consequences are too great. The degree of risk associated with transportation service interruptions should be reduced in order to decrease negative social and economic impacts. Modal diversification in intercity

[1] Joseph G. Morone and Edward J. Woodhouse, Averting Catastrophe: Strategies for Regulating Risky Technologies, University of California Press: Berkeley, Los Angeles, London, 1986, p. 148.
[2] John A Tatum, "The 1990 Oil Price Hike in Perspective," *Federal Reserve Bank of St. Louis*, November/December 1991, p. 12.

corridors is a viable way to reduce the risks caused by service interruptions because a more diverse system is better able to respond to demand and supply fluctuations of the transportation system.

Modal Diversification Benefit Description

The overall outcome of modal diversification is a higher level of service and system capacity during disruptions that affect one or more modes of travel. If transportation alternatives already are operational when a system interruption occurs, then a service expansion on such a mode would not take as long compared to developing an entirely new transportation service. Transportation construction projects take many years to design and build so transportation professionals must plan in advance to ensure that appropriate transportation options are available during emergency situations. Thus, modal diversification helps to reduce the time delay to when a system is able to accommodate supply and demand fluctuations.

One example of a recently diversified transportation system that responded well to a highway service interruption is Los Angeles after the 1993 Northridge earthquake. The Metropolitan Transportation Authority was able to expand capacity on its new commuter rail service in a matter of days, and observed an increase in ridership from 1,000 to 20,000 passengers per day.[4] If the line had not existed, as many as 19,000 travelers would have used their automobiles only to have further exacerbated the post-earthquake congestion problems. This example illustrates that for most types of

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[3] Bert A. Spector, *Air Traffic Controllers*, Harvard Business School, Boston, MA, 1982.

[4] *Northridge Earthquake: Lifeline Performance and Post-Earthquake Response*, Technical Council on Lifeline Earthquake Engineering, Monograph No. 8, edited by Anshel J. Schiff, published by the American Society of Civil Engineers, New York, August 1995, p. 212.

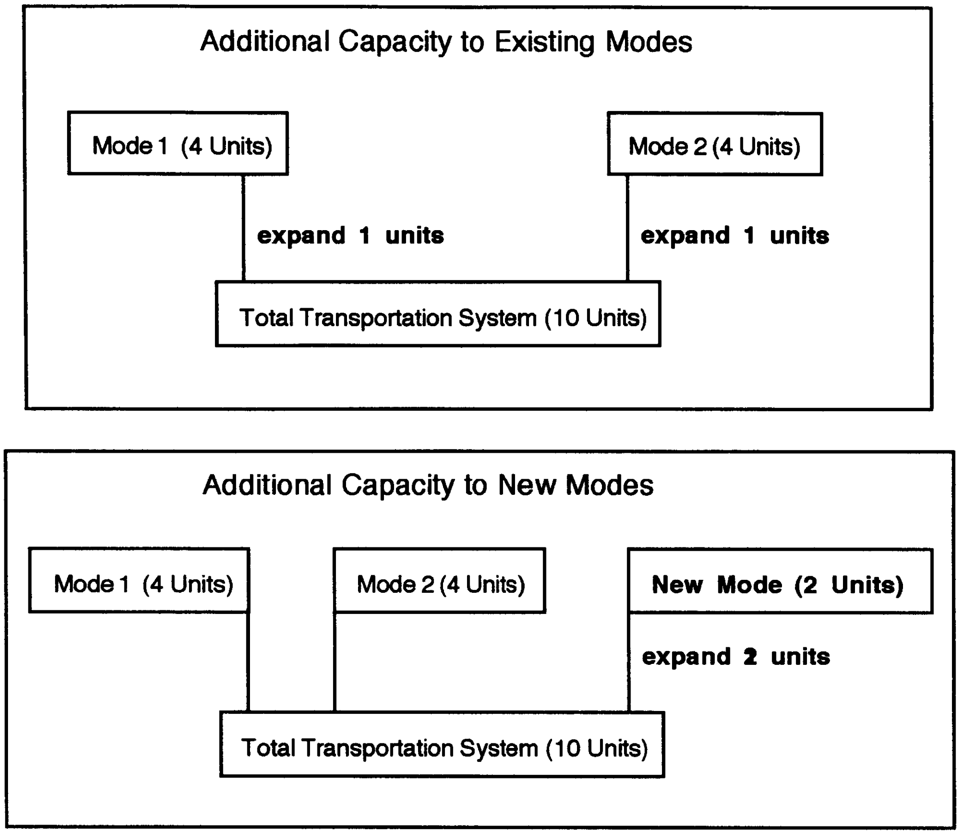
service interruptions, there is an economic value of having a multimodal transportation system already in place, though the benefit varies depending on the service disruption.

A useful time to consider modal diversification occurs when a congested intercity transportation corridor needs additional capacity. In principle, transportation experts may choose between expanding an existing mode or developing a new one. Figure 2 describes a scenario in which transportation planners can expand an eight-unit transportation system to ten units by adding capacity to existing modes or by adding capacity to a new mode valued at two units. Modal diversification may be a superior option to incrementally improving existing modes because this strategy allows the transportation system to respond better to demand and supply fluctuations. The benefits of diversification come with a cost in that the development of a new mode may be more expensive than adding incremental capacity to existing modes.

When deciding whether to add capacity to existing systems or to new modes, transportation planners should consider the "conventional" benefits obtained from increased capacity such as improved mobility as well as benefits gained from modal diversification such as enhanced system flexibility. In order to help justify the need for a new mode, the "conventional" and diversification benefits of an additional mode must outweigh the "conventional" benefits of improving existing modes. If diversification benefits are overlooked, then the development of an additional mode may rank lower than the expansion of existing modes because of higher start-up costs. Since transportation planners are often concerned with reducing short-term costs, modal diversification may not be considered as a viable option.

FIGURE 2

Comparison of Modal Diversification and Incremental Improvements



Rail and HSR Benefit Description

Since rail can withstand many major transportation disruptions, and can accommodate a substantial number of passengers, we argue that it is an effective way to achieve transportation diversification. The position taken in this thesis is that rail is less exposed than air and highway travel to most service interruptions. (Table 1) Nevertheless, the benefits of rail depend on the type and severity of the disruption.

When considering the three categories of potential transportation vulnerabilities (transportation-related policy changes, natural disasters and human-caused interruptions), rail can provide the most relief during policy changes relating to air quality, energy constraints, and global warming. Rail is an energy-efficient and low-emitting mode which can easily be expanded if politicians deem that transportation emissions are too high or when an oil shock occurs. For example, the Worldwatch Institute states that, rail "is three times as energy-efficient as commercial air and six times as efficient as a car with one occupant." (The measurement considers the energy needed to move one traveler one kilometer in the United States.)[5] Concerning natural disasters and human-caused interruptions, rail is able to compensate for excess demand only if it withstands damage from an incident. Even though rail is vulnerable to these interruptions, the recovery tends to be quicker because rail relies on simple technology and sparse infrastructure.

TABLE 1

Maximum Impact of Service Interruptions on the Primary Intercity Modes of Travel

	Rail Travel	**Air Travel**	**Highway Travel**
Transportation Policy Changes			
Air Quality	X	XXX	XXX
Energy Constraints	X	XXX	XXX
Global Warming	X	XXX	XXX
Natural Disasters			
Earthquakes	XX	XX	XXX
Floods	XX	X	XXX
Snow Storms	X	XXX	XXX
Human-Caused Interruptions			
Labor Strikes	XXX	XXX	X
Terrorism	XXX	XXX	X

X Minimally Vulnerable XX Vulnerable XXX Extremely Vulnerable

[5] Marcia D. Lowe, *Back on Track: The Global Rail Revival*, Worldwatch Paper 118, Worldwatch Institute, April 1994, p. 10.

In order to raise the probability that rail transportation is competitive with air and auto travel in terms of travel time and traveler cost, high-speed rail (HSR) service would be required in most corridors. The development of conventional rail is difficult to justify economically because, in most corridors, it is not viable during regular operating conditions. HSR does not exist in the United States except for the Northeast Corridor (NEC) so passengers transferring to rail during air or highway disruptions would have to expect slow and somewhat unreliable service. Some travelers would opt to avoid trips while others would waste valuable time on trains that run at slow speeds. If the disruption was a prolonged one, the overall effect would be an economic slowdown. To prevent such a severe impact, HSR could provide efficient and reliable service that competes with air and automobile travel in both cost and travel time.

Other than providing diversification benefits, rail, and especially high-speed rail, add numerous "conventional" benefits to the mix. Rail's high carrying capacity combined with other "conventional" benefits such as employment opportunities, congestion relief, and accident reductions make it a reasonable intercity mode not only as a type of capacity reserve for service interruptions, but also as a legitimate means of transportation during regular conditions. Some "conventional" benefits of rail, and high-speed rail, are highlighted below:

- Concerning accident reductions, for the Las Vegas - Southern California proposed high-speed rail line, "In the first year of the system, the big switch to trains is expected to prevent more than 270 accidents, 140 injuries and 15 fatalities on or near I-15."[6]

[6] Joseph Vranich, *Supertrains: Solutions to America's Transportation Gridlock*, St. Martin's Press, New York, 1991, p. 346.

- The carrying capacity of a heavy-rail system under heavy demand conditions, "is almost unequaled by any other mode of travel. Existing rapid transit systems can carry comfortably between 20,000 and 34,000 passengers per track per direction each hour. For projected light rail systems, that number is approximately 10,000."[7]

Scenario-Based Analysis Description

In order to illustrate the benefits of modal diversification, this thesis focuses on a proposed high-speed rail service for California between Los Angeles and the San Francisco Bay Area, with possible extensions north to Sacramento, southeast to San Bernardino and Riverside, and south to San Diego. A scenario-based analysis considers several service interruptions that have the potential to cause severe economic losses. The benefits of the HSR service are illustrated in a sensitivity analysis that uses first-order estimates. First-order estimates are necessary because of the inability to predict the exact impact of service disruptions on the transportation system. In general, the benefits of HSR during service interruptions, if they occur, are expected to range from several million dollars (i.e., labor strikes, terrorism, and earthquakes) to several billion dollars (i.e., policy changes relating to air quality, energy constraints and global warming).

[7] U.S. Committee on Banking, Finance and Urban Affairs, *New Urban Rail Transit: How Can its Development and Growth-Shaping Potential be Realized?*, 96th Congress, 1st Session, U.S. Government Printing Office, December 1979, p.207.

Other congested corridors that have established political and financial support for proposed HSR projects through the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) are as follows:

- Buffalo-Albany-New York;
- Chicago Hub (Chicago-Milwaukee, Chicago-Detroit, Chicago-St. Louis);
- Eugene-Portland-Seattle-Vancouver;
- Tampa-Orlando-Miami; and
- Washington-Charlotte.

These corridors, along with the California corridor, are in need of additional capacity because of chronic air and highway congestion. In order to justify the need for high-speed rail, rail advocates should highlight the economic and social benefits obtained from modal diversity during service disruptions. These diversification benefits along with the "conventional" benefits of rail such as improved mobility and reduced accidents may help to push these high-speed rail projects to the top of transportation funding lists.

Introduction Summary

In conclusion, the following thesis will explore the hypothesis that, in specific corridors, the "conventional" and diversification benefits of an additional mode outweigh the benefits of increasing capacity to existing modes, and that diversification benefits could outweigh the additional costs of a new mode. While many studies consider the "conventional" benefits of additional modes, the explicit benefits of modal diversification are most often ignored. These benefits are measured in terms of reduced response time needed for a transportation system to recover from a service interruption. When a system responds well to service disruptions, then the economic and social losses are minimized.

The thesis will discuss three different categories of service interruptions, and will show how modal diversification could help to alleviate their impacts. Chapter II focuses on the myriad of service interruptions that can disrupt transportation systems in the United States. Chapter III highlights the benefits of diversification. Chapter IV illustrates through various scenarios how modal diversification, using high-speed rail, would benefit an intercity corridor in California. Chapter V summarizes the vulnerabilities of the transportation system, the ability of modal diversification to alleviate the impacts of service interruptions, the benefits of diversification as it relates to the proposed high-speed rail project in California, and topics for future research. Appendix A covers in more depth the scenario-based calculations in Chapter IV pertaining to the California high-speed rail project; Appendix B makes available the intercity highway volume data used in the scenario-based analysis calculations for highway service interruptions.

Chapter II: Transportation Vulnerabilities

Introduction

The transportation system is vulnerable to the following service interruptions:

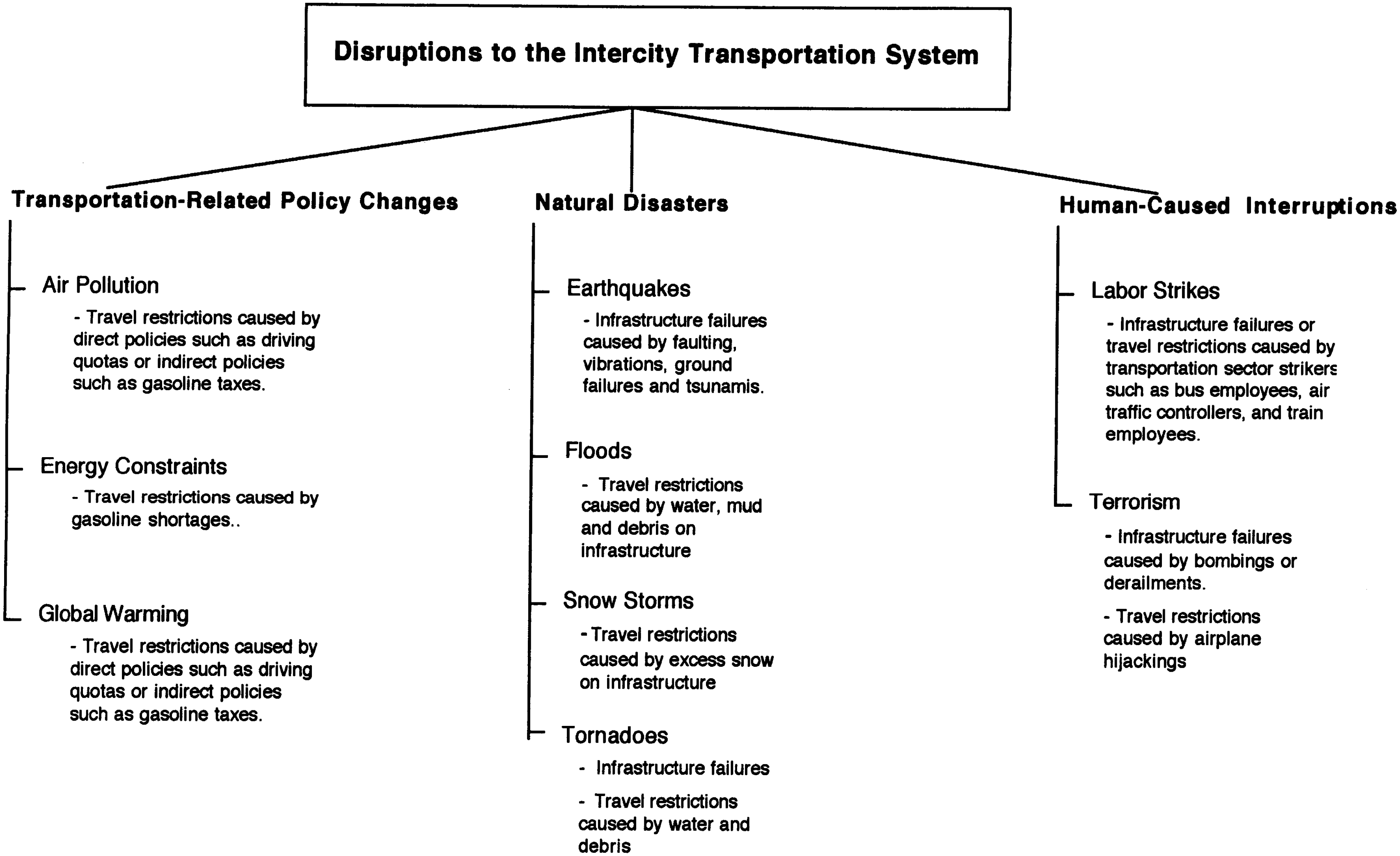
1) Policy changes relating to air quality, energy constraints, and global warming;

2) Natural disasters such as earthquakes, floods, snow storms and tornadoes; and

3) Human-caused disruptions such as terrorism and labor strikes.

The causes of these disruptions range from infrastructure failures (i.e., earthquakes and terrorism) to travel restrictions (i.e., air pollution policy measures and snow emergencies). (Figure 3) For example, the main reasons for earthquake-related service interruptions are infrastructure failures caused by faulting, vibration, tsunamis, and ground failures. The three types of service disruptions are described in more detail below; we discuss the likelihood of their occurrence, their potential impacts on the transportation system (i.e., duration and cost of incident), and the role that diversification may play to reduce the impact of supply and demand fluctuations.

FIGURE 3


Disruptions to the Intercity Transportation System
Transportation-Related Policy Changes
Air Pollution
- Travel restrictions caused by direct policies such as driving quotas or indirect policies such as gasoline taxes.
Energy Constraints
- Travel restrictions caused by gasoline shortages..
Global Warming
- Travel restrictions caused by direct policies such as driving quotas or indirect policies such as gasoline taxes.
Natural Disasters
Earthquakes
- Infrastructure failures caused by faulting, vibrations, ground failures and tsunamis.
Floods
- Travel restrictions caused by water, mud and debris on infrastructure
Snow Storms
- Travel restrictions caused by excess snow on infrastructure
Tornadoes
- Infrastructure failures
- Travel restrictions caused by water and debris
Human-Caused Interruptions
Labor Strikes
- Infrastructure failures or travel restrictions caused by transportation sector strikers such as bus employees, air traffic controllers, and train employees.
Terrorism
- Infrastructure failures caused by bombings or derailments.
- Travel restrictions caused by airplane hijackings

Transportation-Related Policy Changes

Introduction

Transportation-related policy changes for air quality, energy constraints and global warming may occur when the cost to society becomes unbearable. The likelihood and impact of these demand-side policies depends on the extent of the problems, and on the political will to solve them. Air pollution, global warming and oil dependency are protracted problems that need long-term and possibly draconian measures to reverse.

Since highway and air travel are energy-inefficient modes, and are large contributors to air pollution and greenhouse gas emissions, major mode shifts are needed in order for the transportation system to contribute less to these negative externalities. To enforce such a change in behavior, decision makers would have to implement policies that directly affect highway and air travel such as driving restrictions, or policies that indirectly affect transportation systems such as gasoline tax increases or other pricing measures. Since high-speed rail consumes only about one-third of the oil equivalent per unit of traffic as passenger cars and one-quarter for aircraft, this mode would be an integral component of any diversification strategy that is used to minimize the impacts of air quality, energy constraint and global warming regulations.[8]

Modal diversification helps to ease the transition towards a more energy-efficient transportation system. When intercity traveling options are expanded beyond driving and air travel, travelers will not have as much need for their highway vehicles. As their

[8] Michael Walrave, "High-Speed Rail: An Important Asset Reconciling Mobility, Energy Saving and Environmental Requirements," In: *Reconciling Transportation, Energy and Environmental Issues: The Role of Public Transport,* Conference Proceedings, European Conference of Ministers of Transport, European Commission. May - June, 1994, p. 82.

reliance on highway vehicles decreases, fuel consumption and emission rates also decrease, alleviating the need for expensive pollution reduction policies. Modal diversification can be considered as a "carrot" or incentive approach to reducing gasoline consumption since the goal of this strategy is to make it easier for travelers to change their behavior without causing economic hardships. For example, since HSR can be competitive with air and highway travel in terms of both time and cost, a transition to this more energy-efficient mode would not involve major additional economic costs to travelers. Thus, if a transportation-related policy was implemented and a diverse intercity transportation system existed, then the system would be better able to respond to modal shifts towards more energy-efficient, low-emitting travel. Furthermore, with the presence of a multimodal intercity system, transportation-related policy changes may become more politically feasible to deploy because the economic disruptions would be minimized.

Transportation-Related Policy Changes: Air Quality

Air Pollution Problem Description

The population living in areas that exceed National Ambient Air Quality Standards (NAAQS) ranges from 112 million individuals in 101 urban areas in 1988 to 67 million individuals in 96 areas in 1989. Air pollution levels vary in part because of transitory changes in weather; the summer of 1988 was hot while the summer of 1989 was cool.[9] California experiences some of the worst air pollution in the nation if not the world. Highway vehicles are one of the primary sources of emitters. In the South Coast Basin, the region's eight million highway vehicles cause over 50 percent of the pollution. In

[9] Alan J. Krupnick, *Vehicle Emissions, Urban Smog, and Clean Air Policy*, JEL Classification No(s): 722, 933, 1993, pp. 4-5.

order to meet national ambient air quality standards by the year 2010, highway vehicle miles traveled (VMT) need to be reduced by 60 percent in this region.[10]

Other examples of non-attainment areas in the United States include the following:

- **Extreme Exceedance Level**: Denver, and Los Angeles;
- **Severe**: Baltimore, Chicago, Houston, Milwaukee, San Diego, and Ventura County;
- **Serious**: Atlanta, Boston, Sacramento Valley, and San Joaquin Valley; and
- **Moderate**: Charlotte, Phoenix, Salt Lake City, and the San Francisco Bay Area.

In general, exposure to air pollution exacerbates preexisting respiratory, circulatory and olfactory system conditions, and decreases crop productivity. Olfactory system problems are difficult to evaluate, yet doctors have received reports of vomiting, coughing, nausea, shallow breathing, changes in respiratory and cardiovascular systems and depression.[11] Individuals who are particularly vulnerable to air pollution include the elderly, young children, and persons with asthma, emphysema and heart disease. The effects of exposure range from minor eye irritation to death. Concerning reductions in crop productivity, air pollution causes the United States to lose a total of several billion dollars in crops annually.[12]

Causes of Air Pollution

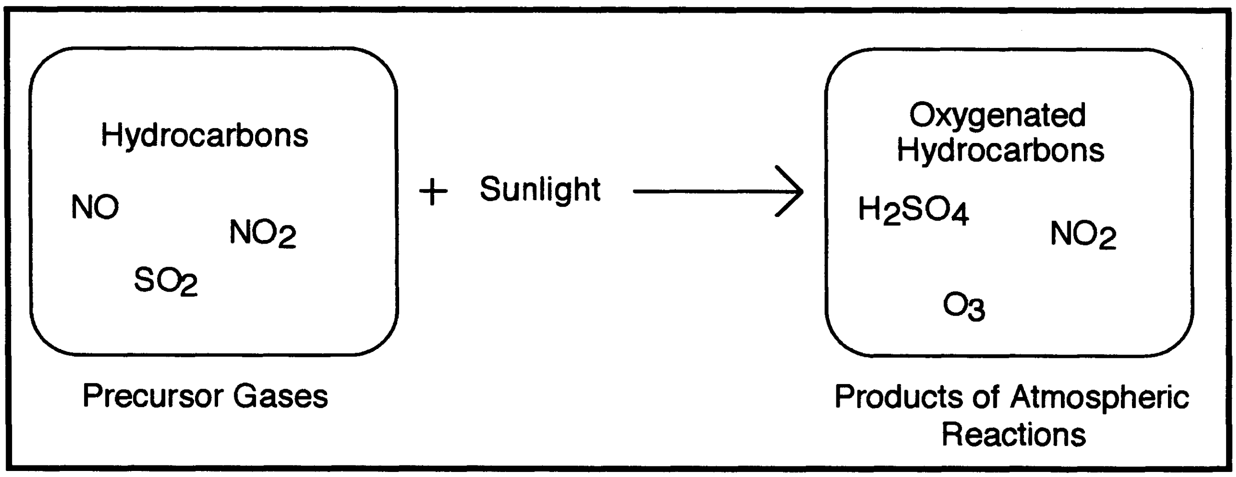
Air pollution occurs when primary emissions such as nitric oxide (NO) and sulfur dioxide (SO_2) react with sunlight in the troposphere (i.e., the lower atmosphere about

[10] Michael Cameron, *Transportation Efficiency: Tackling Southern California's Air Pollution and Congestion*, Environmental Defense Fund, Regional Institute of Southern California, March 1991, p. 5.
[11] Richard W. Boubel, Donald L. Fox, D. Bruce Turner, and Arthur C. Stern, *Fundamentals of Air Pollution*, Third Edition, Academic Press, New York, 1994, p. 107.

six to 12 miles from the earth) to form secondary products such as nitrogen dioxide (NO_2) and sulfuric acid (H_2SO_4), respectively. (Figure 4) Natural and anthropogenic (human-made) sources are responsible for discharging primary emissions. Natural sources consist of volcanoes that emit particulate matter, fires that emit carbon dioxide and hydrocarbons, and even oceans that emit salt forming aerosols. Anthropogenic sources include stationary emissions such as industries and utilities, and mobile emissions such as automobiles. When natural and anthropogenic sources are combined, emissions exceed healthy levels in many urban areas throughout the nation.[13]

FIGURE 4

Precursor-Product Relationship of Atmospheric Chemical Reactions



Note: NO = nitric oxide; SO_2 = sulfur dioxide; NO_2 = nitrous oxide; H_2SO_4 = sulfuric acid; O_3 = ozone.

Source: Richard W. Boubel, Donald L. Fox, D. Bruce Turner, and Arthur C. Stern, *Fundamentals of Air Pollution*, Third Edition, Academic Press, New York, 1994.

[12] James J. MacKenzie, Michael P. Walsh, *Driving Forces: Motor Vehicle Trends and their Implications for Global Warming, Energy Strategies, and Transportation Planning*, World Resources Institute, Washington, D.C., December 1990, p. 8.

[13] Richard W. Boubel, Donald L. Fox, D. Bruce Turner, and Arthur C. Stern, *Fundamentals of Air Pollution*, Third Edition, Academic Press, New York, 1994, pp. 72-78.

Highway vehicles contribute the largest share of air pollution emissions despite cleaner tailpipes because more individuals own automobiles and drive them farther distances.[14] In the United States, 54 percent of the carbon monoxide (CO) emissions, and 30 percent of the nitrogen oxides (NOx) emissions originate from highway vehicles. Concerning volatile organic compounds (VOCs), the contribution from highway vehicles is estimated to range from 28 percent to 45 percent in "ozone non-attainment areas" in 1985. The road vehicle share for CO has reached 90 percent in urban areas while VOCs have been recorded as high as 66 percent in Los Angeles.[15] [16] These estimates may be low because highway travel and, hence, emissions occur primarily during daylight hours when ozone is created from reactions with the sun.

Economic Impacts of Air Pollution Regulations

The economic impacts of air pollution regulations vary depending on the abatement policy. Although there is no single solution to decreasing highway vehicular emissions, some of the more cost effective approaches include targeting high emitters through early retirement programs, and policies that reduce driving through gasoline taxes. Other more stringent policies that restrict demand such as "no drive days" also are possible in the more severe non-attainment areas. These more severe regulations would probably be the most successful at reducing highway vehicle emissions yet also would cause the greatest negative economic impacts.

Regarding the economic costs of these regulations, early retirement programs, for example, are shown to cost an average of $700 per high-emitting highway vehicle

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[14] Ibid, p. 399.

[15] Alan J. Krupnick, Vehicle Emissions, Urban Smog, and Clean Air Policy, JEL Classification No(s): 722, 933, pp. 4-5.

meaning that the total cost of the program for the United States is estimated to equal about $12.6 billion. Since about ten percent of the road vehicle pool is expected to cause about 50 percent of the pollution problems, early retirement programs would target about ten percent of the road vehicles in the United States or approximately 18 million road vehicles. The cost estimate for the program is derived by multiplying the number of high-emitting highway vehicles (18 million) by $700 per vehicle. [17] [18]

Probability of Transportation Service Interruptions due to Air Quality Regulations

The United States Clean Air Act Amendments (CAAA) of 1990 include emission reduction provisions for attainment of national ambient air quality standards. These non-attainment requirements exist for carbon monoxide (CO), particulate matter (PM_{10}) and ozone (O_3). State Implementation Plans (SIP) set pollution reduction levels and timelines depending on the severity of the problem in the air quality control region. The United States Environmental Protection Agency is supposed to implement transportation-related sanctions such as "no-drive days" if non-attainment areas do not succeed in implementing the air quality requirements in the SIP.[19]

Benefits of Modal Diversification

In order to reduce the negative effects of transportation on air quality, policy makers should promote low-emitting means of travel such as high-speed rail for intercity trips. These modes do not emit as many precursor gases such as nitric oxide (NO) and sulfur

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[16] Richard W. Boubel, Donald L. Fox, D. Bruce Turner, and Arthur C. Stern, *Fundamentals of Air Pollution*, Third Edition, Academic Press, New York, 1994, p. 399.
[17] The 18 million figure for road vehicles is derived by multiplying the number of vehicles per household in the United States (1.8 vehicles per household) by the estimated number of households (100 million households) in order to obtain the number of highway vehicles in the United States (180 million). The number of highway vehicles is then multiplied by 10 percent, the percentage of high emitters.
[18] Alan J. Krupnick, Vehicle Emissions, Urban Smog, and Clean Air Policy, JEL Classification No(s): 722, 933, pp. 25-29.

dioxide (SO_2). Even though air pollution is considered an urban problem, emission reductions still can occur by decreasing the number of intercity trips because highway travelers destined for another urban area usually use their vehicles for intracity trips upon their arrival. Therefore, if less travelers were to use highway vehicles, then fewer intercity as well as intracity trips would be made.

When comparing the cost of modal diversification to other strategies, modal diversification is a favorable option because this strategy reduces the need for punitive measures that have high economic and social costs. For example, an early retirement program for highway vehicles is estimated to cost approximately $12.6 billion to implement nationwide.[20] If a few key intercity corridors throughout the nation diversified using HSR, then it is assumed that the effect is to decrease the need for the early retirement program by ten percent, totaling $1.26 million nationwide. Moreover, the early retirement program is not sufficient in alleviating air pollution emissions in most non-attainment areas meaning that the costs of this program represent only a fraction of the investment needed to improve air quality. A wide array of punitive measures would be necessary in order to achieve emission reduction standards. Modal diversification can help offset the costs of these punitive measures.

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[19] Arnold M. Howitt, Joshua P. Anderson, Alan A. Altshuler, *The New Politics of Clean Air and Transportation*, A. Alfred Taubman Center for State and Local Government, John F. Kennedy School of Government, Harvard University, November 1994, pp. 204-214.

[20] Alan J. Krupnick, *Vehicle Emissions, Urban Smog, and Clean Air Policy*, JEL Classification No(s): 722, 933, pp. 25-29.

Transportation-Related Policy Changes: Energy Constraints

Energy Constraint Problem Description

The United States is vulnerable to energy constraints not only because of its dependence on foreign oil, but also because of its unwillingness to recognize that current oil reserves are expected to last another tens-of-years as opposed to thousands-of-years. The U.S. imports more than half of the oil it consumes, exposing the country to world oil price and supply fluctuations, and to an uneven balance of trade. The annual cost of imports totaled more than $60 billion in 1992.[21] This figure does not include the costs of oil spill cleanups (i.e., the Exxon Valdez spill) nor does it consider the costs involved in protecting the nation's oil import supply lines (i.e., the 1990 Gulf War). The United States not only consumes more than it produces, it also uses much more than its proportion of world crude oil (25 percent) compared to its world population (five percent).[22] The rate of consumption is expected to increase causing economists to predict that imports will equal almost 60 percent by the year 2000.[23]

Causes of Energy Constraints

The United States' dependence on automobiles and air travel are major contributing factors to this country's appetite for foreign oil. The transportation sector uses about two-thirds (64.9 percent) of the petroleum consumed in the United States. Motor gasoline represents the majority (68.9 percent) of the petroleum consumed by the transportation sector. (Figure 5) Energy substitutes exist for the transportation sector,

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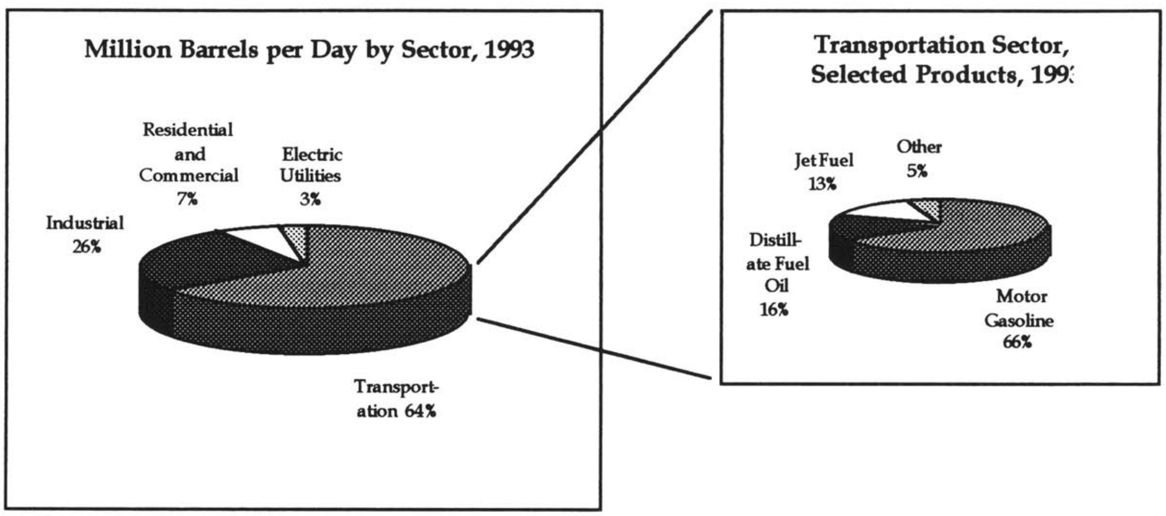
[21] Phillip S. Myers, "Reducing transportation fuel consumption: how far should we go?" Automotive Engineering, September 1992, p. 90

[22] General Accounting Office, *Other Nations' Policies to Reduce Oil and Coal Use in Transport and Industry*, May 1993, p. 42.

[23] Energy Information Administration, *Annual Energy Outlook*, 1994 with Projection to 2010, Department of Energy, 1994, p. 68.

however, they tend to be more expensive and have their own set of negative externalities. For example, an increase in the use of coal would decrease the reliance on imported fuels, and yet it contributes to global climate change, erosion and water quality problems. Nuclear energy is potentially hazardous as Chernobyl and Three Mile Island accidents demonstrate, and has waste storage problems; methanol is expensive and uses valuable croplands; and electric vehicles are not yet cost effective because of inefficient batteries. [24]

FIGURE 5: UNITED STATES PETROLEUM CONSUMPTION



Source: Energy Information Administration/Annual Energy Review, 1993

The transportation system is dependent on petroleum in the short run because the primary means of intercity travel in the United States are via energy-inefficient modes such as air and highway travel. The automobile and the airplane represent two of the most energy-inefficient modes of travel. A single-occupancy automobile consumes 6,530 Btu per passenger mile, a single-occupancy truck/van uses 9,048 Btu per

[24] Energy Information Administration, *Annual Energy Review 1993*, U.S. Department of Energy, 1993, Tables 5.12 and 5.13.

passenger mile while intercity rail consumes only 2,537 Btu per passenger mile.[25] In other words, "for every passenger carried one kilometer, an intercity train uses one-third the energy of a commercial airplane, and one-sixth the energy of an automobile with a sole occupant."[26]

Economic Impacts of Energy Constraint Regulations

A lack of energy policy insight made the national economy vulnerable to oil shocks in 1973/74, 1979 and 1990 causing sharp recessions during and after their occurrences. The economic impacts of these shocks had varying negative effects due to the length of the crisis, the amount of oil supply reduction, the economy before the shock, and monetary policies used to lessen the impact. Regarding the amount of gasoline shortage, the 1973/74 and 1979 oil shocks experienced a maximum quarterly gasoline shortfall of 13 percent and 11 percent, respectively.[27] Concerning the length and size of the crises, the 1973 oil embargo lasted for six months and saw oil prices increase from $10.67 per barrel in 1973 to $21.28 in 1974; the 1979 oil shock persisted for nearly two years with oil price increases from $22.35 per barrel in early 1979 to $50.75 per barrel in early 1981; and the 1990 oil shock reversed itself after five months with oil prices increasing to $33.18 per barrel in October, 1990 from $16.15 in July, 1990.[28] (Table 2)

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[25] Phillip S. Myers, "Reducing Transportation Fuel Consumption: How Far Should We Go?, *Automotive Engineering*, September 1992, p. 90.

[26] Marcia D. Lowe, *Back on Track: The Global Rail Revival*, Worldwatch Paper 118, Worldwatch Institute, April 1994, p. 12.

[27] David T. Hartgen, Joanna M. Brunso, and Alfred J. Neveu, "Initial and Subsequent Consumer Response to Gasoline Shortages," *Special Report 203: Proceedings of the Conference on Energy Contingency Planning in Urban Areas*, Transportation Research Board, National Research Council, Washington, D.C., 1983, p. 38.

[28] John A. Tatom, "The 1990 Oil Price Hike in Perspective," *Federal Reserve Bank of St. Louis*, November/December 1991, p. 12.

TABLE 2

Crude Oil Price Increases

	1973	1979	1990
Before Oil Shock	$10.67	$22.35	$16.15
During Oil Shock (peak price)	$21.28	$50.75	$33.18

Source: *Federal Reserve Bank of St. Louis,* November/December 1991.

Output and productivity declined shortly after oil prices skyrocketed while employment and monetary growth rates had a delayed cyclical response. (Table 3) The productivity growth rate, which is used as an indicator for business sector output per hour, decreased earlier than real gross national product (GNP) during the 1973 and 1979 oil shocks (i.e., OPEC1 and OPEC2, respectively) and remained in a slump for the 1990 oil shock (i.e., IRAQ). The real GNP growth rate, which is used as an indicator for economic output, slowed for all three oil shocks. Another source shows GNP figures that are consistent with Table 3 for OPEC1 and OPEC2. These figures reveal that during the 1973/74 oil shock, the growth rate of the real GNP dropped from 5.8 percent in 1973 to -0.6 percent in 1974 and then another -1.1 percent in 1975. During the 1979 oil shock, the growth rate of the real GNP dropped from 3.2 percent in 1979 to -0.2 percent in 1980.[29]

[29] Ibid, p. 12.

Table 3
Economic Performance Surrounding Three Energy Price Shocks

	Previous Year (%)	First Two-Quarter Period (%)	Second Two-Quarter Period (%)	Third Two-Quarter Period (%)	Fourth Two-Quarter Period (%)
Real GNP growth rate					
OPEC1	4.4%	0.7%	-2.0%	-5.6%	5.5%
OPEC2	5.3	1.6	1.6	-4.5	6.6
IRAQ	1.0	-0.1	-1.7		
Productivity growth rate					
OPEC1	1.5	-1.3	-2.1	0.9	6.8
OPEC2	0.6	-2.6	0.4	-0.4	3.7
IRAQ	-0.6	-0.2	0.2		
Civilian employment growth rate					
OPEC1	3.5	3.3	0.9	-3.9	1.8
OPEC2	3.9	1.6	1.7	-1.9	2.7
IRAQ	0.9	-1.1	-1.0		
Average unemployment rate					
OPEC1	5.0	5.0	5.4	7.4	8.7
OPEC2	5.9	5.8	6.1	7.5	7.4
IRAQ	5.3	5.7	6.7		
Period					
OPEC1	III/1972 to III/1973	IV/1973; I/1974	II and III/1974	IV/1974; I/1975	II and III/1975
OPEC2	I/1978 to I/1979	II and III/1979	IV/1979; I/1980	II and III/1980	IV/1980; I/1981
IRAQ	II/1989 to II/1990	III and IV/1990	I and II/1991		

Source: Federal Reserve Bank of St. Louis, November/December 1991.

Concerning employment changes, these figures did not peak until a year after the oil shocks for the 1973 and 1979 oil embargoes. An article in the European Economic Review, discussed employment figures that are consistent with Table 3 for OPEC1 and OPEC2. For the 1973 oil shock, the rate of unemployment increased from 4.9 (1973), 5.6 (1974) to 8.5 (1975); for the 1979 oil shock, the unemployment rate increased from 6.0 (1978), 5.8 (1979) to 7.2 (1980).[30] For the 1990 oil shock, employment growth rates declined at a much faster rate than the 1970s oil shocks because of the sluggish economy that existed before the oil price hikes.[31]

Probability of Transportation Service Interruptions due to Energy Crises

Since the most recent oil shock in 1990, the United States is even more dependent on foreign oil, and the Clinton Administration has not made any substantial progress in countering the trend. The U.S. consumption of petroleum continues to rise past domestic production causing a gap in 1993 of 6.73 million barrels per day of imported crude oil. (Figure 6) This increased need for imported oil makes the United States more dependent on foreign powers, and less self sufficient. Furthermore, experts predict that worldwide petroleum reserves will last for only another tens-of-years when considering the current level of reserves. As of 1987, about two-thirds of these reserves were concentrated in the hands of a few OPEC countries making the likelihood of price increases almost certain during this time.[32] (Figure 7) Recently, more world reserves have been located in Russia and the North Sea, which helps to decrease the power of OPEC. Nevertheless, OPEC is expected to regain its power as the world appetite for oil

[30] Jeffrey Sachs, "The Oil Shocks and Macroeconomic Adjustment in the United States," *European Economic Review 18*, 1982, p. 244.
[31] John A. Tatom, "The 1990 Oil Price Hike in Perspective," *Federal Reserve Bank of St. Louis*, November/December 1991, pp. 14-16.
[32] Energy Information Administration, Annual Energy Review 1993, United States Department of Energy, Washington, D.C., 1993.

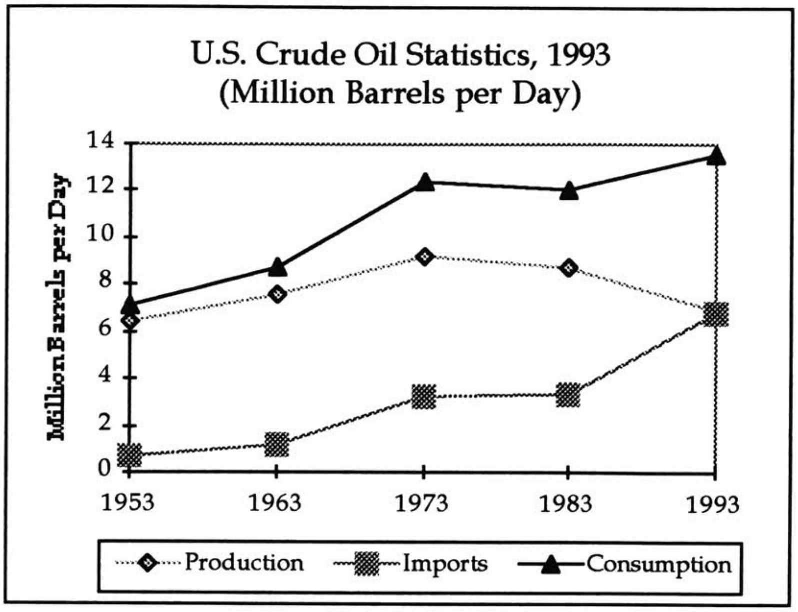
increases. An Economist article helps to justify this argument by stating, "beyond the end of this decade OPEC could become powerful once again. World oil demand is likely to increase sharply. In developing countries, car ownership and electricity demand are growing rapidly. The International Energy Agency predicts that the demand for oil in China alone will rise by 5% a year until 2010."[33]

Benefits of Modal Diversification

In order to create a less energy dependent transportation system, national policies and programs should encourage diversification of the transportation system as a way to minimize use of energy-intensive automobiles and air travel, and to maximize the use of more efficient modes such as buses and rail. Policy makers should establish more energy- efficient systems well before an energy crisis ensues since engineers need time to design and build public transportation infrastructure, and new technological solutions take time to implement.

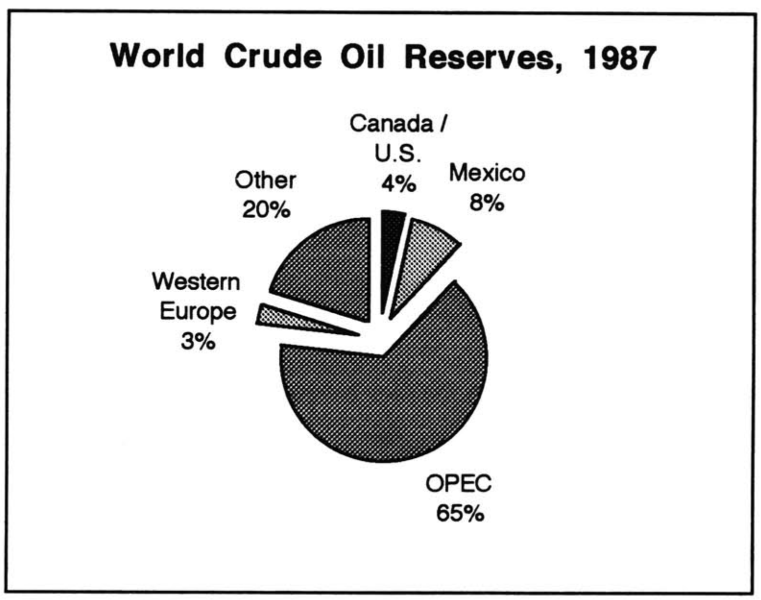
[33] —,"Energy: Pipe Dreams in Central Asia," *The Economist*, May 4, 1996, p.37.

FIGURE 6



Source: Energy Information Administration/Annual Energy Review 1993

FIGURE 7



Source: Energy Information Administration/Annual Energy Review 1993

Transportation-Related Policy Changes: Global Warming

Global Warming Problem Description

By the year 2030, atmospheric carbon dioxide is expected to double (2xCO_2) costing between 1.0 and 2.5 percent of the United States' gross national product (GNP). The cost estimate varies because of scientific uncertainties associated with the impacts of global warming, and the differences in quantifying the costs of non-market items such as mortality and discount rates.[34] Some other predictions of the warming trend are as follows:

- By the year 2030, the average global temperature is expected to increase by 3.6 degrees Fahrenheit (with a confidence interval of 2.5° to 5° F) compared to pre-industrial levels;

- Polar ice caps are expected to melt making the sea level rise by an expected 6 to 20 inches above 1990 levels by 2050. Higher sea levels bring about coastal flooding, erosion and wetland disturbances.[35] One-fourth of Florida and Louisiana, and one-tenth of New Jersey could be inundated.[36]

- Droughts are predicted to occur in greater frequency and with more intensity, especially in mid-continental areas; and[37]

- Drier conditions are expected in the western two-thirds of the United States and Canada.[38]

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[34] Ibid, p. 55.
[35] Michael P. Walsh, "Motor Vehicle Trends and their Implications for Global Warming," *Transport Policy and Global Warming, European Conference of Ministers of Transport*, 1992, pp. 73-74.
[36] Joseph G. Morone and Edward J. Woodhouse, *Averting Catastrophe: Strategies for Regulating Risky Technologies*, University of California Press, Los Angeles, 1986, p. 99.
[37] Michael P. Walsh, "Motor Vehicle Trends and their Implications for Global Warming," *Transport Policy and Global Warming, European Conference of Ministers of Transport*, 1992, pp. 73-74.

Causes of Global Warming

Global warming is caused by an excess of greenhouse gases that have been released into the atmosphere. Greenhouse gases like carbon dioxide (CO_2) allow sunlight to pass to the earth and then they trap radiated infrared heat causing the atmosphere to warm. This process occurs naturally, yet anthropogenic sources such as the burning of fossil fuels for automobile use have accelerated the rate producing an imbalance in the system. (Figure 8) Carbon dioxide accounts for about 50 percent of global warming; chlorofluorocarbons (CFCs) make up approximately 20 percent; methane (CH_4) contributes between 13 and 18 percent; tropospheric (lower atmospheric) ozone accounts for about eight percent and nitrous oxide (N_2O) represents six percent.[39] (Figure 9)

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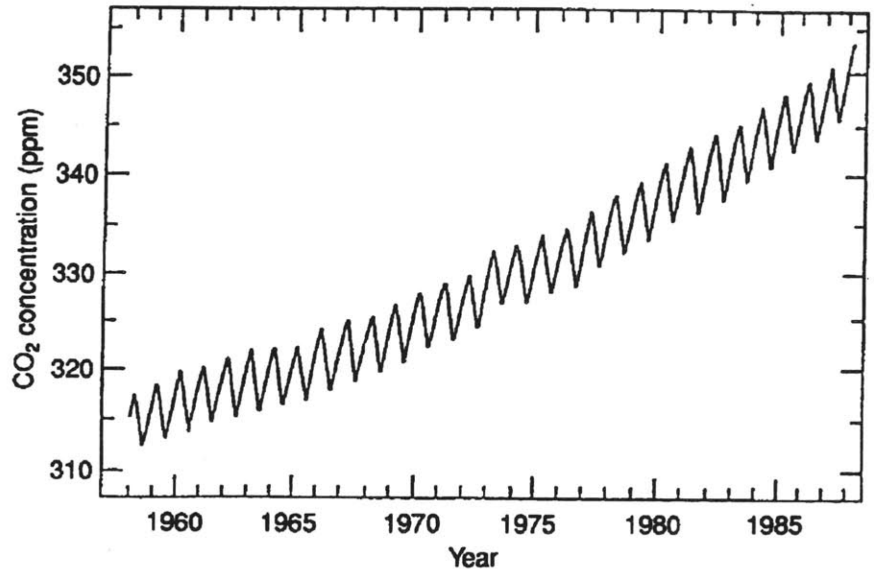
[38] Joseph G. Morone and Edward J. Woodhouse, *Averting Catastrophe: Strategies for Regulating Risky Technologies*, University of California Press, Los Angeles, 1986, p. 99.
[39] Michael P. Walsh, "Motor Vehicle Trends and their Implications for Global Warming," *Transport Policy and Global Warming, European Conference of Ministers of Transport*, 1992, p. 72.

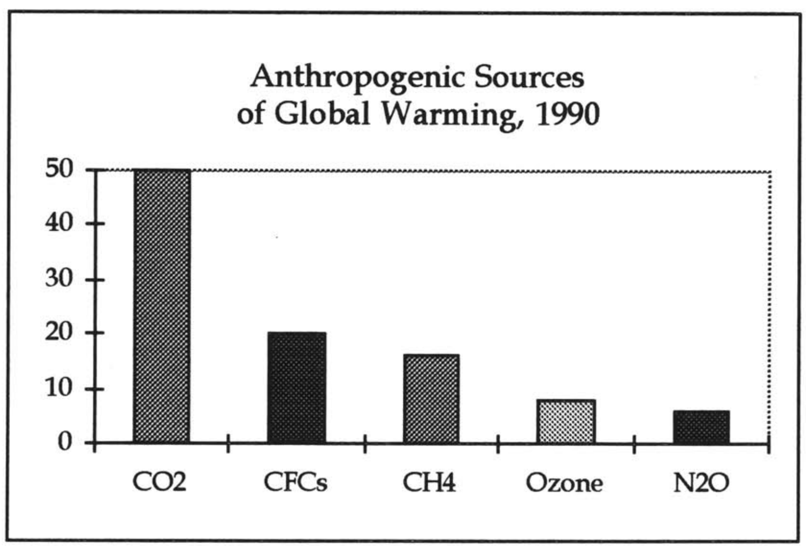
FIGURE 8

Mean Monthly Concentrations of Atmospheric CO_2 at Mauna Loa



Source: Richard W. Boubel, Donald L. Fox, D. Bruce Turner, and Arthur C. Stern, *Fundamentals of Air Pollution*, Third Edition, Academic Press, San Diego, 1994.

FIGURE 9



Source: Michael P. Walsh, "Motor Vehicle Trends and their Implications for Global Warming," *Transport Policy and Global Warming, European Conference of Ministers of Transport*, 1992.

Concerning carbon dioxide, automobiles cause about 25 percent of the anthropogenic carbon dioxide emissions in the United States. The domestic breakdown is as follows: electric power plants (33 percent), motor vehicles, planes and ships (31 percent), industrial plants (24 percent), commercial and residential buildings (11 percent), and other (one percent). The primary global anthropogenic contributions include the burning of fossil fuels (85 percent) and deforestation (15 percent). These emissions have grown by about 25 percent since pre-industrial times and continue to increase by about 0.5 percent per year. Worldwide motor vehicle contributions grow by about 2.4 percent per year, which represents an increase of two-thirds by the year 2030 compared to 1990.[40]

Chlorofluorocarbons (CFCs) not only cause global warming, these gases also reduce the protective layer of stratospheric ozone causing an increase in ultraviolet radiation. According to the Environmental Protection Agency (EPA), vehicle air conditioning represents the primary CFC user in the United States, accounting for about 16 percent of total US CFC use in 1989. The Montreal Protocol mandates a phasing out of CFCs by the year 2000. Nevertheless, these gases will remain in the atmosphere for the next two centuries.[41]

Ozone in the troposphere (i.e., the lower atmosphere about six to 12 miles from the earth) is created when sunlight reacts with nitrogen oxides (NOx). Nitrogen oxides are formed by the burning of fossil fuels and biomass, and by volatile organic compounds. In the United States, motor vehicles are a major source of nitrogen oxides (31 percent)

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[40] Ibid, pp. 72-81.
[41] Ibid, p. 76.

and of volatile organic compounds (44 percent). In the northern hemisphere, ozone concentrations are increasing by about one percent per year.[42]

Motor vehicles contribute only slightly to the production of methane (CH_4) and nitrous oxide (N_2O). The main sources of methane include rice production, termites and anaerobic decay from bogs, wetlands and landfills. Motor vehicle emissions contribute indirectly to methane production because as ozone increases methane also is shown to increase. The main sources of nitrous oxide are suspected to be agricultural fertilizers, the burning of coal, and catalytic converters.[43] Based on GM Research, motor vehicles emit approximately two percent of anthropogenic N_2O emissions.[44]

Economic Impacts of Global Warming Regulations

In order to reduce the production of greenhouse gases, the transportation sector could decrease its consumption of fossil fuels by improving the efficiency of highway vehicles, and by using more energy-efficient means of transportation such as high-speed rail. Since carbon dioxide is the primary global warming culprit, abatement policies tend to concentrate on this gaseous material. A 50 percent reduction from baseline carbon dioxide emissions by 2025 or 2050 would decrease world GNP between one and two percent. This figure ranges from 0.7 percent of GNP for the former Soviet Union, 4.7 percent for China to 1.3 percent for the United States.[45] The financial impact would not

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[42] Ibid, pp. 72-74.
[43] James J. MacKenzie, Michael P. Walsh, *Driving Forces: Motor Vehicle Trends and their Implications for Global Warming, Energy Strategies, and Transportation Planning*, World Resources Institute, Washington, D.C., December 1990, p. 5.
[44] Michael P. Walsh, "Motor Vehicle Trends and their Implications for Global Warming," *Transport Policy and Global Warming, European Conference of Ministers of Transport*, 1992, pp. 72-73.
[45] Samuel Fankhauser, *Valuing Climate Change: the Economics of the Greenhouse*, Economic and Social Research Council, Earthscan Publications Ltd., London., pp. 54-55.

be as high when considering secondary benefits like the reduction of air and noise pollution, balance of trade deficits, traffic congestion and accidents.[46]

Probability of Transportation Service Interruptions due to Global Warming

The most recent global warming mitigation plan, which arose from the 1992 Earth Summit in Rio de Janeiro, calls for a transportation sector greenhouse gas reduction of 8.1 million metric tons of carbon equivalent. This figure represents only 7.5 percent of the total reductions needed to return greenhouse gas emissions to 1990 levels by the year 2000.[47] Some of the largest gross emitting countries such as the United States have failed to make substantial progress towards these greenhouse gas emission reduction goals.

Due to recent advances that help to prove the validity of global warming, these countries are expected to make greater efforts towards decreasing greenhouse gas emissions. Since automobiles are major contributors to global warming, the transportation sector will be a primary target for any greenhouse gas reduction strategy. Emission taxes and other regulatory measures would help to decrease the prevalence of greenhouse gas emissions whereas modal diversification using high-speed rail, for example, would offer travelers lower-emitting traveling options.

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[46] Ibid, pp. 103-105.
[47] President William J. Clinton, Vice President Albert Gore, Jr., *The Climate Change Action Plan*, October 1993, p. 7.

Benefits of Modal Diversification

In order to decrease greenhouse gas emissions, global warming experts agreed that countries should adopt measures that improve transportation efficiency by decreasing highway vehicle miles traveled.[48] As stated in the impacts section, the cost of abatement policies aimed at reducing VMT equals 1.7 percent of the United States' GNP. To decrease the economic effects of emission regulations, policy makers could offer incentives to travelers by developing efficient and effective low-emitting intercity transportation alternatives such as high-speed rail (HSR). If HSR existed in key congested corridors throughout the nation, the transition from high-emitting to low-emitting modes would be easier. When regulatory policies such as emission taxes are mandated, an existing HSR service may become the more economically sound alternative for travelers.

[48] Ibid, p. 23.

Natural Disasters

Introduction

Natural disasters such as earthquakes, major snow storms, tornadoes and floods occur at irregular intervals. The likelihood and impact of these severe conditions depends on geographic location, and on the intensity of the incident. Typically, these hazards cause localized infrastructure problems that may take several months to repair. Diverse transportation systems would help to minimize disaster-related transportation delays in that if one mode was disrupted, another comparable mode if already in service could expand its capacity in order to alleviate the transportation supply constraint.

Natural Disasters: Earthquakes

Earthquake Problem Description

Earthquakes disrupt transportation systems not only by causing infrastructure failures, but also by causing oil supply, communication system, and power generating disturbances. Earthquake-related service interruptions last as short as several hours for safety checks to as long as several months for infrastructure repairs. Diversification of the transportation system would help to alleviate the impacts of these service interruptions in that a variety of transportation services help to spread the excess demand created when a particular mode is disrupted and others are not.

Impacts of Earthquakes

Transportation-related facilities that are at risk include: roads, railroad tracks, bridges, tunnels, airport runways, airport control towers, harbors, pipelines, power-generating facilities, and communication systems.[49] These facilities are prone to damage from ground failure, faulting, vibration, and tsunamis (mistakenly called tidal waves). The most common forms of ground failures are landslides, ground cracks, and longitudinal compression. (Figure 10 and 11) When railroads, highways or runways cross earthquake surface faults, horizontal shifts cause roadways and runways to buckle, and railroad tracks to bend. (Figure 12) Raised highways are particularly vulnerable to vibrations or vertical movement. (Figure 13)[50]

Concerning roads, earthquakes cause street closures because of bridge or structural failures, landslides, ruptured utility lines, collapse or near-collapse of buildings, and fires. Highways, with their numerous and large overpasses, are susceptible to subsidence or liquefaction problems that cause concrete segments to disconnect. The San Fernando earthquake provides an example of destruction that can occur to roads. "Restoration of freeways costs an estimated $12.2 million - $6.5 million for bridge restoration and $5.7 million to restore other facilities."[51] Furthermore, highway travel is indirectly exposed to pipeline and oil storage tank damage. Given the high number of petroleum facilities located near fault lines in California and Alaska, pipeline or storage facility damage could leave the west coast short of petroleum supplies.

Regarding air travel, airports seem to withstand destruction fairly well. Nevertheless, airports still are unprotected because many of them are built on fill, making the control towers and runways vulnerable to soil liquefaction. Also, control towers, communication and power systems, and petroleum facilities are susceptible to

[49] Anshel J. Schiff, "Earthquakes in Transportation Contingency Planning," *Energy*, Vol. 8, No. 8-9, 1983, Pergamon Press Ltd., Great Britain, p. 691.
[50] U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Geophysical Data Center, Boulder, Colorado, 1990, pp. 1 - 5.

malfunctions. For instance, in the 1964 Alaskan earthquake, the control tower at the Anchorage International Airport collapsed causing a disruption in air travel.[52]

Regarding railroads, earthquakes cause subsidence and compaction, which effect railroad tracks and tunnels, respectively. Railroads also are exposed to computer, communication, and power system outages. A 1952 earthquake in Bakersfield, California illustrates the compaction problem: "the walls of a railroad tunnel rose up, the rails compressed, and the walls came back down, leaving the rails penetrating the tunnel wall at several points."[53] Another example is from the 1971 earthquake in San Fernando, California of 6.4 magnitude, which caused railroad tracks to shift and kink in three different areas. Fortunately, workers were able to repair the damage within 24 hours for a cost of only $40,000. As a comparison, roadway repairs for this same earthquake totaled $12.2 million.[54] Because of rail's simple steel track infrastructure, damage to the system tends to be minimal, and repairing it tends to be less costly and take less time than the road system.

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[51] 5151G. Lennis Berlin, *Earthquakes and the Urban Environment*, Volume II, CRC Press, Inc., Boca Raton, Florida, p. 154.
[52] Ibid, pp. 114-115.
[53] Anshel J. Schiff, "Earthquakes in Transportation Contingency Planning,"*Energy*, Vol. 8, No. 8-9, 1983, Pergamon Press Ltd., Great Britain, p. 691.
[5454]G. Lennis Berlin, *Earthquakes and the Urban Environment*, Volume II, CRC Press, Inc., Boca Raton, Florida, p. 154.

FIGURE 10

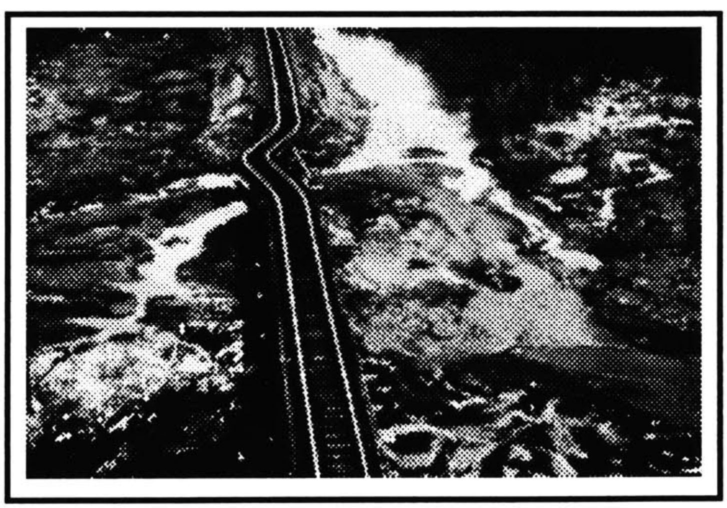
Soil Liquefaction in Mexico City after the 1985 Earthquake

Note: Both streets and runways are exposed to ground failures.

Source: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Geophysical Data Center, 1990.

FIGURE 11

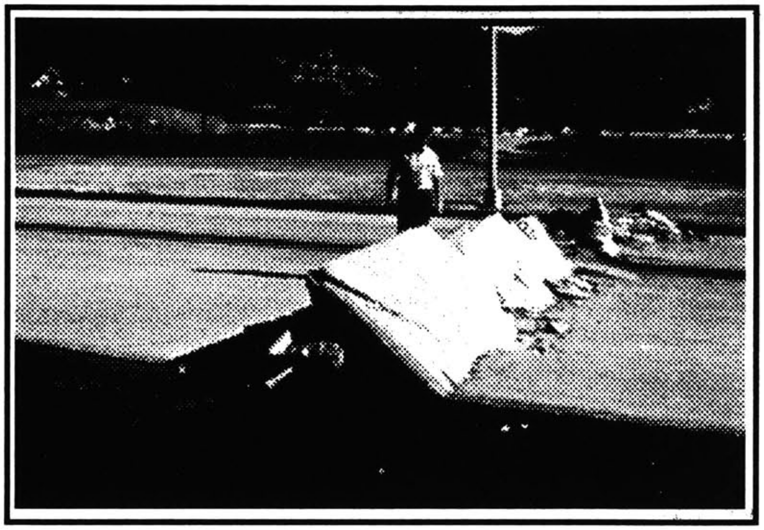
Railroad Track Ground Failure after the 1964 Gulf of Alaska Earthquake



Source: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Geophysical Data Center, 1990.

FIGURE 12

Faulting Caused by Earthquakes:
San Fernando, California after the 1971 Earthquake

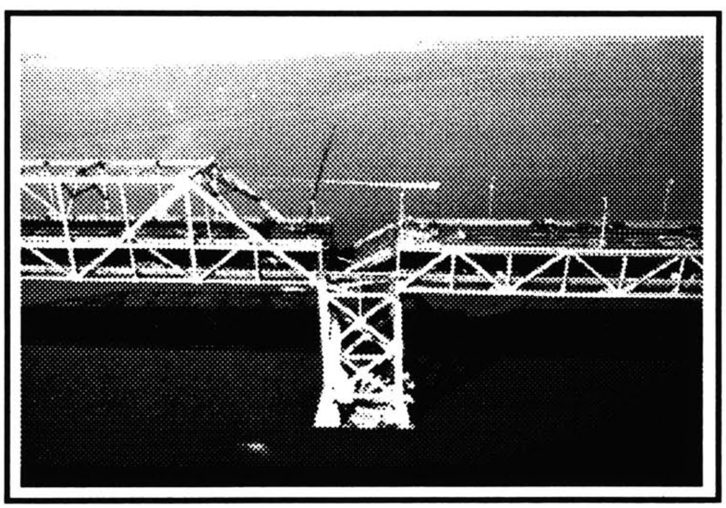


Note: Both streets and runways are exposed to faulting.

Source: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Geophysical Data Center, 1990.

FIGURE 13

Vibration Damage: Oakland Bay Bridge after Loma Prieta



Source: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Geophysical Data Center, 1990.

Comparison of Impacts to the Transportation System: the Loma Prieta and Northridge Earthquakes

A comparison of earthquake damage using the Loma Prieta and Northridge earthquakes as case studies helps to illustrate the damage caused to different modes of transportation. Both the San Francisco Bay Area and the Los Angeles Metropolitan Area endured extensive damage to their transportation systems after the 1989 Loma Prieta and 1993 Northridge earthquakes, respectively. (Table 4) Road infrastructure was the most severely damaged, and the most costly to repair, totaling over $300 million for both earthquakes. (Table 5) Concerning airport damage, runways were susceptible to failure because of soil liquefaction. For example, the Oakland International Airport suffered about $7 million in liquefaction damage while Los Angeles area airports only had to retrofit $275,000 of its runway infrastructure.[55] The rail systems incurred minimal damage; the exact figures were unattainable.

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[55] George W. Housner, Chairman, *Competing Against Time*, Report to Governor George Deukmejian from The Governor's Board of Inquiry on the 1989 Loma Prieta Earthquake, State of California, Office of Planning and Research, May 1990, p. 23.

Table 4

Loma Prieta and Northridge Damage to Transportation Systems

	Rail	Road	Air
Loma Prieta	*BART*: restored to regular service 12 hours later; *Amtrak*: closed briefly for track inspection. [56]	13 state and 5 local bridges failed out of over 4,000; 91 out of 1,896 state bridges incurred minor damage.[57]	*San Francisco International Airport* closed for 13 hours due to control tower damage; *Oakland International Airport*: closed due to liquefaction on runways, minor control tower damage and communication system problems; *San Jose International Airport*: closed briefly for runway inspection; *Alameda Naval Air Station*: closed for about 2 months due to liquefaction on runways; *Watsonville Airport*: loss of power and minor damage.[58]
Northridge [59]	*MTA*: service began the next day, minor delays due to power outage; *Metrolink*: no trains for one day, freight derailment on the Chatsworth line; *Amtrak*: cleared in 3 hours; *L.A. Junction*: began service 3 hours later.	Out of about 1,200 bridges, 7 had severe damage, 230 were damaged to some extent; 4 local bridges damaged.	*Los Angeles International Airport (LAX)*: closed for 2 hours due to power outage, which diverted 2 cargo flights; *Van Nuys Airport*: closed for 1.5 hours, control tower windows cracked or broke; *Burbank Airport*: no major damage was reported.

[56] Earthquake Spectra, *Loma Prieta Earthquake Reconnaissance Report,* The Professional Journal of the Earthquake Engineering Research Institute, Vol. 6, Chapter 8: Lifelines, May 1990, p. 271.

[57] George W. Housner, Chairman, *Competing Against Time,* Report to Governor George Deukmejian from The Governor's Board of Inquiry on the 1989 Loma Prieta Earthquake, State of California, Office of Planning and Research, May 1990, p. 23.

[58] Earthquake Spectra, *Loma Prieta Earthquake Reconnaissance Report,* The Professional Journal of the Earthquake Engineering Research Institute, Vol. 6, Chapter 8: Lifelines, May 1990, pp. 274-281.

[59] *Northridge Earthquake: Lifeline Performance and Post-Earthquake Response,* Technical Council on Lifeline Earthquake Engineering, Monograph No. 8, edited by Anshel J. Schiff, published by the American Society of Civil Engineers, New York, August 1995, p. 158, p. 197, pp. 227-235.

TABLE 5

Loma Prieta and Northridge Damage Costs

	Rail	Road	Air
Loma Prieta	Minimal monetary cost	$308 million for state highways and bridges.[60]	*Oakland International Airport*: about $7 million; No information for other airports.[61]
North-ridge[62]	Minimal monetary cost	Highway repairs: $122 million; Bridge repairs: $144 million.	*Van Nuys Airport*: $160,000; *LAX*: $100,000; *Burbank*: $15,000.

Both the Los Angeles and San Francisco metropolitan areas are fortunate enough to have transportation alternatives in place. The San Francisco Bay Area increased its ferry system, and its two commuter rail services known as the Bay Area Rapid Transit (BART) service and CalTrain; the Los Angeles metropolitan area augmented its Metropolitan Transit Authority (MTA) light rail service and its Metrolink heavy-rail service. For the San Francisco Bay Area, ferry ridership increased by 237 percent from 6,250 weekday passengers to 21,000; BART accommodated an increase in service from 224,400 riders per day to 314,000 riders per day; and CalTrain experienced an increase in ridership of 32 percent one week after the quake, and it stabilized to ten percent by early December.[63] For the Los Angeles area, the Red Line of the MTA increased its ridership by 35 percent after the temblor; Metrolink's Santa Clarita Line expanded the service from 1,000 passengers per day to 20,000 passengers per day in the first week, and the ridership stabilized at 9,000 per day.[64] If these services had not been

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[60] Caltrans, District 7, Office of Operations, *Northridge Earthquake Recovery: Interim Transportation Report #2: April 1 - June 30, 1994*, prepared by Barton-Aschman Associates, Inc., September 8, 1994, p. 3.

[61] Earthquake Spectra, *Loma Prieta Earthquake Reconnaissance Report*, The Professional Journal of the Earthquake Engineering Research Institute, Vol. 6, Chapter 8: Lifelines, May 1990, p. 279.

[62] *Northridge Earthquake: Lifeline Performance and Post-Earthquake Response*, Technical Council on Lifeline Earthquake Engineering, Monograph No. 8, edited by Anshel J. Schiff, published by the American Society of Civil Engineers, New York, August 1995, p. 198, pp. 227-235.

[63] Siamak A. Ardekani, "Transportation Operations Following The 1989 Loma Prieta Earthquake," *Transportation Quarterly*, Eno Transportation Foundation, Inc., Vol. 46, No. 2, April 1992, pp. 223-225.

[64] *Northridge Earthquake: Lifeline Performance and Post-Earthquake Response*, Technical Council on Lifeline Earthquake Engineering, Monograph No. 8, edited by Anshel J. Schiff, published by the American Society of Civil Engineers, New York, August 1995, p. 158, p. 197, p. 211.

immediately available, more travelers would have opted to take their automobiles further exacerbating the highway congestion problems.

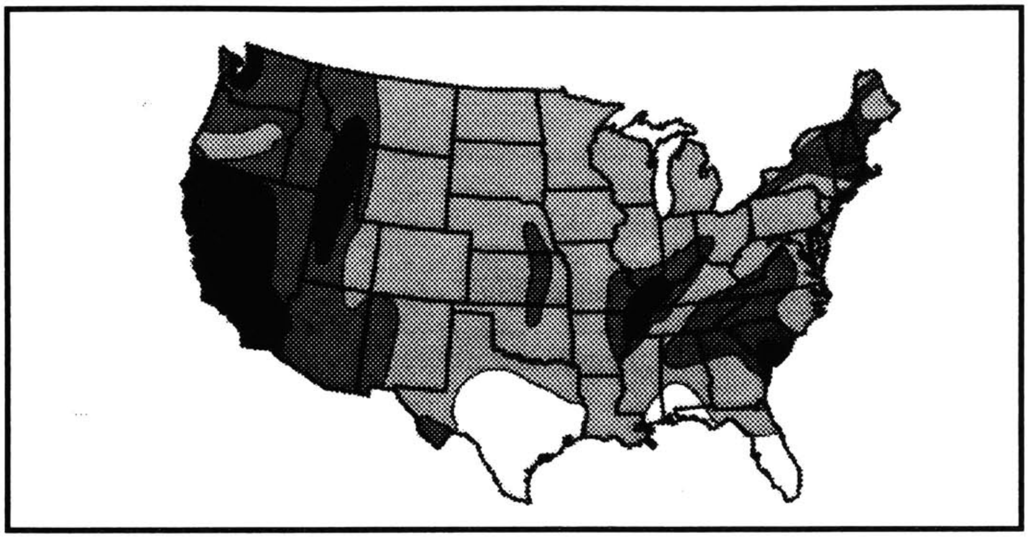
Probability of Earthquakes

Certain areas within the United States are more prone to earthquakes than others. (Figure 14) The riskiest states are Alaska and California. Alaska has endured over 50 percent of all earthquakes in the United States since 1900 while the west coast claims over 25 percent.[65] (Table 6) In general, it is difficult to quantify exact probabilities of major earthquakes because of the small sample size that usually exists. Nevertheless, in California, where there is a larger sample size of earthquakes, experts predict that there is a 93 percent chance of having a major earthquake greater than 6.5 magnitude occur along the San Andreas fault, South San Andreas fault, or San Jacinto fault by the year 2020.[66] (Table 7)

[65] United States Geological Survey National Earthquake Information Center, World Wide Web page, January 1996.
[66] United States Geological Survey, "Probabilities of Large Scale Earthquakes Occurring in California on the San Andreas Fault," Working Group on California Earthquake Probabilities, *U.S. Geological Survey Open File Report 88-398*, Menlo Park, CA, 1988.

FIGURE 14

Distribution of Major Earthquakes in the United States



No damage | Minor damage | Moderate damage | Major damage

Source: Insurance Services Office, Inc., *Catastrophic Insurance Issues Surrounding the Northridge Earthquakes and Other Natural Disasters*, 1994.

TABLE 6

Number of Earthquakes in the United States since 1900

	Western US	Eastern US	Alaska	Hawaii
8 and higher	1	0	7	0
7.0 - 7.9	18	0	84	1
6.0 - 6.9	129	1	411	15
5.0 - 5.9	611	41	1886	36
4.0 - 4.9	3171	335	8362	315

Note: Over 50 percent of all United States earthquakes occurred in Alaska since 1900, and over 25 percent occurred on the West coast.

Source: United States Geological Survey National Earthquake Information Center, 1996

TABLE 7

Probability of Large Earthquakes on the San Andreas System

Geological Region of Fault	Expected Magnitude	Probability circa 2000 (%)	circa 2010 (%)	circa 2020 (%)
San Francisco Bay Area[1]	7	33%	50%	67%
Southern San Andreas Fault[2]	7.5-8	20%	40%	60%
San Jacinto Fault (San Diego)	6.5-7	20%	30%	50%
Combined probability of at least one of the above earthquakes		57%	79%	93%

[1] Includes the San Francisco Peninsula segment of the San Andreas fault and the Northern East Bay and Southern East Bay segments for the Hayward fault.

[2] The total probabilities for the Southern San Andreas fault estimate that the San Bernardino Mountains segment does not have earthquakes independent of the Mojave or Coachella Valley segments.

Source: "Probabilities of Large Scale Earthquakes Occurring in California on the San Andreas Fault," Working Group on California Earthquake Probabilities, *United States Geological Survey Open File Report 88-398*, Menlo Park, CA, 1988.

Figure 15 shows the distribution of earthquakes in California; both the San Francisco Bay Area and the Los Angeles Metropolitan Area have experienced numerous earthquakes along the San Andreas and San Jacinto faults, respectively. According to historical earthquake data, a major earthquake greater than 6.5 magnitude occurred an average of once every 18 years between 1836 and 1994 in the Bay Area.[67] (Table 8) As a rough estimate, the San Francisco Bay Area and the Los Angeles metropolitan area have a 50 and 67 percent chance, respectively, of an earthquake greater than 6.5 magnitude by the year 2020.

[67] Dr. William Ellsworth, "The San Andreas Fault System, California," United States Geological Survey Professional Paper 1515, 1994.

TABLE 8

Significant San Francisco Bay Area Earthquakes, 1836-1994

Year	Magnitude
1836	6.75
1838	7.00
1865	6.50
1868	7.00
1892	6.50
1898	6.50
1906	8.25
1911	6.50
1989	7.10

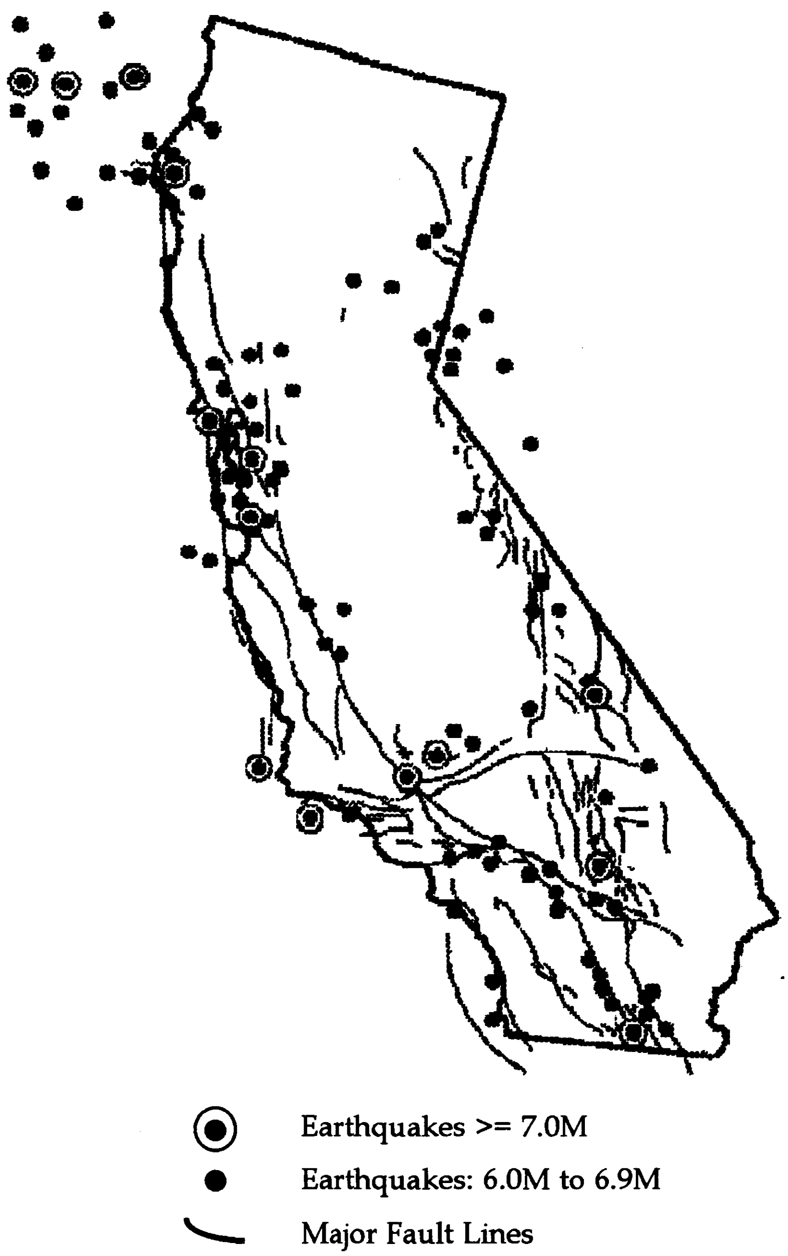
Source: Dr. William Ellsworth, "The San Andreas Fault System, California," USGS Professional Paper 1515.

Benefits of Modal Diversification

Modal diversification helps to raise the probability that at least one intercity mode of transportation remains operational after a major earthquake. Consequently, lower economic and social post-earthquake dislocations are expected as a result of this strategy. Even though the air, rail and highway systems are all exposed to earthquakes, some modes are less than others. Rail, for example, is vulnerable to earthquake damage, however, since the system relies on simple technology and sparse infrastructure, the repairs take less time and are less costly than road and air systems.

FIGURE 15

Major Historic Earthquakes in California



Source: Risa Palm: *Earthquake Insurance: A Longitudinal Study of California Homeowners*, Westview Press, San Francisco, 1995.

Natural Disasters: Severe Weather

Severe Weather Problem Description

Throughout the United States, severe weather conditions such as floods, major snow storms and tornadoes restrict travel on roads, trains and airplanes for as short as several hours to as long as several months or even years. Since there is no way to reduce the probability of these hazards, risk managers need to focus on decreasing the impact of these events on the transportation system.

Impacts of Severe Weather Conditions

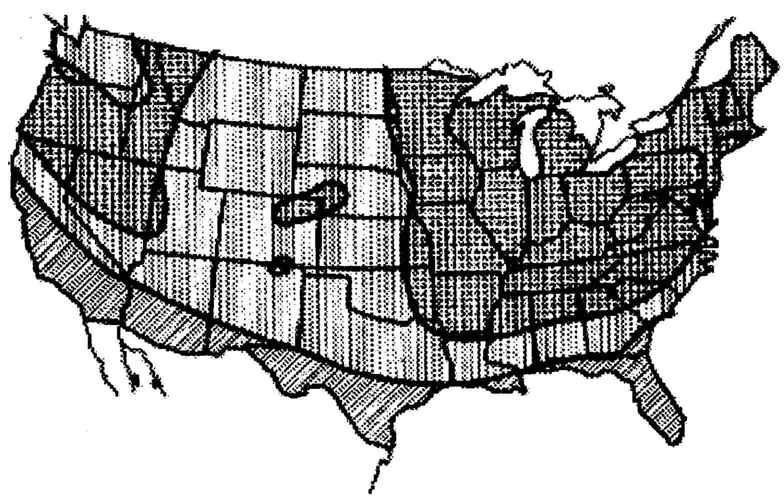
The damage caused by the 1996 Blizzard in the Northeast represents an example of the impacts that can occur from severe weather conditions. The cost of the 1996 Blizzard to the Northeast totaled $10 billion in lost production and $7 billion in lost sales. The cost to the New York region was estimated to be $1 billion when calculating damages and loss of economic activity. These losses were caused primarily because of the inability to travel on highways and by air for several days. Since Amtrak and other commuter rail services were the only forms of transportation available during the blizzard, a more efficient rail system such as a high-speed rail line would have had an even greater effect on reducing the economic losses and social dislocations caused by the blizzard.[68]

Probability of Severe Weather Conditions

The probabilities of severe weather conditions depend foremost on one's geographic location. Concerning floods and major snow storms, the northeast, midwest and northwest regions of the United States receive the largest amount of rainfall and have the longest freezing cycles. (Figure 16) Even though the southwest is fairly immune to regular freezing cycles and heavy rains, this region is still exposed to floods along riparian areas.

FIGURE 16

Weathering Indices Based on Freezing Cycle and Winter Rain



Severe Weather   Moderate Weather   Negligible Weather

Source: MIT Rotch Visual Collections, Construction, Site Views, Climate and Weather, Slide #B3: B7930 "Construction Materials."

[68] Desda Moss and Lori Sharn, "Economic Costs of the '96 Blizzard," *USA Today*, January 11, 1996.

Regarding floods, the definition of a large flood basin is one with exceedance probabilities of at least ten percent. Exceedance probabilities refer to peak discharges or volumes. Rivers with high probabilities of having large snowmelt floods include Ute Creek (Colorado), Judith River (Montana), South Fork Cedar River (Washington), and Middle Crow Creek (Wyoming). Rivers with high probabilities of having large rainfall floods are more numerous, and are listed below:[69]

West

- Alaska: Cascade Creek
- Arizona: Colorado and Salt Rivers
- California: Eel River
- Colorado: Plum Creek
- Hawaii: Kawaikoi Stream
- Idaho: Salmon River
- Montana: Yellow Stone River
- Oregon: Columbia River and Cow Creek
- Utah: Virgin River
- Washington: Skagit River

Central

- Arkansas: Arkansas River
- Indiana: Ohio River
- Louisiana: Red River
- Minnesota to Mississippi: Mississippi River

[69] The Unesco Press, *World Catalogue of Very Large Floods*, A Contribution to the International Hydrological Programme, Paris, 1976, pp. 415 - 423.

- Missouri: Salt River
- Nebraska: Big Blue River
- Texas: San Saba River

East

- Georgia: Altamaha River
- Massachusetts: Connecticut and Quaboag Rivers
- New Hampshire: Otter Brook River
- North Carolina: Beetree Creek
- Pennsylvania: Susquehanna River
- Tennessee: Clinch River
- Virginia: James River

Concerning tornadoes, certain states experience more of these events than others. The state of Texas, for instance, has experienced the most tornadoes from 1950 to 1994 than any other state with 5,490 tornadoes during this period compared to Oklahoma which ranks second with 2,300 tornadoes. The top ten states with the most tornadoes between 1950 and 1994 are as follows: Texas, Oklahoma, Kansas, Florida, Nebraska, Iowa, Missouri, South Dakota, Illinois, and Colorado.[70]

Benefits of Modal Diversification

Diversification of the transportation system would help alleviate the impact of supply and demand fluctuations as a result of damage caused by severe weather incidents. Even though rail systems are susceptible to damage from severe weather, this mode is

[70] Federal Emergency Management Agency Home Page, Tornado Statistics page, March 1996.

one of the most robust means of travel. For example, during the Blizzard of '96, state of emergency conditions persisted in the Northeast for several days causing highway and airport closures as well as train travel delays. An Amtrak spokesperson, who testified at the Pennsylvania House Transportation Committee, stated that, "When airports and roads were closed, Amtrak was running. Of the 94 Amtrak trains scheduled to run between Harrisburg and Philadelphia that week, 77 ran, and 28 of the 32 trains scheduled to run west of Harrisburg got through."[71]

The cost of the 1996 Blizzard to the Northeast totaled $10 billion in lost production and $7 billion in lost sales. The cost to the New York region was estimated to be $1 billion when calculating damages and loss of economic activity.[72] With the addition of a high-speed rail service from Washington, D.C. to Boston, the reduction of economic losses are assumed to range between five percent and 20 percent. Using these assumptions, a HSR service would be able to reduce the economic losses for the Northeast between $500 million and $2.0 billion in increased production and between $350 million and $1.4 billion in increased sales for a major snow storm of similar magnitude.[73]

[71] Testimony of Isabel Kaldenbach, Manager of Government Affairs, Amtrak's Northeast Corridor, Pennsylvania House Transportation Committee, March 19, 1996, p. 4.
[72] Desda Moss and Lori Sharn, "Economic Costs of the '96 Blizzard," *USA Today*, January 11, 1996, p. 3.
[73] Ibid, p. 3.

Human-Caused Interruptions

Introduction

Human-caused interruptions such as terrorist activities and transportation-related labor strikes are highly irregular. The likelihood of these events are difficult to predict and depend primarily on the political situation for terrorist attacks and on labor relations for labor strikes. The duration of these incidents ranges from a few days to a few months. Modal diversification would help to lessen the impact of these incidents because this strategy makes it easier for travelers to switch to a comparable means of travel.

Human-Caused Interruptions: Labor Strikes

Labor Strike Problem Description

Transportation-related labor strikes are most prevalent in the air and rail industries since these systems rely more heavily on labor for system maintenance and operation. Nevertheless, highway vehicle travel is affected by demonstrations that cause road closures.

Impacts of Transportation-Related Labor Strikes

The impact of a strike depends on its duration and on the effect that it has on the overall transportation system. Strikes may affect a local transit operation in a specific city or these incidents may reduce travel nationally on an entire mode of transportation.

Some more well-known transportation-related strikes include the following:

- *1995 Strikes in France*: Transportation unions shutdown the French intercity train services and the metro service in Paris for over three weeks in protest of inadequate pensions, pay and work hours. Air traffic controllers and airport fire brigades also went on strike reducing the number of daily strikes from 4,500 scheduled daily flights to 3,800 over three weeks.[74] The strikes restricted highway travel throughout France, and caused massive traffic congestion delays in Paris because of increased automobile users and mass demonstrations.

- *1981 Professional Air Traffic Controller Strike*: About 12,000 air traffic controllers went on strike for two months beginning on August 3, 1981. Air travel was reduced between 60 and 75 percent compared to regular conditions during the first two weeks of the strike. Two days into the strike, the Air Transportation Association estimated that the strike was costing the air industry $35 million per day. Economic costs to members of the American Hotel and Motel Association were estimated to be between $10 and $15 million per day.[75]

- *1988 Golden Gate Transit Strike*: For over one week, Golden Gate Transit bus drivers and ferry operators along the Highway 101 corridor in the San Francisco Bay Area went on strike. The strike affected approximately 10,000 passengers, and caused a 14 percent increase in highway vehicles during the peak period of travel. Nevertheless, a strike-related increase in traffic congestion did not occur because of travelers' willingness to switch to carpools, and to travel more during off-peak

[74] Alexandre Polozoff, *The French Strikes (en Greve) of 1995*, World Wide Web, December 21, 1995.
[75] Bert A. Spector, *Air Traffic Controllers*, Harvard Business School, Boston, MA, 1982.

hours. Approximately 58 percent of the bus and ferry riders switched to carpools, and over five percent of peak-period trips were switched to off-peak hours.[76]

Probability of Transportation-Related Labor Strikes

The likelihood of having labor strikes is difficult to judge because their frequency depends on the political situation and on labor relations.

Benefits of Modal Diversification

If a multimodal transportation system existed that included high-speed rail services in key intercity corridors, then the impacts of an air-related strike would not be as severe because a diverse system helps to spread the excess transportation demand caused by a service disruption. For example, the hotel and motel industries throughout the nation lost an estimated $10 million to $15 million per day in revenues during the air traffic controllers strike.[77] If HSR lines were in place in well-traveled air corridors, then the impact of this strike is assumed to be reduced between five percent and 20 percent, as a first-order estimation. If this scenario occurred, then HSR in key corridors would reduce the economic losses to the hotel and motel industries between $500,000 and $3 million per day.

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[76] Steve Beroldo, "Effects of Golden Gate Transit Strike on Highway 101 Corridor," *Transportation Quarterly*, Vol. 43, No. 2, April 1989, pp. 225-238.
[77] Bert A. Spector, *Air Traffic Controllers*, Harvard Business School, Boston, MA, 1982.

Human-Caused Interruptions: Terrorism

Terrorism Problem Description

The United States is one of the most frequent terrorist targets abroad totaling about 21 percent of world terrorism; however, the United States has experienced comparatively low levels of terrorism within its borders.[78] The Federal Bureau of Investigation (FBI) defines domestic terrorism as "involving groups or individuals whose terrorist activities are directed at elements of our government or population without foreign direction," and states that international terrorism involves "terrorist activities committed by groups or individuals who are foreign based and/or directed by countries or groups outside the United States or whose activities transcend national boundaries."[79]

Over the past few years, an increase in domestic terrorism has occurred while anti-US attacks abroad have remained relatively constant. The event that shook the United States to the forefront of domestic terrorism was the 1993 bombing of New York City's World Trade Center that killed six people and wounded 1,000 others. (Figure 17) The Oklahoma City bombing, anti-abortionist killings and other events give further evidence that the United States is no longer immune to domestic terrorism.[80]

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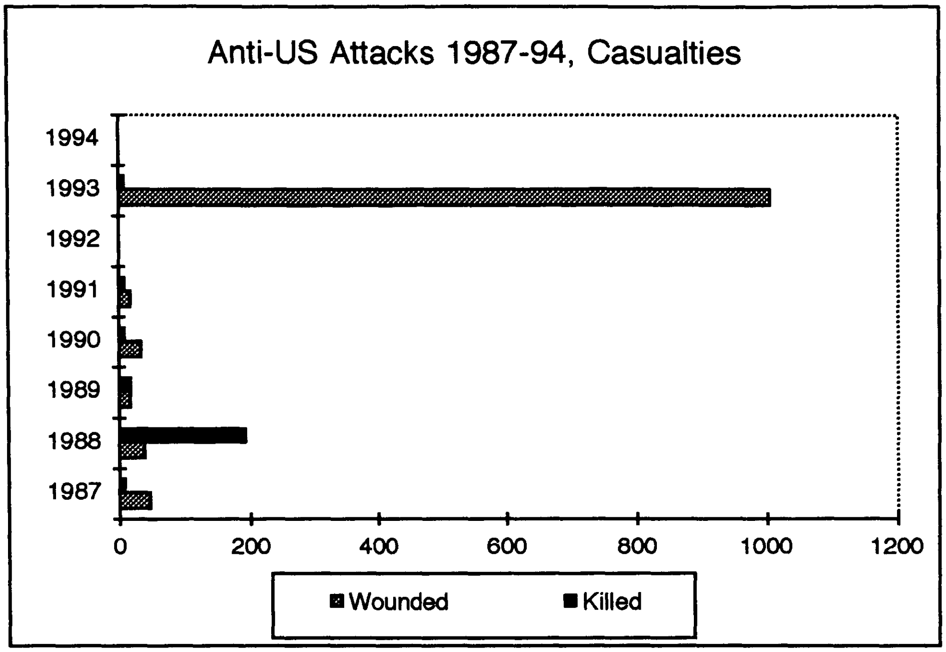
[78] "Recent Trends in Domestic and International Terrorism," *Center for National Security Studies*, CDT Home page on the World Wide Web, Washington, D.C., April 26, 1995.
[79] Kevin Jack Riley, Bruce Hoffman, *Domestic Terrorism: A National Assessment of State and Local Preparedness*, RAND, Santa Monica, California, 1995, p. 3.
[80] Ibid, p. 15.

FIGURE 17



Note: The 1988 outlier occurs because of the Pan Am Flight 103 that exploded over Scotland; the 1993 outlier occurs because of the bombing of New York City's World Trade Center.

Source: United States Department of State, 1994.

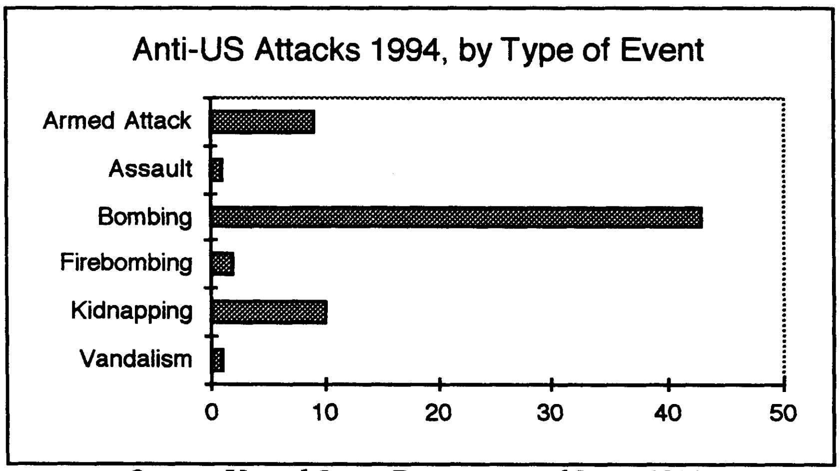
The five most prominent domestic terrorist groups in the United States are as follows:

- Ethnic separatists and émigré groups;
- Left-wing organizations;
- Right-wing racist, anti-authority and survivalist-type groups;
- Foreign terrorist organizations; and
- Issue-oriented groups such as anti-abortion militants, animal rights, and environmental extremists. [81]

[81] Ibid, p. 13.

The event that reminded the United States of its vulnerability to international terrorism was the 1988 Pan Am flight 103 that exploded in mid-air over Lockerbie, Scotland killing 259 passengers and crew members, and 11 persons on the ground. A total of 189 Americans died in this incident, which terrorists targeted in retaliation for the 1986 U.S. airstrike on Libya.[82] The most current statistics on anti-U.S. terrorist attacks abroad reveal that incidents involve bombs about 65 percent of the time, and are more apt to take place in Latin America (67 percent).[83] (Figures 18 and 19)

FIGURE 18

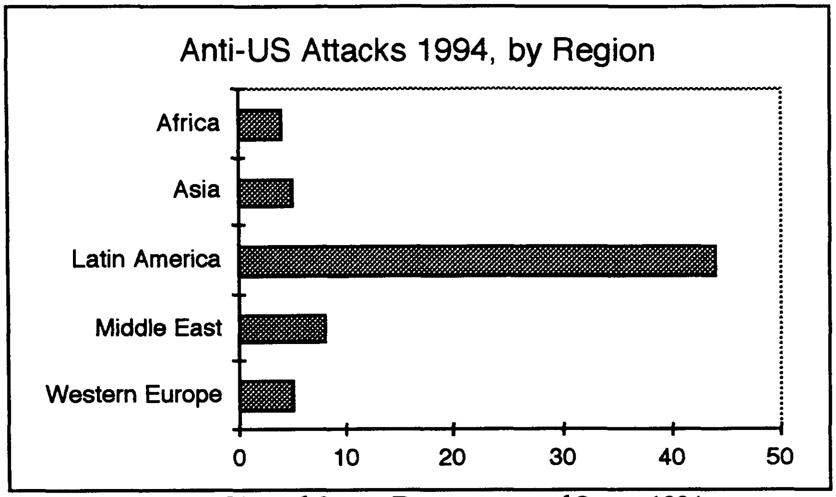


Source: United States Department of State, 1994.

[82] Karen Gardela, Bruce Hoffman, *The RAND Chronology of International Terrorism for 1988*, RAND, Santa Monica, CA, 1992, pp. 80-81.

[83] United States Department of State, *Patterns of Global Terrorism 1994*, Office of the Secretary of State, Office of the Coordinator for Counterterrorism, April 1995, p. 67.

FIGURE 19



Source: United States Department of State, 1994.

Impacts of Transportation-Related Terrorism

All modes of travel are exposed to terrorist incidents, however, the more services in place during such a crisis the better because each mode of travel is vulnerable in different ways. In the past, terrorist tactics have targeted specific modes of travel through bombings and hijackings. The more sophisticated terrorist may use chemical or biological agents, or even portable missiles left-over from the Cold War. Transportation infrastructure that is exposed to bombs includes power lines, bridges, freeways, airplanes, rail tracks, and transportation terminals. Various bombing incidents by mode are shown below:

- Concerning the air industry's exposure to bombs, there were a total of eight explosions aboard aircrafts killing about 700 passengers and crew members between 1986 and 1991.[84] International terrorists bomb not only airplanes but also

[84] William C. Chmelir, "Terrorism and Transportation in the 1990s," *Defense Transportation Journal*, August 1990, p. 22.

airports and airline offices. In 1986, bombs were detonated outside airline offices in Sweden, Peru, Pakistan and Chile.[85]

- Highway vehicles also are susceptible to bombings as the 1993 World Trade Center bombings revealed in which a car bomb was detonated completely destroying a parking garage. These same terrorists also planned an elaborate scheme to destroy two commuter tunnels and a bridge that link New Jersey and Manhattan.[86]

- Rail systems are exposed to bombs at stations, on trains and along tracks. For example, the Belfast-Dublin line in Northern Ireland was closed for 56 days in 1989 because of 18 bombings and 19 hoax warnings. Another example is the use of chemical agents in a Tokyo train station in 1995 that seriously injured many passengers.[87]

Hijackings are a terrorist problem specific to the airline industry. The sophistication of hijackers has steadily increased from the early days in the 1960s when they were mainly individual political dissidents. They come equipped with demands for the release of "comrades" and use hostages as bait to ensure that their requests are met. [88]

With bombings, hijackings, and the advent of biological and chemical agents as well as sophisticated weaponry, terrorism will persist as a considerable threat to the national security. Transportation systems will continue to make ideal targets for terrorists

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[85] Karen Gardela, Bruce Hoffman, *The RAND Chronology of International Terrorism for 1986*, RAND, Santa Monica, CA, 1990.
[86] Kevin Jack Riley, Bruce Hoffman, *Domestic Terrorism: A National Assessment of State and Local Preparedness*, RAND, Santa Monica, California, 1995, p. 16.
[87] William C. Chmelir, "Terrorism and Transportation in the 1990s," *Defense Transportation Journal*, August 1990, p. 22.
[88] Jeffrey D. Simon, *The Terrorist Trap: America's Experience with Terrorism*, Indiana University Press, Bloomington, Indiana, 1994, p. 350.

because travelers are exposed like captive audiences trapped in terminals, on airplanes, or in highway vehicles.

Probability of Transportation-Related Terrorism

The possibility of terrorism depends on the political environment, and most notably for the United States, on the activities of right-wing groups and issue-specific organizations such as abortion activists and anti-authority coalitions. According to the RAND survey, 34 out of 50 states plus Washington, D.C. and Puerto Rico, or 87 percent, reported the prevalence of right-wing terrorist groups in their jurisdictions between 1988 and 1993, while 59 percent reported the prevalence of issue-specific terrorist groups. The RAND survey also reveals that the west and midwest are more likely to have terrorist threats, with 79 percent and 85 percent of the jurisdictions reporting the presence of terrorist incidents, respectively, whereas only 46 percent of the northeastern jurisdictions reported threatening incidents. FBI statistics are consistent with the RAND survey in that more incidents occur in these two regions within the United States.[89]

Terrorist experts anticipate that bombings will continue at a similar rate because this tactic makes a dramatic impact, and does not take much coordination as opposed to kidnappings or assassinations. Terrorist experts also predict that hijackers will continue to be a problem since it is impossible to completely secure an airport, and the usage of fake weapons is always a concern.[90] Furthermore, there is a new generation of terrorists due to the proliferation of sophisticated weapons acquired during the Cold

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[89] Kevin Jack Riley, Bruce Hoffman, *Domestic Terrorism: A National Assessment of State and Local Preparedness*, RAND, Santa Monica, California, 1995, pp. 22-24.

[90] Jeffrey D. Simon, *The Terrorist Trap: America's Experience with Terrorism*, Indiana University Press, Bloomington, Indiana, 1994, p. 350.

War, and chemical and biological agents. For example, some antitank and antiaircraft missiles are portable, and can be used by individuals such as lone terrorists. Existing security measures at airports and other facilities are not sufficient because terrorists using these weapons can stand near a runway and fire at in-bound and out-bound planes. Other high-tech weapons include chemical agents as used in the Tokyo train station in 1995, and biological weapons that spread diseases. Biological warfare is more accessible due to genetic engineering and microencapsulation, which enables a time release of biological agents.[91]

Benefits of Modal Diversification

In order to mitigate against terrorist attacks on the transportation system, transportation planners must provide back-up systems for whichever mode falls victim to this type of incident. With the implementation of high-speed rail, more options would exist for intercity travel in case a terrorist attack debilitates air or highway systems. It is important to acknowledge that rail is susceptible to terrorism, however, this mode is still useful as a way to lessen the impact of terrorist attacks that affect other modes. Since terrorists most often strike random targets at unexpected times, transportation experts must ensure that the system can respond with resilience to any type of terrorist activity that effects the transportation system both directly and indirectly.

[91] Ibid, pp. 354-357.

Transportation Vulnerability Summary

This chapter discussed the following transportation service interruptions:

1) Air quality, energy constraint, and global warming regulations that affect the transportation system;
2) Natural disasters such as earthquakes and severe weather conditions; and
3) Human-caused interruptions such as labor strikes and terrorism.

Concerning transportation policy changes, the bi-modal intercity transportation system that revolves around highway and air travel exacerbates problems relating to air pollution, energy shortages and global warming. The measures used to lessen the impact of these negative externalities directly affect the transportation system through no drive days, and indirectly affect the transportation system through gasoline or emission taxes. The impact of these regulations would most likely be severe since a reversal of chronic air pollution, global warming trends and oil dependency would mean drastic changes in travel behavior, namely reductions in highway vehicle miles traveled. The likelihood of having the policy makers impose such draconian measures is high, especially in light of the air pollution situation in California and other regions throughout the nation as well as new breakthroughs pertaining to global warming research.

Concerning energy-related regulations, the 1996 gasoline price increases act as a reminder of this nation's dependence on oil, and help to justify the need for self-sustaining energy policies. In order to minimize the economic and social disruptions caused by policy measures that directly and indirectly affect the transportation system, policy makers could develop more energy-efficient modes such as high-speed rail. Competitive HSR services would offer intercity travelers an alternative at no greater cost in time or money, and yet this service has a much smaller societal cost in terms of its exposure to transportation-related regulations.

The second group of interruptions includes natural disasters. These incidents range from small-scale events such as snow storms to large-scale disasters like major earthquakes, floods and tornadoes. The likelihood of these occurrences are usually difficult to predict. The timeframe for disruptions caused by snow storms ranges from a few hours to many days, while major earthquakes and floods can cripple the transportation system for several months. The extent of damage to the transportation system and the extent of traveler delays depends not only on the quality of the transportation infrastructure, but also on the travel options available after an incident. Modal diversification helps to raise the probability that multiple transportation options are in place so that if one mode becomes interrupted during a natural disaster, then the other ones will be able to compensate for the excess demand. The more modes in place, the more flexible the transportation system is to supply and demand fluctuations caused by natural disasters. The overall benefit is a reduction in travel delay and economic losses during service interruptions.

The third and last group of service interruptions is classified as human-caused interruptions, and includes labor strikes and terrorist activities. These interruptions directly affect transportation services because their main objective is to disrupt the system. The timeframe for these disturbances varies considerably depending on the tactics used by labor unions or terrorists. For example, these groups may threaten to jeopardize a transportation service causing a few hours of delay or they may actually proceed with their threats causing weeks if not months of service delays or shutdowns. The likelihood of an occurrence is difficult to quantify because labor relations and terrorist activities depend heavily on dynamic economic and political power struggles. Because the intercity transportation system is primarily bi-modal, it is particularly exposed to disruptions involving human intervention. The mere fact that the intercity system is exposed makes it an ideal target for any type of human interruption. Modal diversification would decrease the system's vulnerability by giving travelers more options during these unexpected service reductions or failures.

The next chapter highlights more in depth the benefits of modal diversification. The chapter also discusses the history of this strategy, and pinpoints rail as an effective mode for diversification.

Chapter III: Diversification as a Risk Reduction Strategy

Introduction

Since the number and type of transportation service interruptions is overwhelming, it is almost futile to expect planners to remedy all of them. In addition to creating in-depth contingency plans and procedures for major potential system exposures, transportation experts should address the problems at a more macro level. Diversification of the transportation system decreases the impact of many service disruptions since different modes have different vulnerabilities. This strategy helps to decrease the economic impacts and social dislocations of policy regulations, natural disasters, and human-caused disruptions because a diverse, multimodal transportation system is better able to accommodate excess demand caused by supply service interruptions on other modes. The following chapter will focus on the history of diversification, the costs and benefits of this approach, and then pinpoints rail as an effective way to achieve diversification.

Historical Perspective of Diversification

National, state and local policies have demanded that the transportation system diversify for different reasons throughout history. Since issues compete for attention and time, transportation policies tend to concentrate on a few problems at a time, and then diversify the system in ways that satisfy specific policy goals. For example, in the 1950s and 1960s, the main emphasis was on national defense. The 1956 Federal-Aid Highway Act was politically justified in part on the premise that highways would reduce the United States' vulnerability to attack. The National System of Interstate and Defense Highways was named as "essential to the national interest and is one of and Defense Highways was named as "essential to the national interest and is one of the most important objectives of this Act."[92] Thus, the transportation system diversified its portfolio to include the use of automobiles as a viable intercity mode of transportation.

In the 1970s and 1980s, the main concern was energy conservation. In order to conserve energy, the Federal Transit Administration (formally known as the Urban Mass Transit Authority) promoted the energy conservation benefits of rail when presenting a rationale for federal support of rail transit. According to the 96th Congress in 1978, the official federal policy toward rail transit stated, "rail transit can be a means to more efficient forms of urban settlement and an instrument of *long range energy conservation efforts*...Specifically, rail transit can help in our nation's efforts to revitalize distressed cities and prepare the way for a gradual transition to an *energy-constrained future*."[93] (italics added for emphasis) In this case, policy makers were encouraging diversification by advocating for more federal monies towards an alternative means of transportation.

In the 1990s, air quality and congestion attracted center stage. The 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) formally recognizes the need to improve air quality and congestion. The act appropriates monies for projects that help attain the national ambient air quality standards as stated in the 1990 Clean Air Act amendments. Total funding for the program, titled Congestion Mitigation and Air Quality, is $6 billion over a six-year period. Even though congestion is stated as a key

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92 Public Law 85-767 - August 27, 1958, Title 23-Highways, U.S. Statutes at Large, 85th Congress, 2nd Session, Volume 72, Part I, Chapter 1-Federal-Air Highways, Section 101, p. 887.
93 Urban Mass Transit Administration, *Policy Toward Rail Transit*, Department of Transportation, Federal Register, Appendix, Tuesday, March 7, 1978, Part III.

component of this program, the issue of air quality is the controlling factor. As a result, the United States transportation system is diversifying in that less-polluting modes such as rail, buses and bicycling are gaining more financial support.

In general, transportation policies do not simultaneously consider the full range of disruptions that may besiege transportation systems. As shown above, federal policies attempt to decrease the impacts of these disruptions on a case-by-case basis. The potential service interruptions that are selected may not necessarily be the ones that pose the most risk; rather these problems tend to be those most politically feasible to tackle. For example, current federal policies deem that air quality issues are of greater concern than energy conservation. The federal government has designated an entire ISTEA program to counter air pollution problems whereas energy conservation is barely mentioned. Nevertheless, the probability of oil shocks has not decreased since the 1970s and 1980s; the opposite may be true, as the 1990 Gulf War and the 1996 gasoline price increases have illustrated. The political power needed to achieve substantial difference in oil consumption has faltered, and the short-memory of the American public has moved on to concerns such as congestion and air quality.

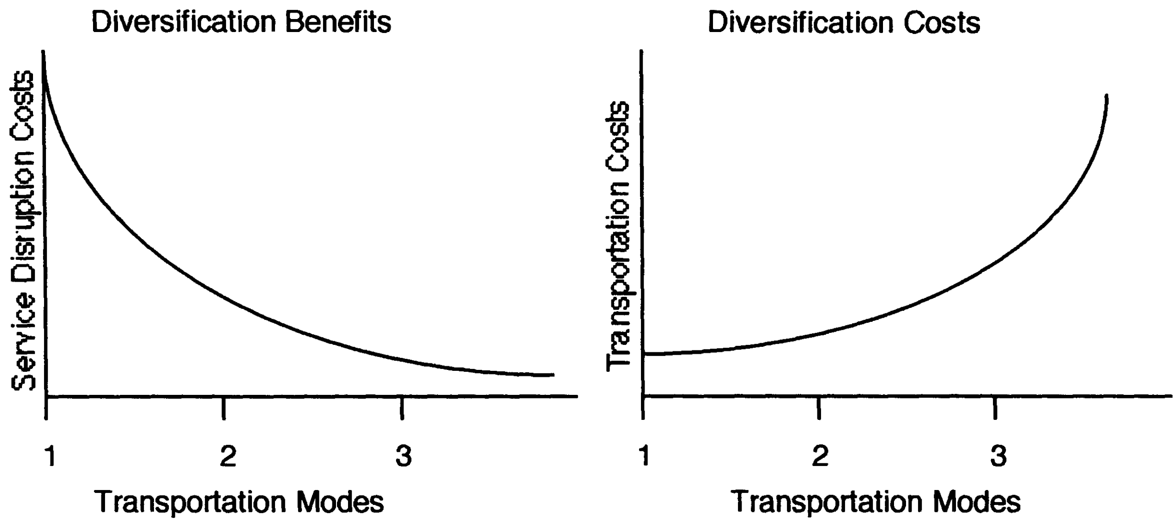
Diversification Benefits and Costs

The main advantage of diversification is that the transportation system becomes more flexible, and better able to respond to supply and demand fluctuations; the main disadvantages of this strategy are high start-up costs, and the inability to fully develop a single mode to its optimal level due to funding constraints. The benefits of diversification may outweigh the costs because the overall effect is a reduction of economic losses and social dislocations caused by service interruptions. As described in the next chapter, for example, a policy relating to energy conservation is assumed to affect highway and air travel most severely. Thus, the development of a more energy-efficient intercity mode such as high-speed rail would give travelers a convenient alternative that is competitive in terms of time and cost to air and highway travel.

Thus, diversification of the transportation system is intended to reduce the impact of incidents such as energy crises, natural disasters, or terrorism. When a disruption to the transportation system occurs, a multiplier effect is felt throughout the economy. In order to alleviate the consequences of a service interruption, multiple transportation options should exist to help spread the excess transportation demand. Figure 20 illustrates the economic benefits of diversification during service interruptions and compares them to the higher costs of constructing a multimodal transportation system. As diversity of the transportation system increases, the costs of service disruptions decrease because of reduced travel delays, and the costs of developing such a system increases. Developing a new mode of transportation takes more time and resources than adding capacity to existing modes because of the more extensive right-of-way acquisition, design, engineering and planning costs associated with developing an additional mode.

FIGURE 20

Diversification Benefits and Costs



Additional modes also are able to respond better to service interruptions of any length, from as short as a few days to as long as several decades. Examples of disruptions with short timeframes include floods, snow storms and terrorist threats; medium-range events consist of earthquakes, energy constraints, air pollution, labor strikes, 100-year floods and terrorist attacks; and long-range occurrences include policies connected to global warming and extreme air pollution situations.

For service interruptions with short timeframes, a transportation system equipped with multiple service options can immediately respond to a sudden decrease in supply. For service disruptions that continue for several months or even years, a diverse transportation system has the ability to increase more capacity in less time and at a quicker rate compared to a bi-modal intercity system that could only expand capacity on one mode assuming the other is interrupted.

The San Francisco Bay Area is an example of an area with a diversified transportation system that responded well to a highway service interruption. After the Loma Prieta earthquake in October 1989, the San Francisco-Oakland Bay Bridge failed forcing 243,116 daily users to find alternative routes or means of transportation.[94] The Bay Area Rapid Transit (BART), a commuter rail operation, increased service to 24 hours and seven days per week, and supplied additional parking spaces and cars per trains. Ridership in the BART tube across the bay increased 122 percent from 102,152 passengers per day to 226,876 passengers per day. The ferry system tripled its service causing an increase in ridership from 6,250 passengers per weekday to over 21,000 passengers per weekday.[95] (Table 9) Since the San Francisco Bay Area already had a diversified transportation system, they were ready to react reducing economic losses and traveler stress.

TABLE 9

Use of the San Francisco Bay Transportation Links
Before and After the Loma Prieta Earthquake[1]

	Before Earthquake	After Earthquake	Difference
San Rafael Bridge	44,000	79,173	+79.9%
Golden Gate	123,754	150,927	+21.9%
Oakland-Bay	243,116	0	-100.0%
San Mateo	65,000	109,791	+68.9%
Dumbarton	41,500	67,189	+61.9%
BART tube	102,152	226,876	+122.1%
All ferries	6,250	21,057	+236.9%

[1]The table represents the total number of two-way trips per weekday, except for the BART tube and ferry figures, which represent two-way riders per weekday.

Source: California Department of Transportation, *Post-Earthquake Commute Summary-Daily Trips*, December 19, 1989.

[94] Richard M. Fahey and George E. Gray, "Bay Area Emergency Ferry Service: Transportation Relief After the October 17, 1989, Earthquake, California Department of Transportation, Transportation Research Record 1297, pp. 148 - 161.
[95] Siamak A. Ardekani, Transportation Operations Following the 1989 Loma Prieta Earthquake, Transportation Quarterly, Vol. 46, No. 2, April 1992, p. 225.

The aftermath of the Northridge earthquake in 1993 highlights an example of a recently diversified transportation system that worked well during a two-month long highway interruption. The Los Angeles metropolitan area runs a commuter rail system called Metrolink that carried 1,000 passengers per day before the earthquake. As a result of the 1993 temblor, one of the busiest freeways in the nation collapsed. In response, Metrolink expanded its services by borrowing coaches from CalTrain, which were rolled south from the San Francisco Bay Area. This operation allowed ridership to increase from 1,000 passengers per day to 20,000 passengers per day in the first week, and then stabilized to 9,000 passengers per day after four weeks. Since the infrastructure was in working order and the service already existed, Metrolink was able to expand the service in a matter of hours to meet emergency needs.[96] If Metrolink did not exist, 19,000 commuters would most likely use their automobiles, only to further exacerbate the post-earthquake congestion problems.

[96] *Northridge Earthquake: Lifeline Performance and Post-Earthquake Response*, Technical Council on Lifeline Earthquake Engineering, Monograph No. 8, edited by Anshel J. Schiff, published by the American Society of Civil Engineers, New York, August 1995, p. 212.

Rail as an Effective Mode for Diversification

Since rail is a robust system that can withstand most major transportation disruptions, and can accommodate a substantial number of passengers, we argue that it is an effective way to achieve transportation diversification. The position taken in this report is that rail is less exposed than air and highway travel to many service interruptions. (Table 10) The benefits of rail depend on the type and severity of the disruption. When considering the three categories of potential transportation vulnerabilities (transportation policy changes, natural disasters and human-caused interruptions), rail would probably provide the most relief during policy changes that affect the transportation systems such as air quality, global warming or energy crisis regulations since it is an energy-efficient and low-emitting mode of transportation.

Regarding transportation policy changes, rail is able to decrease the economic impact and social dislocation of air quality, global warming or energy crisis regulations because it is an energy-efficient, low-polluting mode that can be expanded if politicians deem that transportation emissions are too high or when an oil shock occurs. Since rail uses comparatively small amounts of oil, it has lower air pollution and greenhouse gas emissions and is less dependent on oil. According to the Worldwatch Institute, rail "is three times as energy-efficient as commercial air and six times as efficient as a car with one occupant." (The measurement considers the energy needed to move one traveler one kilometer in the United States.)[97] Furthermore, "fuel represents only three percent of Amtrak's total cost of operations, compared to approximately 15-20 percent in the

[97] Marcia D. Lowe, *Back on Track: The Global Rail Revival*, Worldwatch Paper 118, Worldwatch Institute, April 1994, p. 10.

airline industry."[98] This fuel comparison reveals that during energy crises, airfares will be more susceptible to increases while rail fares are likely to remain stable, and, more importantly, affordable. Thus, the "conventional" benefits of rail such as energy efficiency make this mode less exposed to policy-related service disruptions pertaining to air quality, global warming and energy crises.

Concerning natural disasters, rail has played a pivotal role in the aftermath of earthquakes and snow storms. The 1996 Blizzard helps to illustrate the benefits of rail after natural disasters. During and after the 1996 Blizzard, Amtrak and the commuter rail services were the only intercity transportation systems running for several days in New Jersey and Pennsylvania. Although rail also is vulnerable to natural disasters, it is able to compensate for excess demand if it withstands damage from an incident. Even if rail is damaged, the recovery tends to be much quicker since rail relies on simple technology and sparse infrastructure.

Regarding human-caused interruptions such as labor strikes and terrorism, it is useful to have the presence of another mode such as rail in the event of an air or highway service disruption in order to raise the probability that at least one mode would remain operational. It is important to note that rail also is vulnerable to certain types of terrorist attacks and labor strikes, and that its ability to reduce the economic losses caused by service disruptions depends on the particular situation. Even though rail is exposed to certain incidents, diversification with rail still helps to alleviate the stress on other modes, and to improve mobility during service interruptions.

[98] Joseph Vranich, *Supertrains: Solutions to America's Transportation Gridlock*, St. Martin's Press, New York, 1991, p. 318.

In order to increase the probability that rail transportation is competitive with air and auto travel during normal operations and effective during service interruptions, we argue that high-speed rail service (i.e., not conventional service) would be required in most corridors. The development of conventional rail is difficult to justify economically because, in most corridors, it is not viable during regular conditions. HSR does not exist in the United States except for the Northeast Corridor (NEC) so passengers transferring to conventional rail during an air or highway disruption would have to expect slow and somewhat unreliable service. Some travelers would opt to avoid trips while others would waste valuable time on trains that run at slow speeds. If the disruption was a prolonged one, the overall effect would be an economic slowdown. To prevent such a severe impact, a HSR service that was immediately available could provide efficient and reliable service, which competes with air and automobile travel in both cost and travel time.

The diversification benefits of rail, and especially of HSR, are only part of its appeal in that the "conventional" benefits are also numerous. Rail's high carrying capacity combined with other "conventional" benefits such as employment opportunities, congestion relief, competitiveness with air and highway travel, and accident reductions make it a reasonable intercity mode not only as a type of capacity reserve for service interruptions but also as a legitimate means of transportation during regular conditions.

"Conventional" benefits of rail, and high-speed rail, are illustrated by the following:

- The carrying capacity of a heavy-rail system under heavy demand conditions, "is almost unequaled by any other mode of travel. Existing rapid transit systems can carry comfortably between 20,000 and 34,000 passengers per track per direction each hour. For projected light rail systems, that number is approximately 10,000."[99]

- Concerning accident reductions, for the Las Vegas - Southern California proposed high-speed rail line, "In the first year of the system, the big switch to trains is expected to prevent more than 270 accidents, 140 injuries and 15 fatalities on or near I-15."[100]

- A 1991 commuter rail study by the Urban Institute and Cambridge Systematics, Inc. reveals that for every dollar spent on Philadelphia's commuter rail service, the region and state receive a three dollar return as a result of improved rail systems. On the contrary, driving has negative externalities like air pollution, accidents, and traffic jams that equal $300 to $600 billion annually nationwide, according to the United States Committee on Banking.[101]

- According to the same commuter rail study, another positive externality of rail is improved worker productivity. "A 10-year, $100-billion increase in public transport spending was estimated to boost worker output by $521 billion - compared with $237 billion for the same level of spending on highways."[102]

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[99] U.S. Committee on Banking, Finance and Urban Affairs, *New Urban Rail Transit: How Can its Development and Growth-Shaping Potential be Realized?*, 96th Congress, 1st Session, U.S. Government Printing Office, December 1979, p.207.
[100] Joseph Vranich, *Supertrains: Solutions to America's Transportation Gridlock*, St. Martin's Press, New York, 1991, p. 346.
[101] Marcia D. Lowe, *Back on Track: The Global Rail Revival*, Worldwatch Paper 118, Worldwatch Institute, April 1994, pp. 41-42.
[102] Ibid, pp. 41-42.

In conclusion, modal diversification gives travelers more options not only during regular operating conditions, but also during service disruptions. When a service is interrupted, a diverse transportation system is better able to increase capacity at a higher level as well as at a quicker rate. If diversification is valued as a way to decrease the economic losses during service disruptions, then rail, and especially high-speed rail, would be effective modes to develop. Rail has both "conventional" and diversification benefits; it is a legitimate means of transportation during regular operating conditions, and provides invaluable capacity reserves during transportation supply and demand fluctuations.

TABLE 10

Maximum Impact of Service Interruptions on the Primary Intercity Modes of Travel

	Rail Travel	Air Travel	Highway Travel
Transportation Policy Changes			
Air Quality	Low emitter of carbon, ozone, etc. (X)	High emitter of carbon, ozone, etc. (XXX)	High emitter of carbon, ozone, etc. (XXX)
Energy Constraints	Reduces oil dependence (X)	High energy use (XXX)	High energy use (XXX)
Global Warming	Rail emits only minimal levels of greenhouse gases (X)	Planes are high emitters of greenhouse gases (XXX)	Highway vehicles are high emitters of greenhouse gases (XXX)
Natural Disasters			
Earthquakes	Bridges and tracks are vulnerable (XX)	Runways, and control towers vulnerable (XX)	Expensive and time consuming to rebuild road infrastructure (XXX)
Floods	Vulnerable to mudslides; flooding of moderate concern (XX)	Runways vulnerable to flooding (X)	Roads vulnerable to flooding and mudslides (XXX)
Snow Storms	Limited affect: unable to travel in extreme cases (X)	Unsafe runways, visual impairments restrict travel (XXX)	Highway vehicles have difficulty traveling due to snow on roadways (XXX)
Human-Caused Interruptions			
Labor Strikes	Susceptible to strikes because relies on a labor market to function (XXX)	Susceptible to strikes because relies on a labor market to function (XXX)	Not susceptible to strikes because does not rely on a labor market to function (X)
Terrorism	Exposed to terminals, tracks and trains (XXX)	Vulnerable to hijackings and bombs (XXX)	Limited damage to key links, bridges and car bombs (X)

X: Minimally Vulnerable XX: Vulnerable XXX: Extremely Vulnerable

Chapter IV: California High-Speed Rail Service Scenario-Based Analysis

Introduction

The main objective of the scenario-based analysis is to provide a first-order estimate of potential benefits derived from modal diversification during service interruptions. The analysis uses a proposed high-speed rail (HSR) project in California to help reveal how modal diversification could benefit an intercity corridor. A scenario-based analysis is needed because the *draft California HSR Economic Impact* study does not address how a HSR service could assist during or after an incident. The following chapter shows that a HSR service, when immediately available during a service disruption, can help to decrease the number of eliminated trips and the amount of additional travel time for those diverted to slower modes. These benefits translate into reduced economic losses and increased convenience for travelers.

The analysis identifies several service interruptions that pose a substantial risk to the intercity transportation system in California, and computes benefits given the assumption that those interruptions will occur. As described in earlier chapters, these disruptions were classified into the following three groups:

1) Policy changes relating to air quality, energy constraints, and global warming;

2) Natural disasters such as earthquakes; and

3) Human-caused interruptions such as labor strikes and terrorism.

The analysis then proceeds to estimate the impacts of these service interruptions on the transportation system, and the ability of HSR to reduce their negative consequences.

The benefits of the HSR service and, more broadly of modal diversification, are computed using first-order estimates. Definitive numbers are difficult to obtain because the impacts of service disruptions on the transportation system vary on a case-by-case basis; however, sensitivity analyses can help to bracket possible benefits.

Project Description

The California Intercity High Speed Rail Commission is developing a 20-year high speed intercity ground transportation plan for the state of California. The Commission's objective is to alleviate chronic intercity congestion and air pollution problems. Concerning highway congestion, the proposed HSR service is expected to reduce annual travel time delay by 29 to 35 million passenger hours, approximately $305 to $361 million annually in user time. Regarding air travel congestion, HSR is estimated to yield a cost savings of $238 to $471 million annually in user time by the year 2015. Concerning air quality, HSR is estimated to reduce the costs of air pollution by $52 million annually.[103]

Thus, the draft *Economic Impact* study justifies the need for a HSR service by highlighting its "conventional" benefits such as its ability to improve mobility and air quality. The study does not address the modal diversification benefits of increased system flexibility during service interruptions. For example, if a HSR service was available during an oil shock, travelers could immediately switch from highway or air travel to the HSR service, which is a more energy-efficient mode. Since the HSR service is expected to be competitive with both highway and air travel, the economic losses of

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[103] Wilbur Smith Associates with Flight Transportation Associates and J.R. Ramos Associates, *draft Working Paper #3: Cost Comparison of Mode Alternatives, California HSR Economic Impact*, prepared for Intercity High Speed Rail Commission, February 19, 1996, pp. 3-8 - 3-14.

such a switch would be minimal. If this service did not exist, no other intercity mode would be able to respond to the service interruption in a cost-effective manner. Thus, an economic slowdown would be expected. Therefore, a more comprehensive economic impact analysis would have addressed not only the "conventional" benefits of HSR, but also its diversification benefits such as its ability to reduce economic losses during both air and highway service interruptions.

The proposed base system includes service from Los Angeles to the San Francisco Bay Area, and possibly north to Sacramento, southeast to San Bernardino and Riverside, and south to San Diego. (Figure 21) The distance between Los Angeles and the San Francisco Bay Area is about 380 miles; the distance between San Diego and Sacramento is about 504 miles.[104] The Commission considered two possible north-south corridors (State Route-99 and Interstate-5), and several other more specific alignment alternatives. Twenty-nine Station Service Areas were identified with a spacing of approximately 40 miles; forty-seven different station site locations were targeted within these Station Service Areas.[105]

The favored corridor described in the draft *Economic Impact* study is the State Route-99 alignment. Wilbur Smith Associates with Flight Transportation Associates and J.R. Ramos Associates estimate that a total of 44 trains per day will travel in each direction by the year 2015. The fastest design traveling time between Los Angeles and San

[104] Ibid, pp. 1-1 - 1-5.
[105] Sharon Greene and Associates, *Candidate High Speed Rail Stations and Intermodal Connectivity, California Intercity High Speed Rail Study*, February 15, 1996, pp. 1-5.

Francisco is 2 hours and 49 minutes; the slowest design time is estimated to be 4 hours and 33 minutes (Maglev not included).[106]

FIGURE 21

California High-Speed Rail Proposed Project: Major Origin and Destination Endpoints

[106] Wilbur Smith Associates with Flight Transportation Associates and J.R. Ramos Associates, *draft Working Paper #3: Cost Comparison of Mode Alternatives, California HSR Economic Impact*, prepared for Intercity High Speed Rail Commission, February 19, 1996, p. 2-2.

Estimated ridership, revenue and service costs are as follows (Maglev not included):[107]

- Daily riders would total between 20,188 and 25,233 by the year 2020;
- Annual revenue would equal between $584 and $782 million by the year 2020;
- Capital costs when including extensions to Sacramento and San Diego would total $20.3 billion; and
- Operation and maintenance costs would equal $355 million annually by the year 2020 about $22.33 per train-mile.

The Working Paper predicts that the CA HSR project would pay for operation and maintenance (O&M) costs during regular conditions (i.e., without service interruptions), and is competitive with air and highway travel in terms of cost and travel time. Other proposed HSR projects have comparable O&M costs such as $18.82 per train-mile for the Tampa-Orlando-Miami corridor, and between $29.86 and $35.18 per train-mile for the New York-Montreal corridor.[108] Since the predicted HSR revenue is expected to cover O&M costs, federal support would only be needed to fund capital costs.

When comparing air, rail and highway travel, there is an inverse relationship between cost and time. HSR travel times are greater than air and less than highway vehicles, while HSR fares are usually less than air and greater than the costs of a highway vehicle trip. When traveling between San Francisco and Los Angeles, air travel takes about one

[107] Ibid, pp. 2-3 - 2-4.
[108] Transportation Research Board, *In Pursuit of Speed: New Options for Intercity Passenger Transport*, National Research Council, Special Report 233, Washington, D.C., 1991, p. 79.

hour and 15 minutes, HSR is expected to take less than three hours, and an automobile trip takes about six hours and 30 minutes. HSR fares would average about $80 round-trip between San Francisco and Los Angeles while airfares average over $90. According to a 1991 Transportation Research Board report, average airfare equals $0.24 per passenger mile, meaning that the HSR fare would have to be less than this figure in order to stay competitive.[109] When calculating average HSR fares using $0.21 per passenger mile between San Francisco and Los Angeles, the fare structure is consistent with the $80 figure stated above.[110]

The ridership figures seem optimistic yet plausible at over eight million riders by the year 2020. Even if the ridership was reduced to a more conservative estimate of five million annual riders, the annual revenues of $400 million still would pay for O&M costs. Furthermore, other ridership forecasts for comparable city-pairs are similar to the California corridor:

- Cleveland-Columbus-Cincinnati corridor: 3.5 million;
- Dallas-Houston-Austin-San Antonio corridor: 8.5 to 14.6 million; and
- Philadelphia-Pittsburgh corridor: 6.8 million.[111]

In conclusion, the *draft California HSR Economic Impact* study reveals that the proposed HSR service has numerous "conventional" benefits such as its ability to reduce congestion and air pollution. The project seems to be worthy of consideration when considering its "conventional" benefits, since the proposed service is expected to pay for its operation and maintenance, and is expected to be competitive with air and

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[109] Calculations are made for a 200-mile corridor.
[110] Transportation Research Board, *In Pursuit of Speed: New Options for Intercity Passenger Transport,* National Research Council, Special Report 233, Washington, D.C., 1991, p. 112.
[111] Ibid, p. 105.

highway travel in terms of travel time and cost to traveler. Nevertheless, if the analysis had highlighted the project's modal diversification benefits such as increased system flexibility during service interruptions, the project would look even more attractive. The following analysis derives first-order estimates of these diversification benefits.

Scenario Descriptions of Service Interruptions

Introduction

Scenario-based analyses help to illustrate the potential costs of intercity transportation service interruptions in order to make a case for modal diversification. Economic costs caused by disruptions to the transportation system are shown to decrease when a diverse transportation system exists since it is better able to respond to demand and supply fluctuations. The main reason modal diversification benefits mobility is because different modes have different vulnerabilities to each type of service interruption. The position taken in this report is that high-speed rail is a robust mode that can withstand many transportation disruptions making it an effective way to achieve transportation diversification.

Concerning service disruptions, the analysis does not address the probabilities of such events. Instead, the thesis assumes that the following three types of service interruptions occur and computes the benefits accrued from modal diversification when they do take place:

1) Transportation-related policy changes pertaining to air quality, energy constraints, and global warming;
2) Natural disasters such as earthquakes; and
3) Human-caused interruptions such as labor strikes and terrorism.

These disruptions are estimated to last from one month to three years, and are expected to eliminate trips or divert them to different modes. (Table 11) Eliminated trips are those trips that are not made during a service interruption; diverted trips occur when travelers switch modes.

The year(s) in which a service interruption takes place is not considered; therefore, discounting is not addressed in this analysis. This issue should be considered in a more detailed cost evaluation.

The estimates are first order because of the inability to predict the exact impact of service interruptions on the transportation system. For example, bridge experts did not expect the Oakland Bay Bridge to fail; yet its collapse and subsequent closure was the most critical transportation disruption caused by the 1989 Loma Prieta earthquake.

TABLE 11

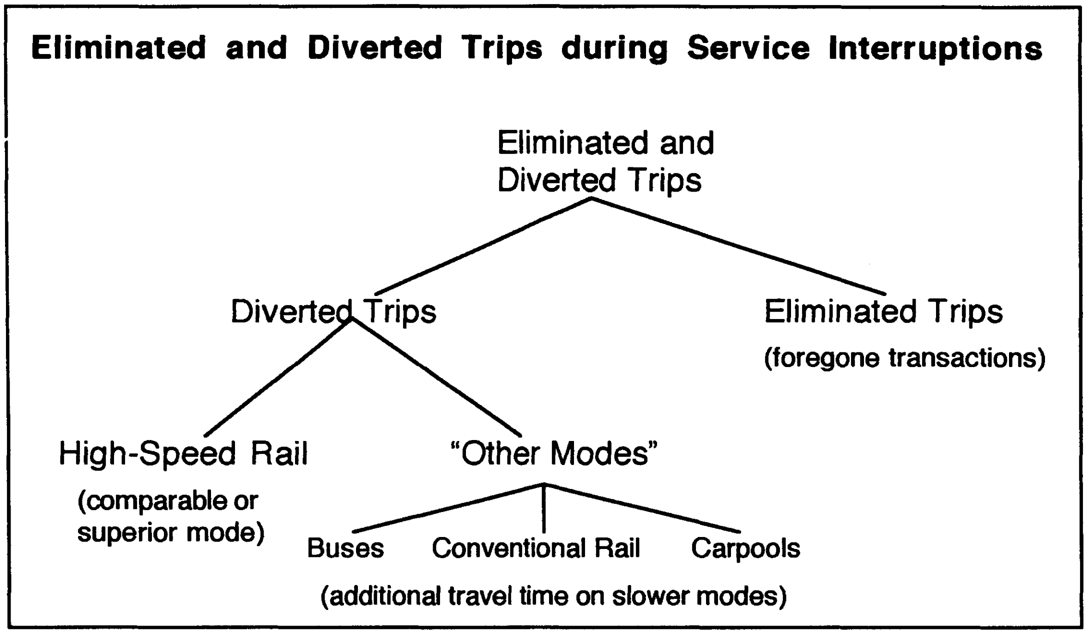
Summary of Scenario Descriptions

	Duration	**Interrupted Mode**	**Eliminated and Diverted Trips (Range)**
Transportation-Related Policy Changes			
Air Quality	Three years	Highway Travel	1% to 20%
Energy Constraints	One year	Highway Travel	1% to 20%
Global Warming	Three years	Highway Travel	1% to 20%
Natural Disasters			
Earthquakes	Two months	Highway Travel	1% to 20%
Human-Caused Interruptions			
Labor Strikes	One month	Air Travel	10% to 75%
Terrorism	One year	Air Travel	1% to 20%

For each of the service interruptions mentioned above, modal diversification using high-speed rail is expected to alleviate economic impacts caused by these disruptions. In the case of policy changes relating to air quality, energy constraints and global warming, HSR would help the corridor transition from relying on energy-inefficient, high-polluting modes to energy-efficient, low-polluting modes. Concerning earthquakes, modal diversification raises the probability that at least one intercity mode of transportation remains operational after a major earthquake. Since HSR uses simple technology and sparse infrastructure, the damage to railroads tends to be minimal, and the recovery time quicker. Regarding terrorist activities and labor strikes, even though rail also is exposed to these human-caused interruptions, diversification with rail still helps to alleviate the stress on other modes if they become disrupted. Refer to Chapter II for a more detailed analysis about the characteristics of the service interruptions.

The analyses assume that each interruption causes a particular mode to lose capacity, and, hence, travel on that mode decreases causing economic losses and social dislocations. The travelers who choose to or are forced to not use the disrupted mode, may either eliminate a trip or may use a different mode such as buses, conventional rail, carpools, or high-speed rail, if available. (Figure 22) Except for HSR, this analysis assumed these choices to be inferior to the trip taken on the disrupted mode. Economic losses are produced because of additional travel time on slower modes, and because of the opportunity costs of missed transactions due to eliminated trips. Air and highway trips that are diverted to an existing HSR service are assumed to generate no extra costs to travelers because they are assumed to view the service as comparable to the disrupted mode. The analysis does not give credit for HSR time savings when present. To estimate the ability of high-speed rail to reduce the economic losses caused by eliminated or diverted trips, the difference between the "HSR" scenarios and the "No HSR" scenarios is computed.

FIGURE 22



Description of Sensitivity Analysis

A sensitivity analysis is used to estimate the economic losses produced by each service disruption with and without HSR. Since it is difficult to predict a service disruption's exact impact on the transportation system, a range of benefits is generated using three different scenarios that illustrate a minimum, medium and maximum level of disruption. The amount of highway trips or air travel eliminated, or diverted to high-speed rail or to "other modes" is varied depending on whether high-speed rail is immediately available, and on the expected contribution of HSR when it is available.

For each disruption level, HSR is assumed to vary in its ability to alleviate economic losses. In the scenarios labeled "A," not as many travelers are assumed to switch to HSR diverting only between ten percent and 25 percent of the eliminated and diverted trips caused by service interruptions; in the scenarios labeled "B," more travelers are assumed to switch to HSR diverting between 40 percent and 50 percent of the eliminated and diverted trips caused by service interruptions. Conventional rail, buses, and carpools (known as "other modes") also are assumed to assist at different levels in that for the scenarios labeled "A," "other modes" are shown to be used more than for the scenarios labeled "B." These "other modes" are assumed to contribute more when a HSR service does not exist.

Concerning eliminated trips, these trips are assumed to range between 10 percent and 30 percent of the eliminated and diverted trips caused by service interruptions, and are varied depending on the availability and contribution of a HSR service. The amount of eliminated trips is the lowest at five percent when HSR is available and making the most contribution.

Analysis Assumptions

The analysis for each service interruption follows the same basic steps in estimating the cost of a service disruption with and without a high-speed rail service. Firstly, it is necessary to estimate the volume of trips along the corridor during normal operating conditions. Except for the earthquake scenario, all of the service disruptions use annual air and highway trip figures from the draft *California HSR Economic Impact* study as the basis of the analyses. These annual traffic volumes range from 21.9 million for air travelers to 149.9 million for highway trips.[112] [113] The earthquake scenario uses data from the 1989 Loma Prieta temblor. For the "HSR" analyses, the draft *California HSR Economic Impact* study states that HSR would divert about 20 percent of air travel and about seven percent of highway trips during regular operating conditions. Thus, the annual air travel volume for the "HSR" analyses is estimated to be 17.5 million (93 percent of 21.9 million air travelers), while the annual highway trip volume for the "HSR" analyses is estimated to be $139.4 million (80 percent of 149.9 million).[114]

As a result of a service disruption, an assumed number of highway or air trips are eliminated or diverted to HSR or to "other modes" at the level of one percent to 75 percent depending on the disruption. These eliminated and diverted trips are grouped into two categories: business and non-business trips, and then highway trips are converted into travelers using vehicle occupancy rates. According to the draft *California HSR Economic Impact* study, 25 percent of the highway trips are business trips and 75 percent are non-business trips; for air travel, there is a one-to-one ratio between business and non-business air travelers. Concerning highway vehicle occupancy rates, the draft *Economic Impact* study uses a vehicle occupancy rate of 1.9 persons per highway vehicle for intercity highway business trips and 2.6 persons per highway vehicle for intercity highway non-business trips.[115]

The total costs of service interruptions equal the cost of additional travel time on slower modes of transportation and the cost of eliminated highway or air travel. In order to

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[112] Wilbur Smith Associates, with Flight Transportation Associates, J.R. Ramos Associates, *draft Working Paper #3: Cost Comparison of Mode Alternatives, California HSR Economic Impact*, February 19, 1996, Table 3-2, Table 4-4.
[113] These numbers are averages taken from 1994 and 2020 air and highway volumes.
[114] Ibid, p. 3-6, p. 4-1.
[115] Ibid, Table 3-2, Table 4-5, p. 3-3.

estimate these cost parameters, the value of business and non-business traveler time must be computed. According to the Charles River Associates in the draft *California HSR Economic Impact* study, the value of business traveler time for highway travel equals $25.38 per hour and for air travel equals $42.42 per hour; the value of non-business traveler time for highway travel equals $14.89 per hour and for air travel equals $30.84 per hour.[116]

In order to estimate the additional travel time caused by a disruption, it is necessary to calculate the amount of trips that would be diverted to slower modes, the average amount of additional travel time per trip, and the value of this time. Using arbitrary, first-order estimates, the additional travel time caused by highway service interruptions is assumed to average .67 hours per trip while the additional cost of traveling by highway during an air service interruption equals 5.35 hours. The additional time for an air service interruption is expected to be much greater than highway interruptions because it is assumed that no other air options are available forcing air travelers to use the highway system if HSR does not exist.

The highway trip time estimates are derived from a weighted average of highway trip distance along the corridor; the average trip length totals 147 miles. An assumed average rate of travel of 55 mph for highway vehicles is used to calculate an average highway trip time of 2.67 hours per trip. A 25 percent increase in travel time is assumed to occur during service interruptions. This time increase, which totals 3.34 hours per trip, is an arbitrary number that was assigned in order to bracket the benefits of HSR. Thus, the additional cost of traveling by highway during service interruptions

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[116] Ibid, p. 3-8, p. 4-14.

equals the difference between the two travel time estimates, a total of .67 hours per trip.

Concerning additional cost estimates for air travel, the calculations assume that air travel between San Francisco and Los Angeles represents a typical air trip taken along the California corridor. The mean air travel time for the corridor is estimated to be 1.25 hours per trip. During an air service interruption, travelers would be forced to use highways or conventional rail, which would take about 6.60 hours per trip. Thus, the additional cost of traveling by highways during an air service interruption equals 5.35 hours, the difference between the two travel time estimates.

In order to estimate the cost of eliminated trips, it is necessary to estimate the number of highway or air trips that would no longer be taken, the average travel time of an eliminated trip, and the value of these trips. The value of a highway trip was estimated by doubling the mean travel time of 2.67 hours per trip, which equals 5.34 hours per trip; the value of an air trip was estimated by tripling the mean travel time of 1.25 hours per trip, which equals 3.75 hours per trip. These trip values are selected arbitrarily with the assumption that travel time acts as a proxy for the value of a trip. The value of a trip must be greater than its cost in travel time. Furthermore, the value selected for highway trips is less than the value for air travel because air travelers pay more to use these services and they tend to value their time more than highway travelers.

Scenario-Based Analysis Characteristics

The following scenario-based analysis begins by describing the characteristics of each service interruption according to their grouping: transportation-related policy changes, natural disasters, and human-caused interruptions. The most important parameters include:

- The duration of the disruption;
- The number of eliminated trips; and
- The number of trips diverted to high-speed rail (when available) and to "other modes."

The analysis then proceeds to compute the economic losses with and without the immediate availability of HSR in this corridor. The impact of the service interruptions and the ability of HSR to alleviate the economic losses varies depending on the type and severity of the incident.

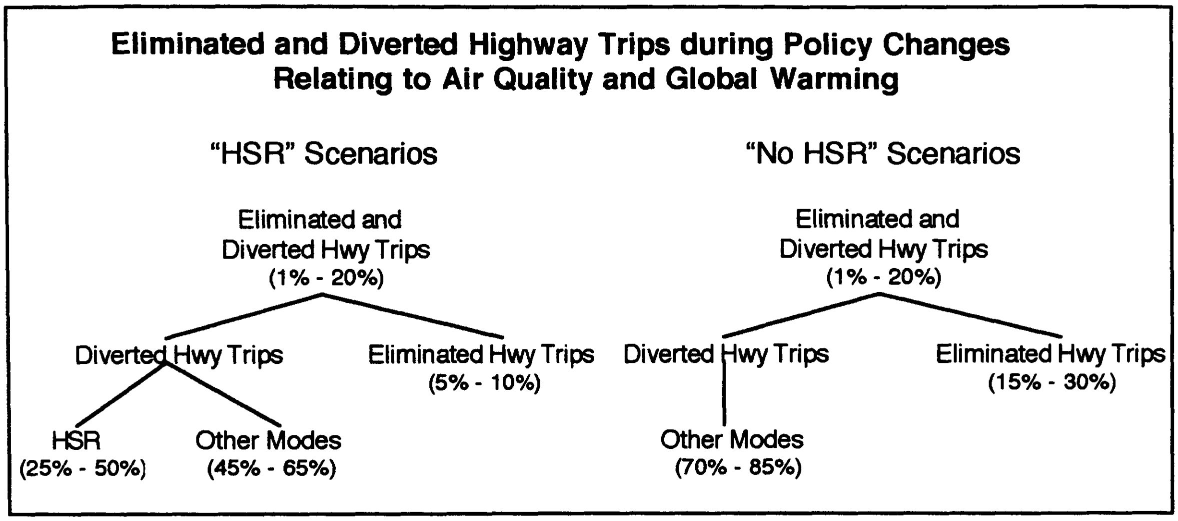
Scenario Descriptions of Transportation-Related Policy Changes

Scenario Description of a Policy Change due to Air Pollution and Global Warming

The scenario for policy changes relating to air pollution and global warming is the same because the regulations both attempt to reduce vehicle emissions. This analysis assumes that United States Environmental Protection Agency and local government officials will impose direct policy measures such as highway travel restrictions and indirect policy measures such as gasoline tax increases in order to reduce highway vehicle miles traveled (VMT) in the state of California, and ultimately to decrease air quality standard exceedances and greenhouse gas emissions. This analysis assumes the need to reduce highway VMT between one percent and twenty percent over three years, and that the government will lift these regulatory restrictions after this time.

The amount of trips eliminated, or diverted to high-speed rail or to other modes is assumed to vary between one percent and 20 percent depending on if high-speed rail is immediately available, and on the expected contribution of HSR when it is available. The distribution of these eliminated and diverted trips is discussed below. (Figure 23) For the "HSR" analyses, the percentage of diverted trips to HSR is assumed to vary between 25 percent and 50 percent; the percentage of diverted trips to "other modes" is assumed to vary between 45 percent and 65 percent; and the percentage of eliminated trips is assumed to vary between five percent and ten percent. For the "No HSR" analyses, the percentage of diverted trips to "other modes" is assumed to vary between 70 percent and 85 percent; and the percentage of eliminated trips is assumed to vary between 15 percent and 30 percent. These percentages of eliminated and diverted trips are not assumed to change over the three years.

FIGURE 23

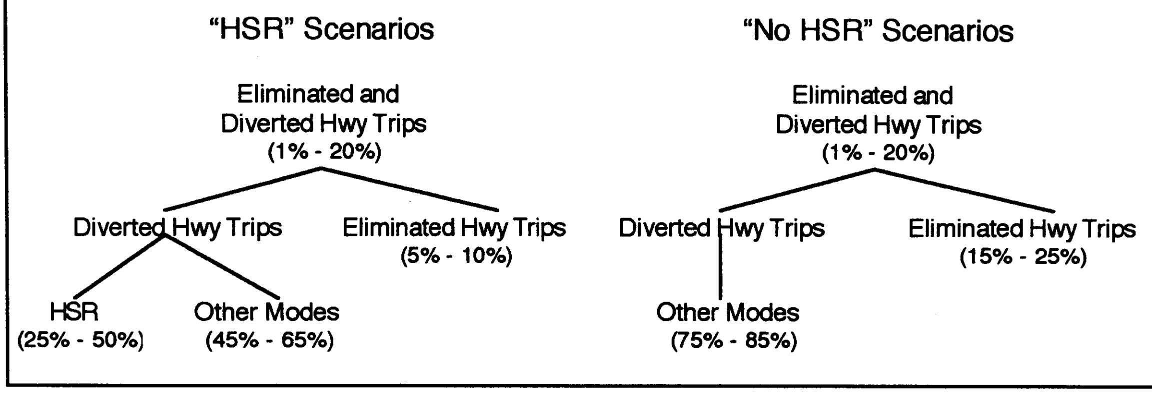


Scenario Description of a Policy Change due to Energy Constraints

An oil shock is expected to last for about one year, which is an average duration of the three previous, and most notable, oil shocks (i.e., 1973/74, 1979 and 1990). The analysis assumes that an oil shock will cause between one percent and 20 percent of highway trips to be diverted or eliminated due to gasoline shortages and price increases in the United States. The distribution of the eliminated and diverted highway trips depends on the availability of a HSR service and on its expected contribution. (Figure 24) For the "HSR" analyses, the percentage of diverted trips to HSR is assumed to vary between 25 percent and 50 percent; the percentage of diverted trips to "other modes" is assumed to vary between 45 percent and 65 percent; and the percentage of eliminated trips is assumed to vary between five percent and ten percent. For the "No HSR" analyses, the percentage of diverted trips to "other modes" is assumed to vary between 75 percent and 85 percent; and the percentage of eliminated trips is assumed to vary between 15 percent and 25 percent.

FIGURE 24

Eliminated and Diverted Highway Trips during Policy Changes Relating to Energy Constraints



Scenario Descriptions of Natural Disasters

Scenario Description of a Service Interruption relating to Earthquakes

This analysis assumes that a major earthquake is expected to cause a critical highway link in the state of California to close for two months. The scenario attempts to replicate the 1989 Loma Prieta earthquake in terms of its impacts on the transportation system, and the duration of the highway interruption. This earthquake caused a key link in the transportation system, the San Francisco Oakland Bay Bridge, to close for two months. In this scenario, a link of comparable importance is assumed to close causing problems for over 500,000 daily highway vehicles that use the five major bridges connecting the San Francisco Bay Area.[117] When considering the number of highway vehicles per month on weekdays, the figure totals 11.4 million highway vehicles during normal conditions. If a HSR service existed, about 10.6 million highway

[117] California Department of Transportation, *Post-Earthquake Commute Summary-Daily Trips*, December 19, 1989.

vehicles per month would use the bridges that link the Bay, approximately seven percent of the highway trips during normal conditions.[118]

According to *Competing Against Time*, the proportion of reduced highway trips after the Loma Prieta earthquake totaled 12.5 percent.[119] Thus, this scenario assumes that the number of highway trips that are eliminated or diverted to other modes or to HSR, if available, ranges between one percent and 20 percent. The maximum mobility disruption is expected to occur during the first month when travelers are learning about other traveling options. For the first month, the percentage of eliminated or diverted highway trips is assumed to range from five percent to 20 percent. For the second month, the percentage of eliminated or diverted highway trips is assumed to range from one percent to ten percent.

For the "HSR" analyses, the percentage of diverted trips to HSR is assumed to vary between ten percent and 40 percent for the first month and between 20 percent and 50 percent for the second month; the percentage of diverted trips to "other modes" is assumed to vary between 45 percent and 80 percent for the first month and between 40 percent and 75 percent for the second month; and the percentage of eliminated trips is assumed to vary between ten percent and 15 percent for the first month and between five percent and ten percent for the second month. For the "No HSR" analyses, the percentage of diverted trips to "other modes" is assumed to vary between 75 percent and 85 percent for the first month and between 85 percent and 90 percent for the second month; the percentage of eliminated trips is assumed to vary between 15

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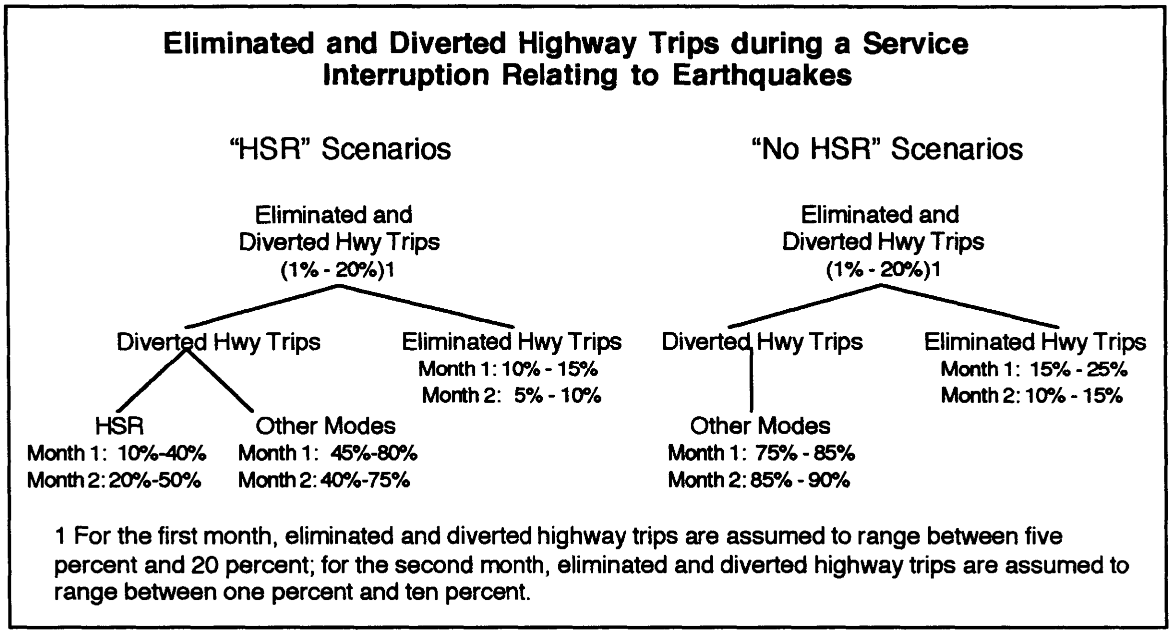
[118] Wilbur Smith Associates, with Flight Transportation Associates, J.R. Ramos Associates, *draft Working Paper #3: Cost Comparison of Mode Alternatives, California HSR Economic Impact*, February 19, 1996, p. 3-6.

percent and 25 percent for the first month and between ten percent and 15 percent for the second month. (Figure 25)

FIGURE 25



Scenario Descriptions of Human-Caused Interruptions

Scenario Description of a Service Interruption relating to Labor Strikes

A labor strike is assumed to reduce air travel for one month by an estimated ten percent to 75 percent of total air passenger volumes. These air travel reduction estimates are similar to the 1981 Professional Air Traffic Controllers Strike that reduced air travel between 60 percent and 75 percent over two months, and the 1995 strikes in France that decreased air travel by about 15 percent over three weeks.[120] [121]

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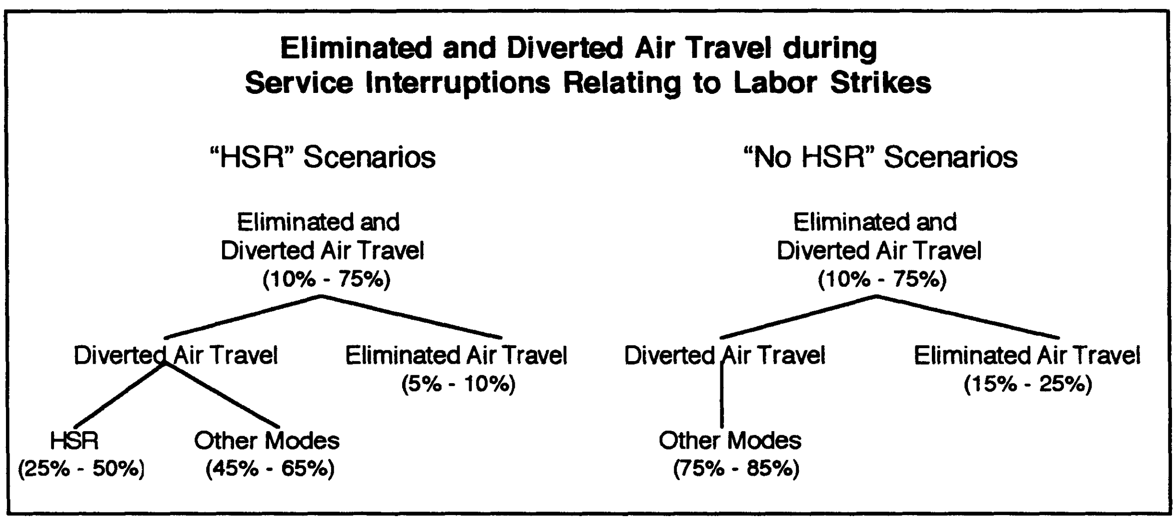
119 George W. Housner, Chairman, *Competing Against Time*, Report to Governor George Deukmejian from The Governor's Board of Inquiry on the 1989 Loma Prieta Earthquake, State of California, Office of Planning and Research, May 1990, pp. 19-41.

120 Bert A. Spector, *Air Traffic Controllers*, Harvard Business School, Boston, MA, 1982.

121 Alexandre Polozoff, The French Strikes (en Greve) of 1995, World Wide Web, December 21, 1995.

For the "HSR" analyses, the percentage of diverted trips to HSR is assumed to vary between 25 percent and 50 percent; the percentage of diverted trips to "other modes" is assumed to vary between 45 percent and 65 percent; and the percentage of eliminated trips is assumed to vary between five percent and ten percent. For the "No HSR" analyses, the percentage of diverted trips to "other modes" is assumed to vary between 75 percent and 85 percent; and the percentage of eliminated trips is assumed to vary between 15 percent and 25 percent. (Figure 26)

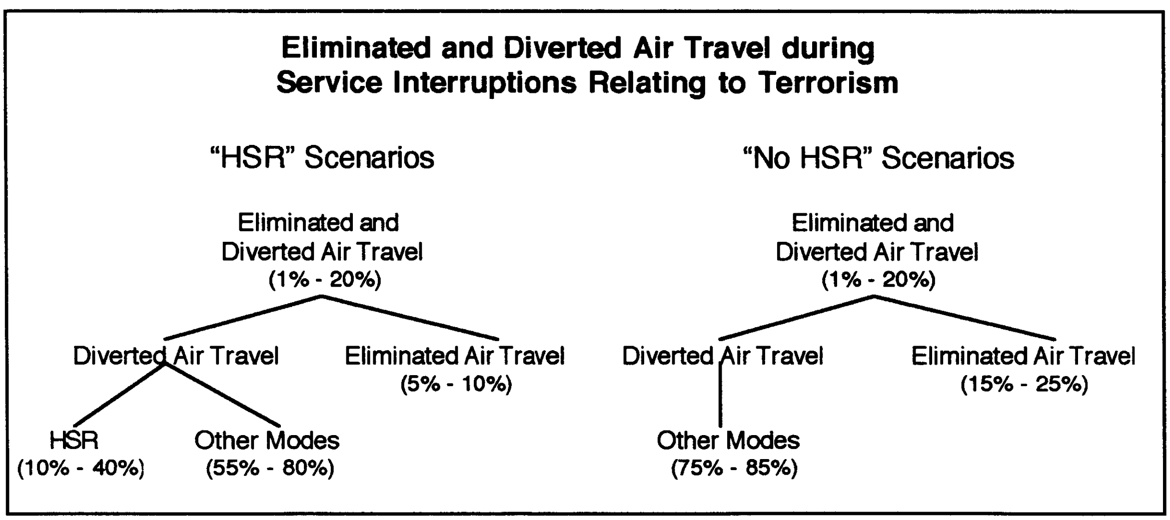
FIGURE 26



Scenario Description of a Service Interruption relating to Terrorism

This analysis assumes that air-related terrorist threats and attacks cause air travelers to eliminate or divert airplane trips between one percent and 20 percent for one year. For the "HSR" analyses, the percentage of diverted trips to HSR is assumed to vary between ten percent and 40 percent; the percentage of diverted trips to "other modes" is assumed to vary between 55 percent and 80 percent; and the percentage of eliminated trips is assumed to vary between five percent and ten percent. For the "No HSR" analyses, the percentage of diverted trips to "other modes" is assumed to vary between 75 percent and 85 percent; and the percentage of eliminated trips is assumed to vary between 15 percent and 25 percent. (Figure 27)

FIGURE 27



Impacts of Service Interruptions with and without a HSR Service

Introduction

The draft *California HSR Economic Impact* study addressed how the proposed HSR project would improve air quality and congestion, yet neglected to mention how the project would lessen the impact of service interruptions such as oil shocks, earthquakes and terrorism. This analysis attempts to illustrate how a high-speed rail service would be able to reduce the economic and social impacts caused by service interruptions in the California corridor. Based on the assumptions of trip eliminations and diversions, the costs of disruptions to the transportation system are shown to be higher in the "No HSR" scenarios than in the "HSR" scenarios. The ability of HSR to reduce the economic losses caused by service disruptions depends on the severity and type of incident because different modes are vulnerable to different service interruptions.

To estimate the economic loss of service interruptions, the analysis calculates the cost of additional travel time and of eliminated trips. As stated above, these are first-order estimates, and are illustrative; they help to demonstrate the benefits of modal diversification under various assumptions. Refer to Appendix A for a more detailed explanation of the calculations pertaining to each service interruption.

It is also important to note that the impacts shown below may be conservative estimates because the scenarios only highlight the impact of service interruptions on one intercity mode, whereas in real life, more than one mode may be affected by an incident. For example, policy changes relating to air quality, energy constraints, and global warming severely affect both air and highway travel.

Impacts of Transportation-Related Policy Changes: Air Quality and Global Warming

"No HSR" Scenarios

A policy change relating to air quality and global warming, as depicted in the above scenario description, is estimated to cost between $251 million and $3.5 billion over three years in additional travel time and in eliminated trips when a HSR service is not immediately available. The impact of these regulations, if they occur, ranges between $84 million and $1.3 billion during the first year, $84 million and $1.2 billion during the second year, and $83 million and $1.0 billion during the third year. The second and third years are not expected to cost as much because the driving pool is smaller.

"HSR" Scenarios

Since HSR is a low-emitting mode of transportation, it is useful during policy changes relating to air quality and global warming. The proposed HSR project for the California corridor is expected to reduce the costs of additional travel time and eliminated trips caused by policy changes relating to air quality and global warming. Over three years, the contribution of HSR (the difference in cost between the "No HSR" scenarios and the "HSR" scenarios) ranges between $184 million for the average minimum disruption, $918 million for the average medium disruption, and $1.7 billion for the average maximum disruption assuming the incident occurs. (Table 12)

TABLE 12

Assumed HSR Contributions: Reduction of Economic and Social Dislocation Costs Caused by Air Quality and Global Warming Regulations
Three Year Total

	"No HSR" Scenarios		"HSR" Scenarios			
Disruption Level	Diverted Hwy Trips to Other Modes	Eliminated Hwy Trips	Diverted Hwy Trips to HSR	Diverted Hwy Trips to Other Modes	Eliminated Hwy Trips	Reduction of Losses due to HSR ($ millions)
Minimum (1A)[1]	85%	15%	25%	65%	10%	$86
Minimum (1B)[2]	70%	30%	50%	45%	5%	$282
Medium (2A)	85%	15%	25%	65%	10%	$481
Medium (2B)	70%	30%	50%	45%	5%	$1,355
Maximum (3A)	85%	15%	25%	65%	10%	$783
Maximum (3B)	70%	30%	50%	45%	5%	$2,574

[1] Scenarios labeled "A" have more eliminated trips and more diversions to "other modes," and have less trips diverted to HSR.
[2] Scenarios labeled "B" have fewer eliminated trips and fewer diversions to "other modes," and have more trips diverted to HSR.

Impacts of Transportation-Related Policy Changes: Energy Constraints

"No HSR" Scenarios

When a HSR service is not immediately available, a policy change relating to energy constraints, as depicted in the above scenario description, is estimated to cost $99 million when assuming an average minimum disruption, $988 million when assuming an average medium disruption, and $2.0 billion when assuming an average maximum disruption.

"HSR" Scenarios

Since HSR is a more energy-efficient mode of transportation, it is not assumed to be as affected by oil shocks. If a HSR service existed in the California corridor, then the transportation system would be better able to respond to policy changes that try to divert travelers to more energy-efficient modes. Assuming that the energy-constraint scenario as described above occurs, the assumed contribution of HSR ranges from as low as $29 million to as high as $1.6 billion. (Table 13)

TABLE 13

Assumed HSR Contributions: Reduction of Economic and Social Dislocation Costs Caused by Energy-Related Regulations

	"No HSR" Scenarios		"HSR" Scenarios			
Disruption Level	Diverted Hwy Trips to Other Modes	Eliminated Hwy Trips	Diverted Hwy Trips to HSR	Diverted Hwy Trips to Other Modes	Eliminated Hwy Trips	Reduction of Losses due to HSR ($ millions)
Minimum (1A)[1]	85%	15%	25%	65%	10%	$29
Minimum (1B)[2]	75%	25%	50%	45%	5%	$81
Medium (2A)	85%	15%	25%	65%	10%	$289
Medium (2B)	75%	25%	50%	45%	5%	$806
Maximum (3A)	85%	15%	25%	65%	10%	$578
Maximum (3B)	75%	25%	50%	45%	5%	$1,612

[1] Scenarios labeled "A" have more eliminated trips and more diversions to "other modes," and have less trips diverted to HSR.
[2] Scenarios labeled "B" have fewer eliminated trips and fewer diversions to "other modes," and have more trips diverted to HSR.

Natural Disaster Impacts: Earthquakes

"No HSR" Scenarios

An earthquake, as depicted in the above scenario description, is estimated to cost more during the first month than the second because travelers need time to find alternative means of transportation. For the first month, the cost in additional travel time and eliminated trips totals $38 million when assuming an average minimum disruption, $75 million when assuming an average medium disruption, and $150 million when assuming an average maximum disruption. For the second month, the cost in additional travel time and eliminated trips totals $6 million when assuming an average minimum disruption, $30 million when assuming an average medium disruption, and $59 million when assuming an average maximum disruption.

"HSR" Scenarios

Even though the Loma Prieta earthquake affected an urban area, more intercity travelers are expected to avoid urban highway congestion during this type of service interruption. A HSR service, as depicted in the above scenario description, is estimated to decrease the number of eliminated trips and additional travel time causing a reduction of economic losses, according to this scenario if it occurs, that total between $17 million for an average assumed minimum disruption, $40 million for an average assumed medium disruption, and $80 million for an average assumed maximum disruption. (Table 14)

TABLE 14

Assumed HSR Contributions: Reduction of Economic and Social Dislocation Costs Caused by Earthquakes

	"No HSR" Scenarios		"HSR" Scenarios			
Disruption Level	Diverted Hwy Trips to Other Modes	Elimi-nated Hwy Trips	Diverted Hwy Trips to HSR	Diverted Hwy Trips to Other Modes	Elimi-nated Hwy Trips	Reduction of Losses due to HSR ($ millions)
Minimum (1A)[1]						
Month 1	85%	15%	10%	80%	10%	$9
Month 2	90%	10%	20%	75%	5%	$2
Total						$11
Minimum (1B)[2]						
Month 1	75%	25%	40%	45%	15%	$19
Month 2	85%	15%	50%	40%	10%	$3
Total						$22
Medium (2A)						
Month 1	85%	15%	10%	80%	10%	$18
Month 2	90%	10%	20%	75%	5%	$10
Total						$28
Medium (2B)						
Month 1	75%	25%	40%	45%	15%	$38
Month 2	85%	15%	50%	40%	10%	$15
Total						$53
Maximum (3A)						
Month 1	85%	15%	10%	80%	10%	$35
Month 2	90%	10%	20%	75%	5%	$20
Total						$55
Maximum (3B)						
Month 1	75%	25%	40%	45%	15%	$76
Month 2	85%	15%	50%	40%	10%	$29
Total						$105

[1] Scenarios labeled "A" have more eliminated trips and more diversions to "other modes," and have less trips diverted to HSR.
[2] Scenarios labeled "B" have fewer eliminated trips and fewer diversions to "other modes," and have more trips diverted to HSR.

Human Interruption Impacts: Labor Strikes

"No HSR" Scenarios

A labor strike incident relating to the air industry, as depicted in the above scenario description, is estimated to cost $33 million when assuming an average minimum disruption, $134 million when assuming an average medium disruption, and $252 million when assuming an average maximum disruption.

"HSR" Scenarios

Air travelers are expected to benefit from HSR during labor strikes that affect the air industry. If a HSR service was in place during an air-related labor strike, then air travelers could switch to this comparable mode with minimal economic losses and maximum convenience. If highway travel was the only option, then travel times and eliminated trips are expected to increase. Thus, the HSR service is estimated to decrease the number of eliminated trips and additional travel time causing a reduction of economic losses, if the incident occurs, that ranges between $17 million for an average assumed minimum disruption, $67 million for an average assumed medium disruption, and $126 million for an average assumed maximum disruption. (Table 15)

TABLE 15

Assumed HSR Contributions: Reduction of Economic and Social Dislocation Costs Caused by Transportation-Related Labor Strikes

	"No HSR" Scenarios		"HSR" Scenarios			
Disruption Level	Diverted Hwy Trips to Other Modes	Eliminated Hwy Trips	Diverted Hwy Trips to HSR	Diverted Hwy Trips to Other Modes	Eliminated Hwy Trips	Reduction of Losses due to HSR ($ millions)
Minimum (1A)[1]	85%	15%	25%	65%	10%	$14
Minimum (1B)[2]	75%	25%	50%	45%	5%	$19
Medium (2A)	85%	15%	25%	65%	10%	$56
Medium (2B)	75%	25%	50%	45%	5%	$78
Maximum (3A)	85%	15%	25%	65%	10%	$105
Maximum (3B)	75%	25%	50%	45%	5%	$146

[1] Scenarios labeled "A" have more eliminated trips and more diversions to "other modes," and have less trips diverted to HSR.

[2] Scenarios labeled "B" have fewer eliminated trips and fewer diversions to "other modes," and have more trips diverted to HSR.

Human Interruption Impacts: Terrorist Activities

"No HSR" Scenarios

A terrorist incident, as described in the above scenario, is estimated to cost $41 million when assuming an average minimum disruption, $403 million when assuming an average medium disruption, and $806 million when assuming an average maximum disruption.

"HSR" Scenarios

If a terrorist incident occurs similar to the one described in the above scenario, the HSR service is estimated to decrease the number of eliminated trips and additional travel time causing a reduction of economic losses that ranges between $16 million for an average assumed minimum disruption, $163 million for an average assumed medium disruption, and $325 million for an average assumed maximum disruption. (Table 16)

TABLE 16

Assumed HSR Contributions: Reduction of Economic and Social Dislocation Costs Caused by Transportation-Related Terrorist Activities

	"No HSR" Scenarios		"HSR" Scenarios			
Disruption Level	Diverted Hwy Trips to Other Modes	Eliminated Hwy Trips	Diverted Hwy Trips to HSR	Diverted Hwy Trips to Other Modes	Eliminated Hwy Trips	Reduction of Losses due to HSR ($ millions)
Minimum (1A)[1]	85%	15%	10%	80%	10%	$11
Minimum (1B)[2]	75%	25%	40%	55%	5%	$20
Medium (2A)	85%	15%	10%	80%	10%	$122
Medium (2B)	75%	25%	40%	55%	5%	$203
Maximum (3A)	85%	15%	10%	80%	10%	$243
Maximum (3B)	75%	25%	40%	55%	5%	$406

[1] Scenarios labeled "A" have more eliminated trips and more diversions to "other modes," and have less trips diverted to HSR.
[2] Scenarios labeled "B" have fewer eliminated trips and fewer diversions to "other modes," and have more trips diverted to HSR.

California High-Speed Rail Summary

The analysis for the proposed high-speed rail project in California considers the costs of eliminated trips and additional travel times associated with service disruptions, as well as the ability of an existing high-speed rail project to reduce these costs. The main objective of this scenario-based analysis is to show, by developing first-order estimates, that substantial modal diversification benefits exist. These rough estimates allow transportation planners to bracket the benefits of modal diversification.

The diversification benefits can be compared to proposed "conventional" benefits of the HSR project to help substantiate the diversification numbers. The first-order estimates described above are similar in magnitude to the "conventional" benefits of improving air quality. For example, the HSR project is expected to reduce the cost of air pollution by $52 million annually in California.[122] Since the proposed HSR project is able to reduce the economic losses pertaining to service interruptions at a similar level as it does for the costs of air pollution, modal diversification benefits should be regarded with legitimacy. A similar type of analysis could be used for other corridors keeping in mind that the service interruptions and parameters pertaining to them would vary.

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[122] Wilbur Smith Associates, with Flight Transportation Associates, J.R. Ramos Associates, *draft Working Paper #3: Cost Comparison of Mode Alternatives, California HSR Economic Impact*, February 19, 1996, p. 3-14.

Chapter V: Conclusion

Main Premise Summary

This thesis shows that transportation system service interruptions have the potential to produce severe economic losses not only on a local level as is the case for damage caused by earthquakes, but also on a national level as has been the case during oil shocks. One way to alleviate the impact of these interruptions is to provide travelers with multiple transportation options. Since service disruptions affect the major intercity modes differently, a more modally-diverse system would raise the probability that at least one service was intact during an incident. The position taken in this thesis is that in order to guard against the impacts of these potential disruptions, we should work to develop a diversified intercity transportation system.

Currently, the intercity transportation system in the United States relies primarily on air and automobile travel causing it to be vulnerable to service interruptions. These service disruptions were classified into the following groups:

1) Policy changes relating to air quality, energy constraints and global warming;
2) Natural disasters such as earthquakes, tornadoes, major snow storms and floods; and
3) Human-caused disruptions such as terrorist attacks and labor strikes.

Modal diversification is a proactive approach to crisis management in that it seeks to lessen the burden of potential service interruptions before they occur. A diverse transportation system is more capable of responding to supply and demand fluctuations that take place when a mode of transportation fails because different modes have different vulnerabilities. Thus, there is an economic value of having a multimodal transportation system already in place because a diverse transportation system helps to reduce the response time needed for a transportation system to recover from a service interruption.

When deciding upon whether to add capacity to an existing mode or to a new one, transportation experts should consider not only the "conventional" benefits of a mode such as congestion alleviation, but also its modal diversification benefits such as increased response time during service interruptions. Planners usually consider only the "conventional" benefits when evaluating and ranking projects for funding. A more cost-effective approach for the long term would be to consider the consequences of potential service interruptions. The analysis would most likely conclude that, for certain corridors, it is better to add capacity in a diverse way in order to hedge against these interruptions. For some corridors, the combined "conventional" and modal diversification benefits of adding capacity to a new mode would outweigh the "conventional" benefits of adding capacity to an existing mode; these diversification benefits may even outweigh the additional costs of a new mode.

If diversification is valued then rail would be the primary benefactor of such a policy. Rail is a more robust service that is less exposed to many service interruptions compared to highway and air travel. For example, if an energy crisis similar to the 1973 and 1979 oil shocks occurred, both air and highway travel would suffer because these modes are not energy efficient. High-speed rail, on the contrary, consumes only about one-third of the oil equivalent per unit of traffic as passenger cars and one-quarter for aircraft.[123] Marcia D. Lowe of the World Watch Institute views rail as playing a vital role in reducing the impact of service interruptions. In the book titled, *Back on Track: The Global Rail Revival*, she states that: "The most daunting transport problems of the twentieth century can be alleviated by creating diverse transport systems in which rail plays a major role."[124]

The proposed high-speed rail (HSR) project in California is examined to help bracket the benefits of modal diversification. Scenario-based analyses were used to consider the following six service disruptions: policy changes relating to air quality, energy constraints and global warming, natural disasters such as earthquakes, and human-caused interruptions such as labor strikes and terrorism. The proposed HSR service is estimated to reduce the economic and social disruptions caused by these incidents, were they to occur, by several million dollars for terrorist activities, earthquakes and labor strikes, and by several billion dollars for policy changes relating to air quality, energy constraints and global warming.

In order to attain both public and private sector support for the California HSR project, elected officials should promote not only the "conventional" benefits of high-speed rail such as congestion alleviation, but also should highlight modal diversification benefits as a way to justify the service's credibility. Intercity travel between northern and southern California would be better equipped to handle service interruptions such as earthquakes, oil shocks, and terrorist attacks with a more diverse intercity transportation system.

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[123] Michael Walrave, "High-Speed Rail: An Important Asset Reconciling Mobility, Energy Saving and Environmental Requirements," In: *Reconciling Transportation, Energy and Environmental Issues: The Role of Public Transport*, Conference Proceedings, European Conference of Ministers of Transport, European Commission. May - June, 1994, p. 82.
[124] Marcia D. Lowe, *Back on Track: The Global Rail Revival*, Worldwatch Paper 118, Worldwatch Institute, April 1994, p. 9.

Future Research

Regarding future research, further study could be directed in two different ways. Firstly, researchers could refine the scenario-based analysis in this thesis by focusing on the following:

1) The costs of modal diversification: This thesis focuses primarily on the benefits of modal diversification. Thus, further analysis could be done in order to verify the claim that the benefits of modal diversification may outweigh the costs of a new mode.

2) Service interruption probabilities: Since this thesis assumes that service interruptions occur, a comprehensive risk-assessment analysis could be used to predict probabilities in order to better estimate the degree of risk associated with each potential service disruption.

3) A first-order estimate of service interruption costs and modal diversification benefits that considers discounting of cash flow: Since money is worth less over time, a more in depth analysis could consider the time value of money. The analysis would have to show different discounted values depending on the years in which a service interruption is assumed to occur.

Secondly, a similar analysis using different parameters could be performed for other key corridors throughout the nation that need to expand capacity.

Some congested corridors that already have established political and financial support for HSR are as follows:

- Buffalo-Albany-New York;
- Chicago Hub (Chicago-Milwaukee, Chicago-Detroit, Chicago-St. Louis);
- Eugene-Portland-Seattle-Vancouver;
- Tampa-Orlando-Miami; and
- Washington-Charlotte.

With the additional benefits of modal diversification, these proposed HSR projects could be pushed to the top of transportation funding lists.

In conclusion, the main premise of the thesis is to illustrate the benefits of modal diversification. When transportation planners analyze whether to add capacity to existing transportation modes or to a new mode, they should consider the increased flexibility of a multimodal intercity transportation system during service interruptions. As modal diversification benefits become more well known, it is hoped that a similar analysis as performed in this thesis will become a more standardized procedure required for project ranking and funding cycles.

Appendices

Appendix A covers in more detail the scenario-based analysis calculations in Chapter IV pertaining to the California high-speed rail project. As described in Chapter IV, a sensitivity analysis is used to estimate the economic losses produced by each service disruption with and without HSR. Since it is difficult to predict a service disruption's exact impact on the transportation system, a range of benefits is generated using three different scenarios that illustrate a minimum, medium and maximum level of disruption. The following five scenario analyses are discussed:

1) Policy changes relating to air quality and global warming;
2) Policy changes relating to energy constraints;
3) Earthquakes;
4) Labor Strikes; and
5) Terrorism.

The scenario for policy changes relating to air pollution and global warming is the same because the regulations both attempt to reduce vehicle emissions. In general, the benefits of HSR during service interruptions, if they occur, are expected to range from several million dollars (i.e., labor strikes, terrorism, and earthquakes) to several billion dollars (i.e., policy changes relating to air quality, energy constraints and global warming).

Appendix B makes available the intercity highway volume data used in the scenario-based analysis calculations for highway service interruptions. The numbers originate from the draft *California HSR Economic Impact* study, which states that annual intercity highway travel in the California corridor totals 126.7 million trips in 1994 and 173.1 million trips in 2020. This analysis uses a mean estimate of these two figures, totaling 149.9 million trips annually. The intercity figures only consider origins and destinations that are expected to be near HSR stations. The average highway trip length is calculated to be 147 miles. Only 5.4 percent of these trips are under 100 miles. The minimum trip length is 32 miles; the maximum trip length is 504 miles.

Appendix A:

Scenario-Based Analysis Calculations pertaining to the California High-Speed Rail Project

**High-Speed Rail Contributions:
Reduction of Economic and Social Dislocation Costs
Caused by Air Pollution and Global Warming Regulations**

Year One	**Reduction of Disruption Costs due to HSR ($ millions/yr)**
Minimum Disruption: Low HSR Contribution (1a)	$29
Minimum Disruption: High HSR Contribution (1b)	$95
Medium Disruption: Low HSR Contribution (2a)	$144
Medium Disruption: High HSR Contribution (2b)	$475
Maximum Disruption: Low HSR Contribution (3a)	$289
Maximum Disruption: High HSR Contribution (3b)	$950

Year Two	**Reduction of Disruption Costs due to HSR ($ millions/yr)**
Minimum Disruption: Low HSR Contribution (1a)	$29
Minimum Disruption: High HSR Contribution (1b)	$94
Medium Disruption: Low HSR Contribution (2a)	$137
Medium Disruption: High HSR Contribution (2b)	$451
Maximum Disruption: Low HSR Contribution (3a)	$260
Maximum Disruption: High HSR Contribution (3b)	$855

Year Three	**Reduction of Disruption Costs due to HSR ($ millions/yr)**
Minimum Disruption: Low HSR Contribution (1a)	$28
Minimum Disruption: High HSR Contribution (1b)	$93
Medium Disruption: Low HSR Contribution (2a)	$200
Medium Disruption: High HSR Contribution (2b)	$429
Maximum Disruption: Low HSR Contribution (3a)	$234
Maximum Disruption: High HSR Contribution (3b)	$769

Total Reductions over Three Years	**Reduction of Disruption Costs due to HSR ($ millions)**
Minimum Disruption: Low HSR Contribution (1a)	$86
Minimum Disruption: High HSR Contribution (1b)	$282
Medium Disruption: Low HSR Contribution (2a)	$481
Medium Disruption: High HSR Contribution (2b)	$1,355
Maximum Disruption: Low HSR Contribution (3a)	$783
Maximum Disruption: High HSR Contribution (3b)	$2,574

	A	B	C	D	E
1	**High-Speed Rail Contributions:**				
2	**Reduction of Economic and Social Dislocation Costs Caused by Air Pollution and Global Warming Regulations**				
3					
4	This analysis assumes that regulatory policies mandate the need to decrease highway trips between one percent and 20 percent depending on the				
5	geographic location within the state of California. It is assumed that the government will lift regulatory restrictions such as no-drive days or emission				
6	taxes after three years.				
7		**Minimum Disruption**			
8	***Year One of Regulations:***	**Scenario 1a**		**Scenario 1b**	
9	***Minimum Disruption Scenarios (1a and 1b)***	No HSR	HSR	No HSR	HSR
10	CA Corridor annual highway trips[1]	149,900,000	139,407,000	149,900,000	139,407,000
11	**Eliminated or diverted hwy trips** per year due to regulations (%)[2]	**1%**	**1%**	**1%**	**1%**
12	Eliminated or diverted hwy trips per year due to regulations (Rw10* Rw11)	1,499,000	1,394,070	1,499,000	1,394,070
13	*Business hwy trips* eliminated or diverted per year due to regulations[3] (Rw12*25%)	374,750	348,518	374,750	348,518
14	*Non-busi hwy trips* eliminated or diverted per year due to regulations[3] (Rw12*75%)	1,124,250	1,045,553	1,124,250	1,045,553
15	Vehicle occupancy for busi travelers per hwy trip (persons/hwy trip)[4]	1.90	1.90	1.90	1.90
16	Vehicle occupancy for non-busi travelers per hwy trip (persons/hwy trip)[4]	2.60	2.60	2.60	2.60
17	**Busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw13*Rw15)	**712,025**	**662,183**	**712,025**	**662,183**
18	**Non-busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw14*Rw16)	**2,923,050**	**2,718,437**	**2,923,050**	**2,718,437**
19	**Travelers per year diverted to HSR** (%)[5]	**0%**	**25%**	**0%**	**50%**
20	*Busi travelers* per year diverted to HSR (Rw17*Rw19)	0.00	165,546	0.00	331,092
21	*Non-busi travelers* per year diverted to HSR (Rw18*Rw19)	0.00	679,609	0.00	1,359,218
22	**Travelers per year diverted to other modes** such as carpools, buses and rail (%)[6]	**85%**	**65%**	**70%**	**45%**
23	*Busi travelers* per year diverted to other modes (Rw17*Rw22)	605,221	430,419	498,418	297,982
24	*Non-busi travelers* per year diverted to other modes (Rw18*Rw22)	2,484,593	1,766,984	2,046,135	1,223,296
25	**Travelers per year who eliminated highway trips** (%)[7]	**15%**	**10%**	**30%**	**5%**
26	*Busi travelers* per year who eliminated hwy trips (Rw17*Rw25)	106,804	66,218	213,608	33,109
27	*Non-busi travelers* per year who eliminated hwy trips (Rw18*Rw25)	438,458	271,844	876,915	135,922

	A	B	C	D	E
28		Minimum Disruption			
29	***Year One of Regulations:***	**Scenario 1a**		**Scenario 1b**	
30	***Minimum Disruption Scenarios (1a and 1b) (cont.)***	No HSR	HSR	No HSR	HSR
31	***Cost of Additional Travel Time***				
32	Additional travel time per traveler when using other modes such as buses, rail and carpools (hours/traveler)[8]	0.67	0.67	0.67	0.67
33	*Busi travelers* per year diverted to other modes (same as Rw23)	605,221	430,419	498,418	297,982
34	*Non-busi travelers* per year diverted to other modes (same as Rw24)	2,484,593	1,766,984	2,046,135	1,223,296
35	Additional travel time for busi travelers when using other modes (hours/yr) (Rw32*Rw33)	405,498	288,381	333,940	199,648
36	Additional travel time for non-busi travelers when using other modes (hours/yr) (Rw32*Rw34)	1,664,677	1,183,879	1,370,910	819,609
37	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
38	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
39	Additional costs to busi travelers for using other modes ($/yr) (Rw35*Rw37)	$10,291,545	$7,319,105	$8,475,390	$5,067,073
40	Additional costs to non-busi travelers for using other modes ($/yr) (Rw36*Rw38)	$24,787,040	$17,627,960	$20,412,857	$12,203,972
41	**Cost of additional travel time to travelers** for using other modes ($/yr) (Rw39+Rw40)	**$35,078,585**	**$24,947,065**	**$28,888,247**	**$17,271,045**
42					
43	***Cost of Eliminated Highway Trips***				
44	Value of a highway trip per traveler (hours/traveler)[10]	5.34	5.34	5.34	5.34
45	Busi travelers per year who eliminated hwy trips (same as Rw26)	106,804	66,218	213,608	33,109
46	Non-busi travelers per year who eliminated hwy trips (same as Rw27)	438,458	271,844	876,915	135,922
47	Value of eliminated busi hwy travel per year (hours/yr) (Rw44*Rw45)	570,332	353,606	1,140,664	176,803
48	Value of eliminated non-busi hwy travel per year (hours/yr) (Rw44*Rw46)	2,341,363	1,451,645	4,682,726	725,823
49	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
50	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
51	Cost of eliminated hwy trips to busi travelers ($/yr) (Rw47*Rw49)	$14,475,027	$8,974,517	$28,950,054	$4,487,258
52	Cost of eliminated hwy trips to non-busi travelers ($/yr) (Rw48*Rw50)	$34,862,896	$21,614,995	$69,725,792	$10,807,498
53	**Cost of eliminated highway trips** ($/yr) (Rw51+Rw52)	**$49,337,923**	**$30,589,512**	**$98,675,845**	**$15,294,756**
54					
55	***Summary of Service Interruption Costs***				
56	Cost of Additional Travel Time (same as Rw41)	$35,078,585	$24,947,065	$28,888,247	$17,271,045
57	Cost of Eliminated Highway Trips (same as Rw53)	$49,337,923	$30,589,512	$98,675,845	$15,294,756
58	Cost of additional travel time and eliminated hwy trips ($) (Rw56+Rw57)	$84,416,508	$55,536,577	$127,564,092	$32,565,801
59	Cost of additional travel time and eliminated hwy trips ($ millions/yr)	**$84**	**$56**	**$128**	**$33**
60	**HSR versus no HSR Cost Difference** ($ millions/yr) (B59-C59)		**$29**		**$95**

	A	B	C	D	E
61		**Medium Disruption**			
62	***Year One of Regulations:***	**Scenario 2a**		**Scenario 2b**	
63	***Medium Disruption Scenarios (2a and 2b)***	No HSR	HSR	No HSR	HSR
64	CA Corridor annual highway trips[1]	149,900,000	139,407,000	149,900,000	139,407,000
65	**Eliminated or diverted hwy trips** per year due to regulations (%)[2]	**5%**	**5%**	**5%**	**5%**
66	Eliminated or diverted hwy trips per year due to regulations (Rw64*Rw65)	7,495,000	6,970,350	7,495,000	6,970,350
67	*Business hwy trips* eliminated or diverted per year due to regulations[3] (Rw66*25%)	1,873,750	1,742,588	1,873,750	1,742,588
68	*Non-busi hwy trips* eliminated or diverted per year due to regulations[3] (Rw66*75%)	5,621,250	5,227,763	5,621,250	5,227,763
69	Vehicle occupancy for busi travelers per hwy trip (persons/hwy trip)[4]	1.90	1.90	1.90	1.90
70	Vehicle occupancy for non-busi travelers per hwy trip (persons/hwy trip)[4]	2.60	2.60	2.60	2.60
71	**Busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw67*Rw69)	**3,560,125**	**3,310,916**	**3,560,125**	**3,310,916**
72	**Non-busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw68*Rw70)	**14,615,250**	**13,592,183**	**14,615,250**	**13,592,183**
73	**Travelers per year diverted to HSR** (%)[5]	**0%**	**25%**	**0%**	**50%**
74	*Busi travelers* per year diverted to HSR (Rw71*Rw73)	0.00	827,729	0.00	1,655,458
75	*Non-busi travelers* per year diverted to HSR (Rw72*Rw73)	0.00	3,398,046	0.00	6,796,091
76	**Travelers per year diverted to other modes** such as carpools, buses and rail (%)[6]	**85%**	**65%**	**70%**	**45%**
77	*Busi travelers* per year diverted to other modes (Rw71*Rw76)	3,026,106	2,152,096	2,492,088	1,489,912
78	*Non-busi travelers* per year diverted to other modes (Rw72*Rw76)	12,422,963	8,834,919	10,230,675	6,116,482
79	**Travelers per year who eliminated hwy trips** (%)[7]	**15%**	**10%**	**30%**	**5%**
80	*Busi travelers* per year who eliminated hwy trips (Rw71*Rw79)	534,019	331,092	1,068,038	165,546
81	*Non-busi travelers* per year who eliminated hwy trips (Rw72*Rw79)	2,192,288	1,359,218	4,384,575	679,609

	A	B	C	D	E
82		Medium Disruption			
83	***Year One of Regulations:***	**Scenario 2a**		**Scenario 2b**	
84	***Medium Disruption Scenarios (2a and 2b) (cont.)***	No HSR	HSR	No HSR	HSR
85	***Cost of Additional Travel Time***				
86	Additional travel time per traveler when using other modes such as buses, rail and carpools (hours/traveler)[8]	0.67	0.67	0.67	0.67
87	*Busi travelers* per year diverted to other modes (same as Rw77)	3,026,106	2,152,096	2,492,088	1,489,912
88	*Non-busi travelers* per yr diverted to other modes (same as Rw78)	12,422,963	8,834,919	10,230,675	6,116,482
89	Additional travel time for busi travelers when using other modes (hours/yr) (Rw86*Rw87)	2,027,491	1,441,904	1,669,699	998,241
90	Additional travel time for non-busi travelers when using other modes (hours/yr) (Rw86*Rw88)	8,323,385	5,919,395	6,854,552	4,098,043
91	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
92	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
93	Additional costs to busi travelers for using other modes ($/yr) (Rw89*Rw91)	$51,457,726	$36,595,524	$42,376,951	$25,335,363
94	Additional costs to non-busi travelers for using other modes ($/yr) (Rw90*Rw92)	$123,935,201	$88,139,799	$102,064,283	$61,019,861
95	**Cost of additional travel time to travelers** for using other modes ($/yr) (Rw93+Rw94)	**$175,392,927**	**$124,735,323**	**$144,441,234**	**$86,355,224**
96					
97	***Cost of Eliminated Highway Trips***				
98	Value of a highway trip per traveler (hours/traveler)[10]	5.34	5.34	5.34	5.34
99	*Busi travelers* per year who eliminated trips (same as Rw80)	534,019	331,092	1,068,038	165,546
100	*Non-busi travelers* per year who eliminated trips (same as Rw81)	2,192,288	1,359,218	4,384,575	679,609
101	Value of eliminated busi hwy travel per year (hours/yr) (Rw98*Rw99)	2,851,660	1,768,029	5,703,320	884,015
102	Value of eliminated non-busi hwy travel per year (hours/yr) (Rw98*Rw100)	11,706,815	7,258,225	23,413,631	3,629,113
103	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
104	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
105	Cost of eliminated hwy trips to busi travelers ($/yr) (Rw101*Rw103)	$72,375,134	$44,872,583	$144,750,268	$22,436,292
106	Cost of eliminated hwy trips to non-busi travelers ($/yr) (Rw102*Rw104)	$174,314,479	$108,074,977	$348,628,958	$54,037,489
107	**Cost of eliminated highway trips** ($/yr) (Rw105+Rw106)	**$246,689,613**	**$152,947,560**	**$493,379,226**	**$76,473,780**
108					
109	***Summary of Service Interruption Costs***				
110	Cost of Additional Travel Time (same as Rw95)	$175,392,927	$124,735,323	$144,441,234	$86,355,224
111	Cost of Eliminated Trips (same as Rw107)	$246,689,613	$152,947,560	$493,379,226	$76,473,780
112	Cost of additional travel time and eliminated hwy trips ($) (Rw110+Rw111)	$422,082,540	$277,682,883	$637,820,460	$162,829,004
113	Cost of additional travel time and eliminated hwy trips ($ millions/yr)	**$422**	**$278**	**$638**	**$163**
114	**HSR versus no HSR Cost Difference** ($ millions/yr) (B113-C113)		**$144**		**$475**

	A	B	C	D	E
115		**Maximum Disruption**			
116	***Year One of Regulations:***	**Scenario 3a**		**Scenario 3b**	
117	***Maximum Disruption Scenarios (3a and 3b)***	No HSR	HSR	No HSR	HSR
118	CA Corridor annual highway trips[1]	149,900,000	139,407,000	149,900,000	139,407,000
119	**Eliminated or diverted hwy trips** per year due to regulations (%)[2]	**10%**	**10%**	**10%**	**10%**
120	Eliminated or diverted hwy trips per year due to regulations (Rw118*Rw119)	14,990,000	13,940,700	14,990,000	13,940,700
121	*Business hwy trips* eliminated or diverted per year due to regulations[3] (Rw120*25%)	3,747,500	3,485,175	3,747,500	3,485,175
122	*Non-busi hwy trips* eliminated or diverted per year due to regulations[3] (Rw120*75%)	11,242,500	10,455,525	11,242,500	10,455,525
123	Vehicle occupancy for busi travelers per hwy trip (persons/hwy trip)[4]	1.90	1.90	1.90	1.90
124	Vehicle occupancy for non-busi travelers per hwy trip (persons/hwy trip)[4]	2.60	2.60	2.60	2.60
125	**Busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw121*Rw123)	**7,120,250**	**6,621,833**	**7,120,250**	**6,621,833**
126	**Non-busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw122*Rw124)	**29,230,500**	**27,184,365**	**29,230,500**	**27,184,365**
127	**Travelers per year diverted to HSR** (%)[5]	**0%**	**25%**	**0%**	**50%**
128	*Busi travelers* per year diverted to HSR (Rw125*Rw127)	0.00	1,655,458	0.00	3,310,916
129	*Non-busi travelers* per year diverted to HSR (Rw126*Rw127)	0.00	6,796,091	0.00	13,592,183
130	**Travelers per year diverted to other modes** such as carpools, buses and rail (%)[6]	**85%**	**65%**	**70%**	**45%**
131	*Busi travelers* per year diverted to other modes (Rw125*Rw130)	6,052,213	4,304,191	4,984,175	2,979,825
132	*Non-busi travelers* per year diverted to other modes (Rw126*Rw130)	24,845,925	17,669,837	20,461,350	12,232,964
133	**Travelers per year who eliminated hwy trips** (%)[7]	**15%**	**10%**	**30%**	**5%**
134	*Busi travelers* per year who eliminated trips (Rw125*Rw133)	1,068,038	662,183	2,136,075	331,092
135	*Non-busi travelers* per year who eliminated trips (Rw126*Rw133)	4,384,575	2,718,437	8,769,150	1,359,218

	A	B	C	D	E
136			**Maximum Disruption**		
137	***Year One of Regulations:***	**Scenario 3a**		**Scenario 3b**	
138	***Maximum Disruption Scenarios (3a and 3b) (cont.)***	No HSR	HSR	No HSR	HSR
139	***Cost of Additional Travel Time***				
140	Additional travel time per traveler when using other modes such as buses, rail and carpools (hours/traveler)[8]	0.67	0.67	0.67	0.67
141	*Busi travelers* per year diverted to other modes (same as Rw131)	6,052,213	4,304,191	4,984,175	2,979,825
142	*Non-busi travelers* per yr diverted to other modes (same as Rw132)	24,845,925	17,669,837	20,461,350	12,232,964
143	Additional travel time for busi travelers when using other modes (hours/yr) (Rw140*Rw141)	4,054,982	2,883,808	3,339,397	1,996,482
144	Additional travel time for non-busi travelers when using other modes (hours/yr) (Rw140*Rw142)	16,646,770	11,838,791	13,709,105	8,196,086
145	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
146	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
147	Additional costs to busi travelers for using other modes ($/yr) (Rw143*Rw145)	$102,915,453	$73,191,048	$84,753,902	$50,670,726
148	Additional costs to non-busi travelers for using other modes($/yr)(Rw144*Rw146)	$247,870,402	$176,279,597	$204,128,566	$122,039,721
149	**Cost of additional travel time to travelers** for using other modes ($/yr) (Rw147+Rw148)	**$350,785,854**	**$249,470,646**	**$288,882,468**	**$172,710,447**
150					
151	***Cost of Eliminated Highway Trips***				
152	Value of a highway trip per traveler (hours/traveler)[10]	5.34	5.34	5.34	5.34
153	*Busi travelers* per year who eliminated trips (same as Rw134)	1,068,038	662,183	2,136,075	331,092
154	*Non-busi travelers* per year who eliminated trips (same as Rw135)	4,384,575	2,718,437	8,769,150	1,359,218
155	Value of eliminated busi hwy travel per year (hours/yr) (Rw152*Rw153)	5,703,320	3,536,059	11,406,641	1,768,029
156	Value of eliminated non-busi hwy travel per year (hours/yr) (Rw152*Rw154)	23,413,631	14,516,451	46,827,261	7,258,225
157	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
158	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
159	Cost of eliminated hwy trips to busi travelers ($/yr) (Rw155*Rw157)	$144,750,268	$89,745,166	$289,500,536	$44,872,583
160	Cost of eliminated hwy trips to non-busi travelers ($/yr) (Rw156*Rw158)	$348,628,958	$216,149,954	$697,257,916	$108,074,977
161	**Cost of eliminated highway trips** ($/yr) (Rw159+Rw160)	**$493,379,226**	**$305,895,120**	**$986,758,452**	**$152,947,560**
162					
163	***Summary of Service Interruption Costs***				
164	Cost of Additional Travel Time (same as Rw149)	350,785,854	249,470,646	288,882,468	172,710,447
165	Cost of Eliminated Highway Trips (same as Rw161)	$493,379,226	$305,895,120	$986,758,452	$152,947,560
166	Cost of additional travel time and eliminated hwy trips ($) (Rw164+Rw165)	$844,165,080	$555,365,766	$1,275,640,920	$325,658,007
167	Cost of additional travel time and eliminated hwy trips ($ millions/yr)	**$844**	**$555**	**$1,276**	**$326**
168	**HSR versus no HSR Cost Difference** ($ millions/yr) (B167-C167)		**$289**		**$950**

	A	B	C	D	E
169		**Minimum Disruption**			
170	***Year Two of Regulations:***	**Scenario 1a**		**Scenario 1b**	
171	***Minimum Disruption Scenarios (1a and 1b)***	No HSR	HSR	No HSR	HSR
172	CA Corridor annual highway trips[1]	148,401,000	138,012,930	148,401,000	138,012,930
173	**Eliminated or diverted hwy trips** per year due to regulations (%)[2]	**1%**	**1%**	**1%**	**1%**
174	Eliminated or diverted hwy trips per year due to regulations (Rw172*Rw173)	1,484,010	1,380,129	1,484,010	1,380,129
175	*Business hwy trips* eliminated or diverted per year due to regulations[3] (Rw174*25%)	371,003	345,032	371,003	345,032
176	*Non-busi hwy trips* eliminated or diverted per year due to regulations[3] (Rw174*75%)	1,113,008	1,035,097	1,113,008	1,035,097
177	Vehicle occupancy for busi travelers per hwy trip (persons/hwy trip)[4]	1.90	1.90	1.90	1.90
178	Vehicle occupancy for non-busi travelers per hwy trip (persons/hwy trip)[4]	2.60	2.60	2.60	2.60
179	**Busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw175*Rw177)	**704,905**	**655,561**	**704,905**	**655,561**
180	**Non-busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw176*Rw178)	**2,893,820**	**2,691,252**	**2,893,820**	**2,691,252**
181	**Travelers per year diverted to HSR** (%)[5]	**0%**	**25%**	**0%**	**50%**
182	*Busi travelers* per year diverted to HSR (Rw179*Rw181)	0.00	163,890	0.00	327,781
183	*Non-busi travelers* per year diverted to HSR (Rw180*Rw181)	0.00	672,813	0.00	1,345,626
184	**Travelers per year diverted to other modes** such as carpools, buses and rail (%)[6]	**85%**	**65%**	**70%**	**45%**
185	*Busi travelers* per year diverted to other modes (Rw179*Rw184)	599,169	426,115	493,433	295,003
186	*Non-busi travelers* per year diverted to other modes (Rw180*Rw184)	2,459,747	1,749,314	2,025,674	1,211,063
187	**Travelers per year who eliminated hwy trips** (%)[7]	**15%**	**10%**	**30%**	**5%**
188	*Busi travelers* per year who eliminated hwy trips (Rw179*Rw187)	105,736	65,556	211,471	32,778
189	*Non-busi travelers* per year who eliminated hwy trips (Rw180*Rw187)	434,073	269,125	868,146	134,563

	A	B	C	D	E
190			**Minimum Disruption**		
191	***Year Two of Regulations:***	**Scenario 1a**		**Scenario 1b**	
192	***Minimum Disruption Scenarios (1a and 1b) (cont.)***	No HSR	HSR	No HSR	HSR
193	***Cost of Additional Travel Time***				
194	Additional travel time per traveler when using other modes such as buses, rail and carpools (hours/traveler)[8]	0.67	0.67	0.67	0.67
195	*Busi travelers* per year diverted to other modes (same as Rw185)	599,169	426,115	493,433	295,003
196	*Non-busi travelers* per yr diverted to other modes (same as Rw186)	2,459,747	1,749,314	2,025,674	1,211,063
197	Additional travel time for busi travelers when using other modes (hours/yr) (Rw194*Rw195)	401,443	285,497	330,600	197,652
198	Additional travel time for non-busi travelers when using other modes (hours/yr) (Rw194*Rw196)	1,648,030	1,172,040	1,357,201	811,413
199	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
200	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
201	Additional costs to busi travelers for using other modes ($/yr) (Rw197*Rw199)	$10,188,630	$7,245,914	$8,390,636	$5,016,402
202	Additional costs to non-busi travelers for using other modes ($/yr) (Rw198*Rw200)	$24,539,170	$17,451,680	$20,208,728	$12,081,932
203	**Cost of additional travel time to travelers** for using other modes ($/yr) (Rw201+Rw202)	**$34,727,800**	**$24,697,594**	**$28,599,364**	**$17,098,334**
204					
205	***Cost of Eliminated Highway Trips***				
206	Value of a highway trip per traveler (hours/traveler)[10]	5.34	5.34	5.34	5.34
207	Busi travelers per year who eliminated hwy trips[7] (same as Rw188)	105,736	65,556	211,471	32,778
208	Non-busi travelers per year who eliminated hwy trips[7] (same as Rw189)	434,073	269,125	868,146	134,563
209	Value of eliminated busi hwy travel per year (hours/yr) (Rw206*Rw207)	564,629	350,070	1,129,257	175,035
210	Value of eliminated non-busi hwy travel per year (hours/yr) (Rw206*Rw208)	2,317,949	1,437,129	4,635,899	718,564
211	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
212	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
213	Cost of eliminated hwy trips to busi hwy travelers ($/yr) (Rw209*Rw211)	$14,330,277	$8,884,771	$28,660,553	$4,442,386
214	Cost of eliminated hwy trips to non-busi hwy travelers ($/yr) (Rw210*Rw212)	$34,514,267	$21,398,845	$69,028,534	$10,699,423
215	**Cost of eliminated highway trips** ($/yr) (Rw213+Rw214)	**$48,844,543**	**$30,283,617**	**$97,689,087**	**$15,141,808**
216					
217	***Summary of Service Interruption Costs***				
218	Cost of Additional Travel Time (same as Rw203)	$34,727,800	$24,697,594	$28,599,364	$17,098,334
219	Cost of Eliminated Highway Trips (same as Rw215)	$48,844,543	$30,283,617	$97,689,087	$15,141,808
220	Cost of additional travel time and eliminated hwy trips ($) (Rw218+Rw219)	$83,572,343	$54,981,211	$126,288,451	$32,240,143
221	Cost of additional travel time and eliminated hwy trips ($ millions/yr)	**$84**	**$55**	**$126**	**$32**
222	**HSR versus no HSR Cost Difference** ($ millions/yr) (B221-C221)		**$29**		**$94**

	A	B	C	D	E
223			**Medium Disruption**		
224	***Year Two of Regulations:***	**Scenario 2a**		**Scenario 2b**	
225	***Medium Disruption Scenarios (2a and 2b)***	No HSR	HSR	No HSR	HSR
226	CA Corridor annual highway trips[1]	142,405,000	132,436,650	142,405,000	132,436,650
227	**Eliminated or diverted hwy trips** per year due to regulations (%)[2]	**5%**	**5%**	**5%**	**5%**
228	Eliminated or diverted hwy trips per year due to regulations (Rw226*Rw227)	7,120,250	6,621,833	7,120,250	6,621,833
229	*Business hwy trips* eliminated or diverted per year due to regulations[3] (Rw228*25%)	1,780,063	1,655,458	1,780,063	1,655,458
230	*Non-busi hwy trips* eliminated or diverted per year due to regulations[3] (Rw228*75%)	5,340,188	4,966,374	5,340,188	4,966,374
231	Vehicle occupancy for busi travelers per hwy trip (persons/hwy trip)[4]	1.90	1.90	1.90	1.90
232	Vehicle occupancy for non-busi travelers per hwy trip (persons/hwy trip)[4]	2.60	2.60	2.60	2.60
233	**Busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw229*Rw231)	**3,382,119**	**3,145,370**	**3,382,119**	**3,145,370**
234	**Non-busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw230*Rw232)	**13,884,488**	**12,912,573**	**13,884,488**	**12,912,573**
235	**Travelers per year diverted to HSR** (%)[5]	**0%**	**25%**	**0%**	**50%**
236	*Busi travelers* per year diverted to HSR (Rw233*Rw235)	0.00	786,343	0.00	1,572,685
237	*Non-busi travelers* per year diverted to HSR (Rw234*Rw235)	0.00	3,228,143	0.00	6,456,287
238	**Travelers per year diverted to other modes** such as carpools, buses and rail (%)[6]	**85%**	**65%**	**70%**	**45%**
239	*Busi travelers* per year diverted to other modes (Rw233*Rw238)	2,874,801	2,044,491	2,367,483	1,415,417
240	*Non-busi travelers* per year diverted to other modes (Rw234*Rw238)	11,801,814	8,393,173	9,719,141	5,810,658
241	**Travelers per year who eliminated highway trips** (%)[7]	**15%**	**10%**	**30%**	**5%**
242	*Busi travelers* per year who eliminated hwy trips (Rw233*Rw241)	507,318	314,537	1,014,636	157,269
243	*Non-busi travelers* per year who eliminated hwy trips (Rw234*Rw241)	2,082,673	1,291,257	4,165,346	645,629

	A	B	C	D	E
244		Medium Disruption			
245	***Year Two of Regulations:***	**Scenario 2a**		**Scenario 2b**	
246	***Medium Disruption Scenarios (2a and 2b) (cont.)***	No HSR	HSR	No HSR	HSR
247	***Cost of Additional Travel Time***				
248	Additional travel time per traveler when using other modes such as buses, rail and carpools (hours/traveler)[8]	0.67	0.67	0.67	0.67
249	*Busi travelers* per year diverted to other modes (same as Rw239)	2,874,801	2,044,491	2,367,483	1,415,417
250	*Non-busi travelers* per yr diverted to other modes (same as Rw240)	11,801,814	8,393,173	9,719,141	5,810,658
251	Additional travel time for busi travelers when using other modes (hours/yr) (Rw248*Rw249)	1,926,117	1,369,809	1,586,214	948,329
252	Additional travel time for non-busi travelers when using other modes (hours/yr) (Rw248*Rw250)	7,907,216	5,623,426	6,511,825	3,893,141
253	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
254	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
255	Additional costs to busi travelers for using other modes ($/yr) (Rw251*Rw253)	$48,884,840	$34,765,748	$40,258,104	$24,068,595
256	Additional costs to non-busi travelers for using other modes ($/yr) (Rw252*Rw254)	$117,738,441	$83,732,809	$96,961,069	$57,968,868
257	**Cost of additional travel time to travelers** for using other modes ($/yr) (Rw255+Rw256)	**$166,623,281**	**$118,498,557**	**$137,219,172**	**$82,037,462**
258					
259	***Cost of Eliminated Highway Trips***				
260	Value of a highway trip per traveler (hours/traveler)[10]	5.34	5.34	5.34	5.34
261	*Busi travelers* per year who eliminated hwy trips[7] (same as Rw242)	507,318	314,537	1,014,636	157,269
262	*Non-busi travelers* per year who eliminated hwy trips[7] (same as Rw243)	2,082,673	1,291,257	4,165,346	645,629
263	Value of eliminated busi hwy travel per year (hours/yr) (Rw260*Rw261)	2,709,077	1,679,628	5,418,154	839,814
264	Value of eliminated non-busi hwy travel per year (hours/yr) (Rw260*Rw262)	11,121,474	6,895,314	22,242,949	3,447,657
265	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
266	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
267	Cost of eliminated hwy trips to busi travelers ($/yr) (Rw263*Rw265)	$68,756,377	$42,628,954	$137,512,755	$21,314,477
268	Cost of eliminated hwy trips to non-busi travelers ($/yr) (Rw264*Rw266)	$165,598,755	$102,671,228	$331,197,510	$51,335,614
269	**Cost of eliminated hwy trips** ($/yr) (Rw267+Rw268)	**$234,355,132**	**$145,300,182**	**$468,710,265**	**$72,650,091**
270					
271	***Summary of Service Interruption Costs***				
272	Cost of Additional Travel Time (same as Rw257)	$166,623,281	$118,498,557	$137,219,172	$82,037,462
273	Cost of Eliminated Highway Trips (same as Rw269)	$234,355,132	$145,300,182	$468,710,265	$72,650,091
274	Cost of additional travel time and eliminated hwy trips ($) (Rw272+Rw273)	$400,978,413	$263,798,739	$605,929,437	$154,687,553
275	Cost of additional travel time and eliminated hwy trips ($ millions/yr)	**$401**	**$264**	**$606**	**$155**
276	**HSR versus no HSR Cost Difference** ($ millions/yr) (B275-C275)		**$137**		**$451**

	A	B	C	D	E
277		**Maximum Disruption**			
278	***Year Two of Regulations:***	**Scenario 3a**		**Scenario 3b**	
279	***Maximum Disruption Scenarios (3a and 3b)***	No HSR	HSR	No HSR	HSR
280	CA Corridor annual highway trips[1]	134,910,000	125,466,300	134,910,000	125,466,300
281	**Eliminated or diverted hwy trips** per year due to regulations (%)[2]	**10%**	**10%**	**10%**	**10%**
282	Eliminated or diverted hwy trips per year due to regulations (Rw280*Rw281)	13,491,000	12,546,630	13,491,000	12,546,630
283	*Business hwy trips* eliminated or diverted per year due to regulations[3] (Rw282*25%)	3,372,750	3,136,658	3,372,750	3,136,658
284	*Non-busi hwy trips* eliminated or diverted per year due to regulations[3] (Rw282*75%)	10,118,250	9,409,973	10,118,250	9,409,973
285	Vehicle occupancy for busi travelers per hwy trip (persons/hwy trip)[4]	1.90	1.90	1.90	1.90
286	Vehicle occupancy for non-busi travelers per hwy trip (persons/hwy trip)[4]	2.60	2.60	2.60	2.60
287	**Busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw283*Rw285)	**6,408,225**	**5,959,649**	**6,408,225**	**5,959,649**
288	**Non-busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw284*Rw286)	**26,307,450**	**24,465,929**	**26,307,450**	**24,465,929**
289	**Travelers per year diverted to HSR** (%)[5]	**0%**	**25%**	**0%**	**50%**
290	*Busi travelers* per year diverted to HSR (Rw287*Rw289)	0.00	1,489,912	0.00	2,979,825
291	*Non-busi travelers* per year diverted to HSR (Rw288*Rw289)	0.00	6,116,482	0.00	12,232,964
292	**Travelers per year diverted to other modes** such as carpools, buses and rail (%)[6]	**85%**	**65%**	**70%**	**45%**
293	*Busi travelers* per year diverted to other modes (Rw287*Rw292)	5,446,991	3,873,772	4,485,758	2,681,842
294	*Non-busi travelers* per year diverted to other modes (Rw288*Rw292)	22,361,333	15,902,854	18,415,215	11,009,668
295	**Travelers per year who eliminated hwy trips** (%)[7]	**15%**	**10%**	**30%**	**5%**
296	*Busi travelers* per year who eliminated hwy trips (Rw287*Rw295)	961,234	595,965	1,922,468	297,982
297	*Non-busi travelers* per year who eliminated hwy trips (Rw288*Rw295)	3,946,118	2,446,593	7,892,235	1,223,296

	A	B	C	D	E
298		Maximum Disruption			
299	***Year Two of Regulations:***	**Scenario 3a**		**Scenario 3b**	
300	***Maximum Disruption Scenarios (3a and 3b) (cont.)***	No HSR	HSR	No HSR	HSR
301	***Cost of Additional Travel Time***				
302	Additional travel time per traveler when using other modes such as buses, rail and carpools (hours/traveler)[8]	0.67	0.67	0.67	0.67
303	*Busi travelers* per year diverted to other modes (same as Rw293)	5,446,991	3,873,772	4,485,758	2,681,842
304	*Non-busi travelers* per yr diverted to other modes (same as Rw294)	22,361,333	15,902,854	18,415,215	11,009,668
305	Additional travel time for busi travelers when using other modes (hours/yr) (Rw302*Rw303)	3,649,484	2,595,427	3,005,458	1,796,834
306	Additional travel time for non-busi travelers when using other modes (hours/yr) (Rw302*Rw304)	14,982,093	10,654,912	12,338,194	7,376,477
307	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
308	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
309	Additional costs to busi travelers for using other modes ($/yr) (Rw305*Rw307)	$92,623,907	$65,871,944	$76,278,512	$45,603,653
310	Additional costs to non-busi travelers for using other modes ($/yr) (Rw306*Rw308)	$223,083,361	$158,651,638	$183,715,709	$109,835,749
311	**Cost of additional travel time to travelers** for using other modes ($/yr) (Rw309+Rw310)	**$315,707,269**	**$224,523,581**	**$259,994,221**	**$155,439,402**
312					
313	***Cost of Eliminated Highway Trips***				
314	Value of a highway trip per traveler (hours/traveler)[10]	5.34	5.34	5.34	5.34
315	Busi travelers per year who eliminated hwy trips (same as Rw296)	961,234	595,965	1,922,468	297,982
316	Non-busi travelers per year who eliminated hwy trips (same as Rw297)	3,946,118	2,446,593	7,892,235	1,223,296
317	Value of eliminated busi hwy travel per year (hours/yr) (Rw314*Rw315)	5,132,988	3,182,453	10,265,976	1,591,226
318	Value of eliminated non-busi hwy travel per year (hours/yr) (Rw314*Rw316)	21,072,267	13,064,806	42,144,535	6,532,403
319	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
320	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
321	Cost of eliminated hwy trips to busi travelers ($/yr) (Rw317*Rw319)	$130,275,241	$80,770,650	$260,550,482	$40,385,325
322	Cost of eliminated hwy trips to non-busi travelers ($/yr) (Rw318*Rw320)	$313,766,062	$194,534,959	$627,532,125	$97,267,479
323	**Cost of eliminated highway trips** ($/yr) (Rw321+Rw322)	**$444,041,303**	**$275,305,608**	**$888,082,607**	**$137,652,804**
324					
325	***Summary of Service Interruption Costs***				
326	Cost of Additional Travel Time (same as Rw311)	$315,707,269	$224,523,581	$259,994,221	$155,439,402
327	Cost of Eliminated Highway Trips (same as Rw323)	$444,041,303	$275,305,608	$888,082,607	$137,652,804
328	Cost of additional travel time and eliminated hwy trips ($) (Rw326+Rw327)	$759,748,572	$499,829,189	$1,148,076,828	$293,092,206
329	Cost of additional travel time and eliminated hwy trips ($ millions/yr)	**$760**	**$500**	**$1,148**	**$293**
330	**HSR versus no HSR Cost Difference** ($ millions/yr) (B329-C329)		**$260**		**$855**

	A	B	C	D	E
331		**Minimum Disruption**			
332	***Year Three of Regulations:***	**Scenario 1a**		**Scenario 1b**	
333	***Minimum Disruption Scenarios (1a and 1b)***	No HSR	HSR	No HSR	HSR
334	CA Corridor annual highway trips[1]	146,916,990	136,632,801	146,916,990	136,632,801
335	**Eliminated or diverted hwy trips** per year due to regulations (%)[2]	**1%**	**1%**	**1%**	**1%**
336	Hwy trips eliminated or diverted per year due to regulations (Rw334*Rw335)	1,469,170	1,366,328	1,469,170	1,366,328
337	*Business hwy trips* eliminated or diverted per year due to regulations[3] (Rw336*25%)	367,292	341,582	367,292	341,582
338	*Non-busi hwy trips* eliminated or diverted per year due to regulations[3] (Rw336*75%)	1,101,877	1,024,746	1,101,877	1,024,746
339	Vehicle occupancy for busi travelers per hwy trip (persons/hwy trip)[4]	1.90	1.90	1.90	1.90
340	Vehicle occupancy for non-busi travelers per hwy trip (persons/hwy trip)[4]	2.60	2.60	2.60	2.60
341	**Busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw337*Rw339)	**697,856**	**649,006**	**697,856**	**649,006**
342	**Non-busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw338*Rw340)	**2,864,881**	**2,664,340**	**2,864,881**	**2,664,340**
343	**Travelers per year diverted to HSR** (%)[5]	**0%**	**25%**	**0%**	**50%**
344	*Busi travelers* per year diverted to HSR (Rw341*Rw343)	0.00	162,251	0.00	324,503
345	*Non-busi travelers* per year diverted to HSR (Rw342*Rw343)	0.00	666,085	0.00	1,332,170
346	**Travelers per year diverted to other modes** such as carpools, buses and rail (%)[6]	**85%**	**65%**	**70%**	**45%**
347	*Busi travelers* per year diverted to other modes (Rw341*Rw346)	593,177	421,854	488,499	292,053
348	*Non-busi travelers* per year diverted to other modes (Rw342*Rw346)	2,435,149	1,731,821	2,005,417	1,198,953
349	**Travelers per year who eliminated highway trips** (%)[7]	**15%**	**10%**	**30%**	**5%**
350	*Busi travelers* per year who eliminated hwy trips (Rw341*Rw349)	104,678	64,901	209,357	32,450
351	*Non-busi travelers* per year who eliminated hwy trips (Rw342*Rw349)	429,732	266,434	859,464	133,217

	A	B	C	D	E
352		Minimum Disruption			
353	***Year Three of Regulations:***	**Scenario 1a**		**Scenario 1b**	
354	***Minimum Disruption Scenarios (1a and 1b) (cont.)***	No HSR	HSR	No HSR	HSR
355	***Cost of Additional Travel Time***				
356	Additional travel time per traveler when using other modes such as buses, rail and carpools (hours/traveler)[8]	0.67	0.67	0.67	0.67
357	*Busi travelers* per year diverted to other modes (same as Rw347)	593,177	421,854	488,499	292,053
358	*Non-busi travelers* per yr diverted to other modes (same as Rw348)	2,435,149	1,731,821	2,005,417	1,198,953
359	Additional travel time for busi travelers when using other modes (hours/yr) (Rw356*Rw357)	397,429	282,642	327,294	195,675
360	Additional travel time for non-busi travelers when using other modes (hours/yr) (Rw356*Rw358)	1,631,550	1,160,320	1,343,629	803,298
361	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
362	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
363	Additional costs to busi travelers for using other modes ($/yr) (Rw359*Rw361)	$10,086,744	$7,173,455	$8,306,730	$4,966,238
364	Additional costs to non-busi travelers for using other modes ($/yr) (Rw360*Rw362)	$24,293,778	$17,277,163	$20,006,641	$11,961,113
365	**Cost of additional travel time to travelers** for using other modes ($/yr) (Rw363+Rw364)	**$34,380,522**	**$24,450,618**	**$28,313,371**	**$16,927,351**
366					
367	***Cost of Eliminated Highway Trips***				
368	Value of a highway trip per traveler (hours/traveler)[10]	5.34	5.34	5.34	5.34
369	Busi travelers per year who eliminated hwy trips (same as Rw350)	104,678	64,901	209,357	32,450
370	Non-busi travelers per year who eliminated hwy trips (same as Rw351)	429,732	266,434	859,464	133,217
371	Value of eliminated busi hwy travel per year (hours/yr) (Rw368*Rw369)	558,982	346,569	1,117,965	173,285
372	Value of eliminated non-busi hwy travel per year (hours/yr) (Rw368*Rw370)	2,294,770	1,422,757	4,589,540	711,379
373	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
374	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
375	Cost of eliminated hwy trips to busi travelers ($/yr) (Rw371*Rw373)	$14,186,974	$8,795,924	$28,373,948	$4,397,962
376	Cost of eliminated hwy trips to non-busi travelers ($/yr) (Rw372*Rw374)	$34,169,124	$21,184,857	$68,338,248	$10,592,428
377	**Cost of eliminated highway trips** ($/yr) (Rw375+Rw376)	**$48,356,098**	**$29,980,781**	**$96,712,196**	**$14,990,390**
378					
379	***Summary of Service Interruption Costs***				
380	Cost of Additional Travel Time (same as Rw365)	$34,380,522	$24,450,618	$28,313,371	$16,927,351
381	Cost of Eliminated Highway Trips (same as Rw377)	$48,356,098	$29,980,781	$96,712,196	$14,990,390
382	Cost of additional travel time and eliminated hwy trips ($) (Rw380+Rw381)	$82,736,620	$54,431,399	$125,025,567	$31,917,741
383	Cost of additional travel time and eliminated hwy trips ($ millions/yr)	**$83**	**$54**	**$125**	**$32**
384	**HSR versus no HSR Cost Difference** ($ millions/yr) (B383-C383)		**$28**		**$93**

	A	B	C	D	E
385			**Medium Disruption**		
386	***Year Three of Regulations:***	**Scenario 2a**		**Scenario 2b**	
387	***Medium Disruption Scenarios (2a and 2b)***	No HSR	HSR	No HSR	HSR
388	CA Corridor annual highway trips[1]	135,284,750	125,814,818	135,284,750	125,814,818
389	**Eliminated or diverted hwy trips** per year due to regulations (%)[2]	**5%**	**5%**	**5%**	**5%**
390	Hwy trips eliminated or diverted per year due to regulations (Rw388*Rw389)	6,764,238	6,290,741	6,764,238	6,290,741
391	*Business hwy trips* eliminated or diverted per year due to regulations[3] (Rw390*25%)	1,691,059	1,572,685	1,691,059	1,572,685
392	*Non-busi hwy trips* eliminated or diverted per year due to regulations[3] (Rw390*75%)	5,073,178	4,718,056	5,073,178	4,718,056
393	Vehicle occupancy for busi travelers per hwy trip (persons/hwy trip)[4]	1.90	1.90	1.90	1.90
394	Vehicle occupancy for non-busi travelers per hwy trip (persons/hwy trip)[4]	2.60	2.60	2.60	2.60
395	**Busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw391*Rw393)	**3,213,013**	**2,988,102**	**3,213,013**	**2,988,102**
396	**Non-busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw392*Rw394)	**13,190,263**	**12,266,945**	**13,190,263**	**12,266,945**
397	**Travelers per year diverted to HSR** (%)[5]	**0%**	**65%**	**0%**	**50%**
398	*Busi travelers* per year diverted to HSR (Rw395*Rw397)	0.00	1,942,266	0.00	1,494,051
399	*Non-busi travelers* per year diverted to HSR (Rw396*Rw397)	0.00	7,973,514	0.00	6,133,472
400	**Travelers per year diverted to other modes** such as carpools, buses and rail (%)[6]	**85%**	**25%**	**70%**	**45%**
401	*Busi travelers* per year diverted to other modes (Rw395*Rw400)	2,731,061	747,025	2,249,109	1,344,646
402	*Non-busi travelers* per year diverted to other modes (Rw396*Rw400)	11,211,724	3,066,736	9,233,184	5,520,125
403	**Travelers per year who eliminated highway trips** (%)[7]	**15%**	**10%**	**30%**	**5%**
404	*Busi travelers* per year who eliminated hwy trips (Rw395*Rw403)	481,952	298,810	963,904	149,405
405	*Non-busi travelers* per year who eliminated hwy trips (Rw396*Rw403)	1,978,539	1,226,694	3,957,079	613,347

	A	B	C	D	E
406		**Medium Disruption**			
407	***Year Three of Regulations:***	**Scenario 2a**		**Scenario 2b**	
408	***Medium Disruption Scenarios (2a and 2b) (cont.)***	No HSR	HSR	No HSR	HSR
409	***Cost of Additional Travel Time***				
410	Additional travel time per traveler when using other modes such as buses, rail and carpools (hours/traveler)[8]	0.67	0.67	0.67	0.67
411	*Busi travelers* per year diverted to other modes (same as Rw401)	2,731,061	747,025	2,249,109	1,344,646
412	*Non-busi travelers* per yr diverted to other modes (same as Rw402)	11,211,724	3,066,736	9,233,184	5,520,125
413	Additional travel time for busi travelers when using other modes (hours/yr) (Rw410*Rw411)	1,829,811	500,507	1,506,903	900,913
414	Additional travel time for non-busi travelers when using other modes (hours/yr) (Rw410*Rw412)	7,511,855	2,054,713	6,186,233	3,698,484
415	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
416	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
417	Additional costs to busi travelers for using other modes ($/yr) (Rw413*Rw415)	$46,440,598	$12,702,869	$38,245,198	$22,865,165
418	Additional costs to non-busi travelers for using other modes ($/yr) (Rw414*Rw416)	$111,851,519	$30,594,680	$92,113,015	$55,070,424
419	**Cost of additional travel time to travelers** for using other modes ($/yr) (Rw417+Rw418)	**$158,292,117**	**$43,297,550**	**$130,358,214**	**$77,935,589**
420					
421	***Cost of Eliminated Highway Trips***				
422	Value of a highway trip per traveler (hours/traveler)[10]	5.34	5.34	5.34	5.34
423	*Busi travelers* per year who eliminated hwy trips (same as Rw404)	481,952	298,810	963,904	149,405
424	*Non-busi travelers* per year who eliminated hwy trips (same as Rw405)	1,978,539	1,226,694	3,957,079	613,347
425	Value of eliminated busi hwy travel per year (hours/yr) (Rw422*Rw423)	2,573,623	1,595,646	5,147,247	797,823
426	Value of eliminated non-busi hwy travel per year (hours/yr) (Rw422*Rw424)	10,565,401	6,550,548	21,130,802	3,275,274
427	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
428	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
429	Cost of eliminated hwy trips to busi travelers ($/yr) (Rw425*Rw427)	$65,318,558	$40,497,506	$130,637,117	$20,248,753
430	Cost of eliminated hwy trips to non-busi travelers ($/yr) (Rw426*Rw428)	$157,318,817	$97,537,667	$314,637,635	$48,768,833
431	**Cost of eliminated highway trips** ($/yr) (Rw429+Rw430)	**$222,637,376**	**$138,035,173**	**$445,274,752**	**$69,017,586**
432					
433	***Summary of Service Interruption Costs***				
434	Cost of Additional Travel Time (same as Rw419)	$158,292,117	$43,297,550	$130,358,214	$77,935,589
435	Cost of Eliminated Highway Trips (same as Rw431)	$222,637,376	$138,035,173	$445,274,752	$69,017,586
436	Cost of additional travel time and eliminated hwy trips ($) (Rw434+Rw435)	$380,929,493	$181,332,723	$575,632,965	$146,953,176
437	Cost of additional travel time and eliminated hwy trips ($ millions/yr)	**$381**	**$181**	**$576**	**$147**
438	**HSR versus no HSR Cost Difference** ($ millions/yr) (B437-C437)		**$200**		**$429**

	A	B	C	D	E
439			**Maximum Disruption**		
440	***Year Three of Regulations:***	**Scenario 3a**		**Scenario 3b**	
441	***Maximum Disruption Scenarios (3a and 3b)***	No HSR	HSR	No HSR	HSR
442	CA Corridor annual highway trips[1]	121,419,000	112,919,670	121,419,000	112,919,670
443	**Eliminated or diverted hwy trips** per year due to regulations (%)[2]	**10%**	**10%**	**10%**	**10%**
444	Hwy trips eliminated or diverted per year due to regulations (Rw442*Rw443)	12,141,900	11,291,967	12,141,900	11,291,967
445	*Business hwy trips* eliminated or diverted per year due to regulations[3] (Rw444*25%)	3,035,475	2,822,992	3,035,475	2,822,992
446	*Non-busi hwy trips* eliminated or diverted per year due to regulations[3] (Rw444*75%)	9,106,425	8,468,975	9,106,425	8,468,975
447	Vehicle occupancy for busi travelers per hwy trip (persons/hwy trip)[4]	1.90	1.90	1.90	1.90
448	Vehicle occupancy for non-busi travelers per hwy trip (persons/hwy trip)[4]	2.60	2.60	2.60	2.60
449	**Busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw445*Rw447)	**5,767,403**	**5,363,684**	**5,767,403**	**5,363,684**
450	**Non-busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw446*Rw448)	**23,676,705**	**22,019,336**	**23,676,705**	**22,019,336**
451	**Travelers per year diverted to HSR** (%)[5]	**0%**	**25%**	**0%**	**50%**
452	*Busi travelers* per year diverted to HSR (Rw449*Rw451)	0.00	1,340,921	0.00	2,681,842
453	*Non-busi travelers* per year diverted to HSR (Rw450*Rw451)	0.00	5,504,834	0.00	11,009,668
454	**Travelers per year diverted to other modes** such as carpools, buses and rail (%)[6]	**85%**	**65%**	**70%**	**45%**
455	*Busi travelers* per year diverted to other modes (Rw449*Rw454)	4,902,292	3,486,395	4,037,182	2,413,658
456	*Non-busi travelers* per year diverted to other modes (Rw450*Rw454)	20,125,199	14,312,568	16,573,694	9,908,701
457	**Travelers per year who eliminated highway trips** (%)[7]	**15%**	**10%**	**30%**	**5%**
458	*Busi travelers* per year who eliminated hwy trips (Rw449*Rw457)	865,110	536,368	1,730,221	268,184
459	*Non-busi travelers* per year who eliminated hwy trips (Rw450*Rw457)	3,551,506	2,201,934	7,103,012	1,100,967

	A	B	C	D	E
460		**Maximum Disruption**			
461	***Year Three of Regulations:***	**Scenario 3a**		**Scenario 3b**	
462	***Maximum Disruption Scenarios (3a and 3b) (cont.)***	No HSR	HSR	No HSR	HSR
463	***Cost of Additional Travel Time***				
464	Additional travel time per traveler when using other modes such as buses, rail and carpools (hours/traveler)[8]	0.67	0.67	0.67	0.67
465	*Busi travelers* per year diverted to other modes (same as Rw455)	4,902,292	3,486,395	4,037,182	2,413,658
466	*Non-busi travelers* per yr diverted to other modes (same as Rw456)	20,125,199	14,312,568	16,573,694	9,908,701
467	Additional travel time for busi travelers when using other modes (hours/yr) (Rw464*Rw465)	3,284,536	2,335,885	2,704,912	1,617,151
468	Additional travel time for non-busi travelers when using other modes (hours/yr) (Rw464*Rw466)	13,483,883	9,589,421	11,104,375	6,638,830
469	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
470	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
471	Additional costs to busi travelers for using other modes ($/yr) (Rw467*Rw469)	$83,361,517	$59,284,749	$68,650,661	$41,043,288
472	Additional costs to non-busi travelers for using other modes ($/yr) (Rw468*Rw470)	$200,775,025	$142,786,474	$165,344,138	$98,852,174
473	**Cost of additional travel time to travelers** for using other modes ($/yr) (Rw471+Rw472)	**$284,136,542**	**$202,071,223**	**$233,994,799**	**$139,895,462**
474					
475	***Cost of Eliminated Highway Trips***				
476	Value of a highway trip per traveler (hours/traveler)[10]	5.34	5.34	5.34	5.34
477	*Busi travelers* per year who eliminated hwy trips (same as Rw458)	865,110	536,368	1,730,221	268,184
478	*Non-busi travelers* per year who eliminated hwy trips (same as Rw459)	3,551,506	2,201,934	7,103,012	1,100,967
479	Value of eliminated busi hwy travel per year (hours/yr) (Rw476*Rw477)	4,619,689	2,864,207	9,239,379	1,432,104
480	Value of eliminated non-busi hwy travel per year (hours/yr) (Rw476*Rw478)	18,965,041	11,758,325	37,930,081	5,879,163
481	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
482	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
483	Cost of eliminated hwy trips to busi travelers ($/yr) (Rw479*Rw481)	$117,247,717	$72,693,585	$234,495,434	$36,346,792
484	Cost of eliminated hwy trips to non-busi travelers ($/yr) (Rw480*Rw482)	$282,389,456	$175,081,463	$564,778,912	$87,540,731
485	**Cost of eliminated highway trips** ($/yr) (Rw483+Rw484)	**$399,637,173**	**$247,775,047**	**$799,274,346**	**$123,887,524**
486					
487	***Summary of Service Interruption Costs***				
488	Cost of Additional Travel Time (same as Rw473)	284,136,542	202,071,223	233,994,799	139,895,462
489	Cost of Eliminated Highway Trips (same as Rw485)	$399,637,173	$247,775,047	$799,274,346	$123,887,524
490	Cost of additional travel time and eliminated hwy trips ($) (Rw488+Rw489)	$683,773,715	$449,846,270	$1,033,269,146	$263,782,986
491	Cost of additional travel time and eliminated hwy trips ($ millions/yr)	**$684**	**$450**	**$1,033**	**$264**
492	**HSR versus no HSR Cost Difference** ($ millions/yr) (B491-C491)		**$234**		**$769**

Air Quality and Global Warming Assumptions

1. The *Draft California HSR Economic Impact* study states that annual intercity highway travel in the California Corridor totals 126.7 million trips in 1994 and 173.1 million trips in 2020. This analysis uses a mean estimate of these two figures, totaling 149.9 million trips annually. The intercity figures only consider origins and destinations that are expected to be near HSR stations. The average highway trip length is calculated to be 147 miles. Only 5.4 percent of these trips are under 100 miles. The minimum trip length is 32 miles; the maximum trip length is 504 miles. Refer to Appendix B to view the actual numbers used for this intercity highway travel analysis.

   For the "HSR" analyses: According to the *Economic Impact* study, about seven percent of the highway trips are expected to be diverted to HSR during normal conditions, totaling 139.4 million annual highway trips.

   For years two and three, the number of annual highway trips are assumed to decrease according to the effects of the regulation from the previous year.

2. The second and third years are not expected to cost as much because the number of highway vehicles is smaller. The policies call for highway trip reductions ranging from one percent to 20 percent.

3. According to the *Draft California HSR Economic Impact* study, 25 percent of the highway trips are business trips and 75 percent are non-business trips.

4. According to the *Draft California HSR Economic Impact* study, vehicle occupancy rates total 1.9 persons per vehicle for intercity highway business trips and 2.6 persons per vehicle for intercity highway non-business trips.

5. Highway trips that are diverted to high-speed rail generate no extra costs because these travelers view the service as comparable to private autos, and as an optimal choice when comparing it to carpools and conventional rail. Even though the HSR service is considered to be optimal in some cases, this analysis does not give credit for its time savings when present. The highway trips that are diverted to high-speed rail are assumed to vary from 25 percent in the scenarios labeled "A" to 50 percent in the scenarios labeled "B" in order to show a range of responses to the service interruption. Implicit in the analysis is that short and long trips are diverted to high-speed rail at the same rate.

6. The term "other modes" considers buses, conventional rail and carpools. "Other modes" are assumed to be more responsive to service disruptions in the analyses labeled "A" than in the analyses labeled "B." For the "HSR" analyses, the percentage of diverted trips to "other modes" is assumed to vary between 45 percent and 65 percent for the "B" and "A" analyses, respectively. For the "No HSR" analyses, the percentage of diverted trips to "other modes" is assumed to vary between 70 percent and 85 percent for the "B" and "A" analyses, respectively. Implicit in the analysis is that short and long trips are diverted to "other modes" at the same rate.

7. The percentage of eliminated highway trips is assumed to vary between 5 percent and 10 percent for the "HSR" analyses and between 15 percent and 30 percent for the "No HSR" analyses. Thus, fewer travelers are expected to eliminate a trip when an HSR service exists. Implicit in the analysis is that short and long trips are eliminated at the same rate.

8. The mean highway trip time is assumed to be 3.34 hours per trip during service interruptions and 2.67 hours per trip during regular conditions (i.e., periods without service interruptions). Thus, the additional cost of traveling by highway during service interruptions equals .67 hours per trip, the difference between the two travel times. The additional cost of traveling via conventional rail is expected to be even higher, so .67 hours represents a conservative estimate. The trip time estimates are derived from a weighted average of highway trip distance along the corridor, which totals 147 miles. An assumed average rate of travel of 55 mph for highway vehicles is used to calculate an average highway trip time of 2.67 hours. A 25 percent increase in travel time is assumed to occur during service interruptions. This time increase is an arbitrary number that was assigned in order to bracket the benefits of HSR.

9. According to Charles River Associates estimates in the *Draft California HSR Economic Impact* study, the value of business traveler time for highway travel equals $25.38 per hour and the value of non-business traveler time for highway travel equals $14.89 per hour.

10. The mean highway travel time is estimated to be 2.67 hours per trip. (See #8 for analysis.) Travel time acts as a proxy for the cost of a trip. The value of a trip must be greater than its cost. A highway trip value of 5.34 hours is selected as an arbitrary estimate, which is double the cost of an average highway trip. The value selected for highway trips is less than the value for air travel because air travelers pay more to use these services.

High-Speed Rail Contributions:
Reduction of Economic and Social Dislocation Costs
Caused by Energy-Related Regulations

Year One	**Reduction of Disruption Costs due to HSR ($ millions/yr)**
Minimum Disruption: Low HSR Contribution (1a)	$29
Minimum Disruption: High HSR Contribution (1b)	$81
Medium Disruption: Low HSR Contribution (2a)	$289
Medium Disruption: High HSR Contribution (2b)	$806
Maximum Disruption: Low HSR Contribution (3a)	$578
Maximum Disruption: High HSR Contribution (3b)	$1,612

	A	B	C	D	E
1	**High-Speed Rail Contributions:**				
2	**Reduction of Economic and Social Dislocation Costs Caused by Regulations Relating to Energy Constraints**				
3					
4	Gasoline shortages and price increases will cause between one percent and 20 percent of highway travel to be eliminated or diverted for one year.				
5	The one year estimate is derived from previous energy crises, which lasted for six months (1973/74, 1990) and for two years (1979).				
6					
7		**Minimum Disruption**			
8	***Year One of Regulations:***	**Scenario 1a**		**Scenario 1b**	
9	***Minimum Disruption Scenarios (1a and 1b)***	No HSR	HSR	No HSR	HSR
10	CA Corridor annual highway trips[1]	149,900,000	139,407,000	149,900,000	139,407,000
11	**Eliminated or diverted hwy trips** per year due to regulations (%)[2]	**1%**	**1%**	**1%**	**1%**
12	Eliminated or diverted hwy trips per year due to regulations (Rw10* Rw11)	1,499,000	1,394,070	1,499,000	1,394,070
13	*Business hwy trips* eliminated or diverted per year due to regulations[3] (Rw12*25%)	374,750	348,518	374,750	348,518
14	*Non-busi hwy trips* eliminated or diverted per year due to regulations[3] (Rw12*75%)	1,124,250	1,045,553	1,124,250	1,045,553
15	Vehicle occupancy for busi travelers per hwy trip (persons/hwy trip)[4]	1.90	1.90	1.90	1.90
16	Vehicle occupancy for non-busi travelers per hwy trip (persons/hwy trip)[4]	2.60	2.60	2.60	2.60
17	**Busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw13*Rw15)	**712,025**	**662,183**	**712,025**	**662,183**
18	**Non-busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw14*Rw16)	**2,923,050**	**2,718,437**	**2,923,050**	**2,718,437**
19	**Travelers per year diverted to HSR** (%)[5]	**0%**	**25%**	**0%**	**50%**
20	*Busi travelers* per year diverted to HSR (Rw17*Rw19)	0.00	165,546	0.00	331,092
21	*Non-busi travelers* per year diverted to HSR (Rw18*Rw19)	0.00	679,609	0.00	1,359,218
22	**Travelers per year diverted to other modes** such as carpools, buses and rail (%)[6]	**85%**	**65%**	**75%**	**45%**
23	*Busi travelers* per year diverted to other modes (Rw17*Rw22)	605,221	430,419	534,019	297,982
24	*Non-busi travelers* per year diverted to other modes (Rw18*Rw22)	2,484,593	1,766,984	2,192,288	1,223,296
25	**Travelers per year who eliminated highway trips** (%)[7]	**15%**	**10%**	**25%**	**5%**
26	*Busi travelers* per year who eliminated hwy trips (Rw17*Rw25)	106,804	66,218	178,006	33,109
27	*Non-busi travelers* per year who eliminated hwy trips (Rw18*Rw25)	438,458	271,844	730,763	135,922

	A	B	C	D	E
28		**Minimum Disruption**			
29	***Year One of Regulations:***	**Scenario 1a**		**Scenario 1b**	
30	***Minimum Disruption Scenarios (1a and 1b) (cont.)***	No HSR	HSR	No HSR	HSR
31	***Cost of Additional Travel Time***				
32	Additional travel time per traveler when using other modes such as buses, rail and carpools (hours/traveler)[8]	0.67	0.67	0.67	0.67
33	*Busi travelers* per year diverted to other modes (same as Rw23)	605,221	430,419	534,019	297,982
34	*Non-busi travelers* per year diverted to other modes (same as Rw24)	2,484,593	1,766,984	2,192,288	1,223,296
35	Additional travel time for busi travelers when using other modes (hours/yr) (Rw32*Rw33)	405,498	288,381	357,793	199,648
36	Additional travel time for non-busi travelers when using other modes (hours/yr) (Rw32*Rw34)	1,664,677	1,183,879	1,468,833	819,609
37	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
38	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
39	Additional costs to busi travelers for using other modes ($/yr) (Rw35*Rw37)	$10,291,545	$7,319,105	$9,080,775	$5,067,073
40	Additional costs to non-busi travelers for using other modes ($/yr) (Rw36*Rw38)	$24,787,040	$17,627,960	$21,870,918	$12,203,972
41	**Cost of additional travel time to travelers** for using other modes ($/yr) (Rw39+Rw40)	**$35,078,585**	**$24,947,065**	**$30,951,693**	**$17,271,045**
42					
43	***Cost of Eliminated Highway Trips***				
44	Value of a highway trip per traveler (hours/traveler)[10]	5.34	5.34	5.34	5.34
45	Busi travelers per year who eliminated hwy trips (same as Rw26)	106,804	66,218	178,006	33,109
46	Non-busi travelers per year who eliminated hwy trips (same as Rw27)	438,458	271,844	730,763	135,922
47	Value of eliminated busi hwy travel per year (hours/yr) (Rw44*Rw45)	570,332	353,606	950,553	176,803
48	Value of eliminated non-busi hwy travel per year (hours/yr) (Rw44*Rw46)	2,341,363	1,451,645	3,902,272	725,823
49	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
50	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
51	Cost of eliminated hwy trips to busi travelers ($/yr) (Rw47*Rw49)	$14,475,027	$8,974,517	$24,125,045	$4,487,258
52	Cost of eliminated hwy trips to non-busi travelers ($/yr) (Rw48*Rw50)	$34,862,896	$21,614,995	$58,104,826	$10,807,498
53	**Cost of eliminated highway trips** ($/yr) (Rw51+Rw52)	**$49,337,923**	**$30,589,512**	**$82,229,871**	**$15,294,756**
54					
55	***Summary of Service Interruption Costs***				
56	Cost of Additional Travel Time (same as Rw41)	$35,078,585	$24,947,065	$30,951,693	$17,271,045
57	Cost of Eliminated Highway Trips (same as Rw53)	$49,337,923	$30,589,512	$82,229,871	$15,294,756
58	(Rw56+Rw57)	$84,416,508	$55,536,577	$113,181,564	$32,565,801
59	Cost of additional travel time and eliminated hwy trips ($ millions/yr)	**$84**	**$56**	**$113**	**$33**
60	**HSR versus no HSR Cost Difference** ($ millions/yr) (B59-C59)		**$29**		**$81**

	A	B	C	D	E
61		**Medium Disruption**			
62	***Year One of Regulations:***	**Scenario 2a**		**Scenario 2b**	
63	***Medium Disruption Scenarios (2a and 2b)***	No HSR	HSR	No HSR	HSR
64	CA Corridor annual highway trips[1]	149,900,000	139,407,000	149,900,000	139,407,000
65	**Eliminated or diverted hwy trips** per year due to regulations (%)[2]	**10%**	**10%**	**10%**	**10%**
66	Eliminated or diverted hwy trips per year due to regulations (Rw64* Rw65)	14,990,000	13,940,700	14,990,000	13,940,700
67	*Business hwy trips* eliminated or diverted per year due to regulations[3] (Rw66*25%)	3,747,500	3,485,175	3,747,500	3,485,175
68	*Non-busi hwy trips* eliminated or diverted per year due to regulations[3] (Rw66*75%)	11,242,500	10,455,525	11,242,500	10,455,525
69	Vehicle occupancy for busi travelers per hwy trip (persons/hwy trip)[4]	1.90	1.90	1.90	1.90
70	Vehicle occupancy for non-busi travelers per hwy trip (persons/hwy trip)[4]	2.60	2.60	2.60	2.60
71	**Busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw67*Rw69)	**7,120,250**	**6,621,833**	**7,120,250**	**6,621,833**
72	**Non-busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw68*Rw70)	**29,230,500**	**27,184,365**	**29,230,500**	**27,184,365**
73	**Travelers per year diverted to HSR** (%)[5]	**0%**	**25%**	**0%**	**50%**
74	*Busi travelers* per year diverted to HSR (Rw71*Rw73)	0.00	1,655,458	0.00	3,310,916
75	*Non-busi travelers* per year diverted to HSR (Rw72*Rw73)	0.00	6,796,091	0.00	13,592,183
76	**Travelers per year diverted to other modes** such as carpools, buses and rail (%)[6]	**85%**	**65%**	**75%**	**45%**
77	*Busi travelers* per year diverted to other modes (Rw71*Rw76)	6,052,213	4,304,191	5,340,188	2,979,825
78	*Non-busi travelers* per year diverted to other modes (Rw72*Rw76)	24,845,925	17,669,837	21,922,875	12,232,964
79	**Travelers per year who eliminated hwy trips** (%)[7]	**15%**	**10%**	**25%**	**5%**
80	*Busi travelers* per year who eliminated hwy trips (Rw71*Rw79)	1,068,038	662,183	1,780,063	331,092
81	*Non-busi travelers* per year who eliminated hwy trips (Rw72*Rw79)	4,384,575	2,718,437	7,307,625	1,359,218

	A	B	C	D	E
82		**Medium Disruption**			
83	***Year One of Regulations:***	**Scenario 2a**		**Scenario 2b**	
84	***Medium Disruption Scenarios (2a and 2b) (cont.)***	No HSR	HSR	No HSR	HSR
85	***Cost of Additional Travel Time***				
86	Additional travel time per traveler when using other modes such as buses, rail and carpools (hours/traveler)[8]	0.67	0.67	0.67	0.67
87	*Busi travelers* per year diverted to other modes (same as Rw77)	6,052,213	4,304,191	5,340,188	2,979,825
88	*Non-busi travelers* per yr diverted to other modes (same as Rw78)	24,845,925	17,669,837	21,922,875	12,232,964
89	Additional travel time for busi travelers when using other modes (hours/yr) (Rw86*Rw87)	4,054,982	2,883,808	3,577,926	1,996,482
90	Additional travel time for non-busi travelers when using other modes (hours/yr) (Rw86*Rw88)	16,646,770	11,838,791	14,688,326	8,196,086
91	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
92	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
93	Additional costs to busi travelers for using other modes ($/yr) (Rw89*Rw91)	$102,915,453	$73,191,048	$90,807,752	$50,670,726
94	Additional costs to non-busi travelers for using other modes ($/yr) (Rw90*Rw92)	$247,870,402	$176,279,597	$218,709,178	$122,039,721
95	**Cost of additional travel time to travelers** for using other modes ($/yr) (Rw93+Rw94)	**$350,785,854**	**$249,470,646**	**$309,516,930**	**$172,710,447**
96					
97	***Cost of Eliminated Highway Trips***				
98	Value of a highway trip per traveler (hours/traveler)[10]	5.34	5.34	5.34	5.34
99	*Busi travelers* per year who eliminated trips (same as Rw80)	1,068,038	662,183	1,780,063	331,092
100	*Non-busi travelers* per year who eliminated trips (same as Rw81)	4,384,575	2,718,437	7,307,625	1,359,218
101	Value of eliminated busi hwy travel per year (hours/yr) (Rw98*Rw99)	5,703,320	3,536,059	9,505,534	1,768,029
102	Value of eliminated non-busi hwy travel per year (hours/yr) (Rw98*Rw100)	23,413,631	14,516,451	39,022,718	7,258,225
103	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
104	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
105	Cost of eliminated hwy trips to busi travelers ($/yr) (Rw101*Rw103)	$144,750,268	$89,745,166	$241,250,447	$44,872,583
106	Cost of eliminated hwy trips to non-busi travelers ($/yr) (Rw102*Rw104)	$348,628,958	$216,149,954	$581,048,264	$108,074,977
107	**Cost of eliminated highway trips** ($/yr) (Rw105+Rw106)	**$493,379,226**	**$305,895,120**	**$822,298,710**	**$152,947,560**
108					
109	***Summary of Service Interruption Costs***				
110	Cost of Additional Travel Time (same as Rw95)	$350,785,854	$249,470,646	$309,516,930	$172,710,447
111	Cost of Eliminated Trips (same as Rw107)	$493,379,226	$305,895,120	$822,298,710	$152,947,560
112	Cost of additional travel time and eliminated hwy trips ($) (Rw110+Rw111)	$844,165,080	$555,365,766	$1,131,815,640	$325,658,007
113	Cost of additional travel time and eliminated hwy trips ($ millions/yr)	**$844**	**$555**	**$1,132**	**$326**
114	**HSR versus no HSR Cost Difference** ($ millions/yr) (B113-C113)		**$289**		**$806**

	A	B	C	D	E
115			Maximum Disruption		
116	***Year One of Regulations:***	**Scenario 3a**		**Scenario 3b**	
117	***Maximum Disruption Scenarios (3a and 3b)***	No HSR	HSR	No HSR	HSR
118	CA Corridor annual highway trips[1]	149,900,000	139,407,000	149,900,000	139,407,000
119	**Eliminated or diverted hwy trips** per year due to regulations (%)[2]	**20%**	**20%**	**20%**	**20%**
120	Rw119)	29,980,000	27,881,400	29,980,000	27,881,400
121	*Business hwy trips* eliminated or diverted per year due to regulations[3] (Rw120*25%)	7,495,000	6,970,350	7,495,000	6,970,350
122	*Non-busi hwy trips* eliminated or diverted per year due to regulations[3] (Rw120*75%)	22,485,000	20,911,050	22,485,000	20,911,050
123	Vehicle occupancy for busi travelers per hwy trip (persons/hwy trip)[4]	1.90	1.90	1.90	1.90
124	Vehicle occupancy for non-busi travelers per hwy trip (persons/hwy trip)[4]	2.60	2.60	2.60	2.60
125	**Busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw121*Rw123)	**14,240,500**	**13,243,665**	**14,240,500**	**13,243,665**
126	**Non-busi travelers** per year who eliminated or diverted hwy trips due to regulations (Rw122*Rw124)	**58,461,000**	**54,368,730**	**58,461,000**	**54,368,730**
127	**Travelers per year diverted to HSR** (%)[5]	**0%**	**25%**	**0%**	**50%**
128	*Busi travelers* per year diverted to HSR (Rw125*Rw127)	0.00	3,310,916	0.00	6,621,833
129	*Non-busi travelers* per year diverted to HSR (Rw126*Rw127)	0.00	13,592,183	0.00	27,184,365
130	**Travelers per year diverted to other modes** such as carpools, buses and rail (%)[6]	**85%**	**65%**	**75%**	**45%**
131	*Busi travelers* per year diverted to other modes (Rw125*Rw130)	12,104,425	8,608,382	10,680,375	5,959,649
132	*Non-busi travelers* per year diverted to other modes (Rw126*Rw130)	49,691,850	35,339,675	43,845,750	24,465,929
133	**Travelers per year who eliminated hwy trips** (%)[7]	**15%**	**10%**	**25%**	**5%**
134	*Busi travelers* per year who eliminated trips (Rw125*Rw133)	2,136,075	1,324,367	3,560,125	662,183
135	*Non-busi travelers* per year who eliminated trips (Rw126*Rw133)	8,769,150	5,436,873	14,615,250	2,718,437

	A	B	C	D	E
136			**Maximum Disruption**		
137	***Year One of Regulations:***	**Scenario 3a**		**Scenario 3b**	
138	***Maximum Disruption Scenarios (3a and 3b) (cont.)***	No HSR	HSR	No HSR	HSR
139	***Cost of Additional Travel Time***				
140	Additional travel time per traveler when using other modes such as buses, rail and carpools (hours/traveler)[8]	0.67	0.67	0.67	0.67
141	*Busi travelers* per year diverted to other modes (same as Rw131)	12,104,425	8,608,382	10,680,375	5,959,649
142	*Non-busi travelers* per yr diverted to other modes (same as Rw132)	49,691,850	35,339,675	43,845,750	24,465,929
143	Additional travel time for busi travelers when using other modes (hours/yr) (Rw140*Rw141)	8,109,965	5,767,616	7,155,851	3,992,965
144	Additional travel time for non-busi travelers when using other modes (hours/yr) (Rw140*Rw142)	33,293,540	23,677,582	29,376,653	16,392,172
145	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
146	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
147	Additional costs to busi travelers for using other modes ($/yr) (Rw143*Rw145)	$205,830,905	$146,382,097	$181,615,505	$101,341,452
148	Additional costs to non-busi travelers for using other modes($/yr)(Rw144*Rw146)	$495,740,803	$352,559,195	$437,418,356	$244,079,442
149	**Cost of additional travel time to travelers** for using other modes ($/yr) (Rw147+Rw148)	**$701,571,709**	**$498,941,292**	**$619,033,860**	**$345,420,894**
150					
151	***Cost of Eliminated Highway Trips***				
152	Value of a highway trip per traveler (hours/traveler)[10]	5.34	5.34	5.34	5.34
153	*Busi travelers* per year who eliminated trips (same as Rw134)	2,136,075	1,324,367	3,560,125	662,183
154	*Non-busi travelers* per year who eliminated trips (same as Rw135)	8,769,150	5,436,873	14,615,250	2,718,437
155	Value of eliminated busi hwy travel per year (hours/yr) (Rw152*Rw153)	11,406,641	7,072,117	19,011,068	3,536,059
156	Value of eliminated non-busi hwy travel per year (hours/yr) (Rw152*Rw154)	46,827,261	29,032,902	78,045,435	14,516,451
157	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
158	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
159	Cost of eliminated hwy trips to busi travelers ($/yr) (Rw155*Rw157)	$289,500,536	$179,490,332	$482,500,893	$89,745,166
160	Cost of eliminated hwy trips to non-busi travelers ($/yr) (Rw156*Rw158)	$697,257,916	$432,299,908	$1,162,096,527	$216,149,954
161	**Cost of eliminated highway trips** ($/yr) (Rw159+Rw160)	**$986,758,452**	**$611,790,240**	**$1,644,597,420**	**$305,895,120**
162					
163	***Summary of Service Interruption Costs***				
164	Cost of Additional Travel Time (same as Rw149)	$701,571,709	$498,941,292	$619,033,860	$345,420,894
165	Cost of Eliminated Highway Trips (same as Rw161)	$986,758,452	$611,790,240	$1,644,597,420	$305,895,120
166	Cost of additional travel time and eliminated hwy trips ($) (Rw164+Rw165)	$1,688,330,161	$1,110,731,532	$2,263,631,281	$651,316,014
167	Cost of additional travel time and eliminated hwy trips ($ millions/yr)	**$1,688**	**$1,111**	**$2,264**	**$651**
168	**HSR versus no HSR Cost Difference** ($ millions/yr) (B167-C167)		**$578**		**$1,612**

Energy Constraint Assumptions

1. The *Draft California HSR Economic Impact* study states that annual intercity highway travel in the California Corridor totals 126.7 million trips in 1994 and 173.1 million trips in 2020. This analysis uses a mean estimate of these two figures, totaling 149.9 million trips annually. The intercity figures only consider origins and destinations that are expected to be near HSR stations. The average highway trip length is calculated to be 147 miles. Only 5.4 percent of these trips are under 100 miles. The minimum trip length is 32 miles; the maximum trip length is 504 miles. Refer to Appendix B to view the actual numbers used for this intercity highway travel analysis.

   For the "HSR" analyses: HSR would divert approximately seven percent of highway trips during normal conditions totaling to 139.4 million annual highway trips, according to the *Economic Impact* study.

2. During the energy crises of the 1970s, automobile trips decreased about 10 percent, according to a 1983 Transportation Research Board report.[1] This scenario assumes that between one percent and 20 percent of intercity highway vehicles will be eliminated or diverted over one year.

3. According to the *Draft California HSR Economic Impact* study, 25 percent of the highway trips are business trips and 75 percent are non-business trips.

4. According to the *Draft California HSR Economic Impact* study, vehicle occupancy rates total 1.9 persons per vehicle for intercity highway business trips and 2.6 persons per vehicle for intercity highway non-business trips.

5. Highway trips that are diverted to high-speed rail generate no extra costs because these travelers view the service as comparable to private autos, and as an optimal choice when comparing it to carpools and conventional rail. Even though the HSR service is considered to be optimal in some cases, this analysis does not give credit for its time savings when present. The highway trips that are diverted to high-speed rail are assumed to vary from 25 percent in the scenarios labeled "A" to 50 percent in the scenarios labeled "B" in order to show a range of responses to the service interruption. Implicit in this analysis is that short and long trips are diverted to high-speed rail at the same rate.

6. The term "other modes" considers buses, conventional rail and carpools. "Other modes" are assumed to be more responsive to service disruptions in the analyses labeled "A" than in the analyses labeled "B." For the "HSR" analyses, the percentage of diverted trips to "other modes" is assumed to vary between 45 percent and 65 percent for the "B" and "A" analyses, respectively. For the "No HSR" analyses, the percentage of diverted trips to "other modes" is assumed to vary between 75 percent and 85 percent for the "B" and "A" analyses, respectively. Implicit in this analysis is that short and long trips are diverted to "other modes" at the same rate.

7. The percentage of eliminated highway trips is assumed to vary between 5 percent and 10 percent for the "HSR" analyses and between 15 percent and 25 percent for the "No HSR" analyses. Thus, fewer travelers are expected to eliminate a trip when a HSR service exists. Implicit in this analysis is that short and long trips are eliminated at the same rate.

8. The mean highway trip time is assumed to be 3.34 hours per trip during service interruptions and 2.67 hours per trip during regular conditions (i.e., periods without service interruptions). Thus, the additional cost of traveling by highway during service interruptions equals .67 hours per trip, the difference between the two travel times. The additional cost of traveling via conventional rail is expected to be even higher, so .67 hours represents a conservative estimate. The trip time estimates are derived from a weighted average of highway trip distance along the corridor, which totals 147 miles. An assumed average rate of travel of 55 mph for highway vehicles is used to calculate an average highway trip time of 2.67 hours. A 25 percent increase in travel time is assumed to occur during service interruptions. This time increase is an arbitrary number that was assigned in order to bracket the benefits of HSR.

9. According to Charles River Associates estimates in the *Draft California HSR Economic Impact* study, the value of business traveler time for highway travel equals $25.38 per hour and the value of non-business traveler time for highway travel equals $14.89 per hour.

10. The mean highway travel time is estimated to be 2.67 hours per trip. (See #8 for analysis.) Travel time acts as a proxy for the cost of a trip. The value of a trip must be greater than its cost. A highway trip value of 5.34 hours is selected as an arbitrary estimate, which is double the cost of an average highway trip. The value selected for highway trips is less than the value for air travel because air travelers pay more to use these services.

1 David T. Hartgen, Joanna M. Brunso, and Alfred J. Neveu, "Initial and Subsequent Consumer Response to Gasoline Shortages," *Special Report 203: Proceedings of the Conference on Energy Contingency Planning in Urban Areas,* Transportation Research Board, National Research Council, Washington, D.C., 1983, p. 38.

High-Speed Rail Contributions:
Reduction of Earthquake-Related Economic and Social Dislocation Costs

Month One	**Reduction of Disruption Costs due to HSR ($ millions/month)**
Minimum Disruption: Low HSR Contribution (1a)	$9
Minimum Disruption: High HSR Contribution (1b)	$19
Medium Disruption: Low HSR Contribution (2a)	$18
Medium Disruption: High HSR Contribution (2b)	$38
Maximum Disruption: Low HSR Contribution (3a)	$35
Maximum Disruption: High HSR Contribution (3b)	$76

Month Two	**Reduction of Disruption Costs due to HSR ($ millions/month)**
Minimum Disruption: Low HSR Contribution (1a)	$2
Minimum Disruption: High HSR Contribution (1b)	$3
Medium Disruption: Low HSR Contribution (2a)	$10
Medium Disruption: High HSR Contribution (2b)	$15
Maximum Disruption: Low HSR Contribution (3a)	$20
Maximum Disruption: High HSR Contribution (3b)	$29

Total Reductions	**Reduction of Disruption Costs due to HSR ($ millions)**
Minimum Disruption: Low HSR Contribution (1a)	$11
Minimum Disruption: High HSR Contribution (1b)	$22
Medium Disruption: Low HSR Contribution (2a)	$27
Medium Disruption: High HSR Contribution (2b)	$53
Maximum Disruption: Low HSR Contribution (3a)	$55
Maximum Disruption: High HSR Contribution (3b)	$105

	A	B	C	D	E
1	**High-Speed Rail Contributions:**				
2	**Reduction of Earthquake-Related Economic and Social Dislocation Costs**				
3					
4	An earthquake is assumed to cause a major highway to fail, and the closure is estimated to last for two months. This scenario attempts to replicate the				
5	1989 Loma Prieta earthquake in terms of its impacts on the transportation system, and the duration of the highway interruption.				
6					
7		**Minimum Disruption**			
8	***Month One:***	**Scenario 1a**		**Scenario 1b**	
9	***Minimum Disruption Scenarios (1a and 1b)***	No HSR	HSR	No HSR	HSR
10	Highway trips per month on key Bay links[1]	11,382,140	10,585,390	11,382,140	10,585,390
11	**Eliminated or diverted hwy trips** per month due to the earthquake (%)[2]	**5%**	**5%**	**5%**	**5%**
12	Eliminated or diverted hwy trips per month due to the earthquake (Rw10*Rw11)	569,107	529,270	569,107	529,270
13	*Business hwy trips* eliminated or diverted per month due to the earthquake[3] (Rw12*25%)	142,277	132,317	142,277	132,317
14	*Non-busi hwy trips* eliminated or diverted per month due to the earthquake[3] (Rw12*75%)	426,830	396,952	426,830	396,952
15	Vehicle occupancy for busi travelers per hwy trip (persons/hwy trip)[4]	1.90	1.90	1.90	1.90
16	Vehicle occupancy for non-busi travelers per hwy trip (persons/hwy trip)[4]	2.60	2.60	2.60	2.60
17	**Busi travelers** per month who eliminated or diverted hwy trips due to the earthquake (Rw13*Rw15)	**270,326**	**251,403**	**270,326**	**251,403**
18	**Non-busi travelers** per month who eliminated or diverted hwy trips due to the earthquake (Rw14*Rw16)	**1,109,759**	**1,032,076**	**1,109,759**	**1,032,076**
19	**Travelers per month diverted to HSR** (%)[5]	**0%**	**10%**	**0%**	**40%**
20	*Busi travelers* per month diverted to HSR (Rw17*Rw19)	0.00	25,140	0.00	100,561
21	*Non-busi travelers* per month diverted to HSR (Rw18*Rw19)	0.00	103,208	0.00	412,830
22	**Travelers per month diverted to other modes** such as carpools, buses and rail (%)[6]	**85%**	**80%**	**75%**	**45%**
23	*Busi travelers* per month diverted to other modes (Rw17*Rw22)	229,777	201,122	202,744	113,131
24	*Non-busi travelers* per month diverted to other modes (Rw18*Rw22)	943,295	825,660	832,319	464,434
25	**Travelers per month who eliminated hwy trips** (%)[7]	**15%**	**10%**	**25%**	**15%**
26	*Busi travelers* per month who eliminated hwy trips (Rw17*Rw25)	40,549	25,140	67,581	37,710
27	*Non-busi travelers* per month who eliminated hwy trips (Rw18*Rw25)	166,464	103,208	277,440	154,811

	A	B	C	D	E
28			Minimum Disruption		
29	***Month One:***	**Scenario 1a**		**Scenario 1b**	
30	***Minimum Disruption Scenarios (1a and 1b) (cont.)***	No HSR	HSR	No HSR	HSR
31	***Cost of Additional Travel Time***				
32	Additional travel time per traveler when using other modes such as buses, rail and carpools (hours/traveler)[8]	0.67	0.67	0.67	0.67
33	*Busi travelers* per month diverted to other modes (same as Rw23)	229,777	201,122	202,744	113,131
34	*Non-busi travelers* per month diverted to other modes (same as Rw24)	943,295	825,660	832,319	464,434
35	Additional travel time for busi travelers when using other modes (hours/month) (Rw32*Rw33)	153,951	134,752	135,839	75,798
36	Additional travel time for non-busi travelers when using other modes (hours/month) (Rw32*Rw34)	632,008	553,192	557,654	311,171
37	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
38	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
39	Additional costs to busi travelers for using other modes ($/month) (Rw35*Rw37)	$3,907,265	$3,420,006	$3,447,587	$1,923,753
40	Additional costs to non-busi travelers for using other modes ($/month) (Rw36*Rw38)	$9,410,592	$8,237,036	$8,303,464	$4,633,333
41	**Cost of additional travel time to travelers** for using other modes ($/month) (Rw39+Rw40)	**$13,317,858**	**$11,657,042**	**$11,751,051**	**$6,557,086**
43	***Cost of Eliminated Highway Trips***				
44	Value of a highway trip per traveler (hours/traveler)[10]	5.34	5.34	5.34	5.34
45	*Busi travelers* per month who eliminated hwy trips (same as Rw26)	40,549	25,140	67,581	37,710
46	*Non-busi travelers* per month who eliminated hwy trips (same as Rw27)	166,464	103,208	277,440	154,811
47	Value of eliminated busi hwy travel per month (hours/month) (Rw44*Rw45)	216,531	134,249	360,885	201,374
48	Value of eliminated non-busi hwy travel per month (hours/month) (Rw44*Rw46)	888,917	551,128	1,481,528	826,693
49	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
50	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
51	Cost of eliminated hwy trips to busi travelers ($/month) (Rw47*Rw49)	$5,495,556	$3,407,245	$9,159,261	$5,110,867
52	Cost of eliminated hwy trips to non-busi travelers ($/month) (Rw48*Rw50)	$13,235,969	$8,206,301	$22,059,949	$12,309,451
53	**Cost of eliminated highway trips** ($/month) (Rw51+Rw52)	**$18,731,526**	**$11,613,546**	**$31,219,210**	**$17,420,319**
55	***Summary of Service Interruption Costs***				
56	Cost of Additional Travel Time (same as Rw41)	$13,317,858	$11,657,042	$11,751,051	$6,557,086
57	Cost of Eliminated Highway Trips (same as Rw53)	$18,731,526	$11,613,546	$31,219,210	$17,420,319
58	Cost of additional travel time and eliminated hwy trips ($) (Rw56+Rw57)	$32,049,383	$23,270,588	$42,970,260	$23,977,405
59	Cost of additional travel time and eliminated hwy trips ($ millions/month)	**$32**	**$23**	**$43**	**$24**
60	**HSR versus no HSR Cost Difference** ($ millions/month) (B59-C59)		**$8.8**		**$19.0**

	A	B	C	D	E
61		**Medium Disruption**			
62	***Month One:***	**Scenario 2a**		**Scenario 2b**	
63	***Medium Disruption Scenarios (2a and 2b)***	No HSR	HSR	No HSR	HSR
64	Highway trips per month on key Bay links[1]	11,382,140	10,585,390	11,382,140	10,585,390
65	**Eliminated or diverted hwy trips** per month due to the earthquake (%)[2]	**10%**	**10%**	**10%**	**10%**
66	Eliminated or diverted hwy trips per month due to the earthquake (Rw64*Rw65)	1,138,214	1,058,539	1,138,214	1,058,539
67	*Business hwy trips* eliminated or diverted per month due to the earthquake[3] (Rw66*25%)	284,554	264,635	284,554	264,635
68	*Non-busi hwy trips* eliminated or diverted per month due to the earthquake[3] (Rw66*75%)	853,661	793,904	853,661	793,904
69	Vehicle occupancy for busi travelers per hwy trip (persons/hwy trip)[4]	1.90	1.90	1.90	1.90
70	Vehicle occupancy for non-busi travelers per hwy trip (persons/hwy trip)[4]	2.60	2.60	2.60	2.60
71	**Busi travelers** per month who eliminated or diverted hwy trips due to the earthquake (Rw67*Rw69)	**540,652**	**502,806**	**540,652**	**502,806**
72	**Non-busi travelers** per month who eliminated or diverted hwy trips due to the earthquake (Rw68*Rw70)	**2,219,517**	**2,064,151**	**2,219,517**	**2,064,151**
73	**Travelers per month diverted to HSR** (%)[5]	**0%**	**10%**	**0%**	**40%**
74	*Busi travelers* per month diverted to HSR (Rw71*Rw73)	0.00	50,281	0.00	201,122
75	*Non-busi travelers* per month diverted to HSR (Rw72*Rw73)	0.00	206,415	0.00	825,660
76	**Travelers per month diverted to other modes** such as carpools, buses and rail (%)[6]	**85%**	**80%**	**75%**	**45%**
77	*Busi travelers* per month diverted to other modes (Rw71*Rw76)	459,554	402,245	405,489	226,263
78	*Non-busi travelers* per month diverted to other modes (Rw72*Rw76)	1,886,590	1,651,321	1,664,638	928,868
79	**Travelers per month who eliminated highway trips** (%)[7]	**15%**	**10%**	**25%**	**15%**
80	*Busi travelers* per month who eliminated hwy trips (Rw71*Rw79)	81,098	50,281	135,163	75,421
81	*Non-busi travelers* per month who eliminated hwy trips (Rw72*Rw79)	332,928	206,415	554,879	309,623

	A	B	C	D	E
82		**Medium Disruption**			
83	***Month One:***	**Scenario 2a**		**Scenario 2b**	
84	***Medium Disruption Scenarios (2a and 2b) (cont.)***	No HSR	HSR	No HSR	HSR
85	***Cost of Additional Travel Time***				
86	Additional travel time per traveler when using other modes such as buses, rail and carpools (hours/traveler)[8]	0.67	0.67	0.67	0.67
87	*Busi travelers* per month diverted to other modes (same as Rw77)	459,554	402,245	405,489	226,263
88	*Non-busi travelers* per month diverted to other modes (same as Rw78)	1,886,590	1,651,321	1,664,638	928,868
89	Additional travel time for busi travelers when using other modes (hours/month) (Rw86*Rw87)	307,901	269,504	271,677	151,596
90	Additional travel time for non-busi travelers when using other modes (hours/month) (Rw86*Rw88)	1,264,015	1,106,385	1,115,307	622,342
91	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
92	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
93	Additional costs to busi travelers for using other modes ($/month)(Rw89*Rw91)	$7,814,530	$6,840,012	$6,895,174	$3,847,507
94	Additional costs to non-busi travelers for using other modes ($/month) (Rw90*Rw92)	$18,821,185	$16,474,072	$16,606,928	$9,266,666
95	**Cost of additional travel time to travelers** for using other modes ($/month) (Rw93+Rw94)	**$26,635,715**	**$23,314,085**	**$23,502,102**	**$13,114,173**
97	***Cost of Eliminated Highway Trips***				
98	Value of a highway trip per traveler (hours/traveler)[10]	5.34	5.34	5.34	5.34
99	*Busi travelers* per month who eliminated hwy trips (same as Rw80)	81,098	50,281	135,163	75,421
100	*Non-busi travelers* per month who eliminated hwy trips (same as Rw81)	332,928	206,415	554,879	309,623
101	Value of eliminated busi hwy travel per month (hours/month) (Rw98*Rw99)	433,062	268,498	721,770	402,748
102	Value of eliminated non-busi hwy travel per month (hours/month) (Rw98*Rw100)	1,777,833	1,102,257	2,963,056	1,653,385
103	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
104	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
105	Cost of eliminated hwy trips to busi travelers ($/month) (Rw101*Rw103)	$10,991,113	$6,814,490	$18,318,521	$10,221,735
106	Cost of eliminated hwy trips to non-busi travelers ($/month) (Rw102*Rw104)	$26,471,939	$16,412,602	$44,119,898	$24,618,903
107	**Cost of eliminated highway trips** ($/month) (Rw105+Rw106)	**$37,463,052**	**$23,227,092**	**$62,438,419**	**$34,840,638**
109	***Summary of Service Interruption Costs***				
110	Cost of Additional Travel Time (same as Rw95)	$26,635,715	$23,314,085	$23,502,102	$13,114,173
111	Cost of Eliminated Highway Trips (same as Rw107)	$37,463,052	$23,227,092	$62,438,419	$34,840,638
112	Cost of additional travel time and eliminated hwy trips ($) (Rw110+Rw111)	$64,098,767	$46,541,177	$85,940,521	$47,954,811
113	Cost of additional travel time and eliminated hwy trips ($ millions/month)	**$64**	**$47**	**$86**	**$48**
114	**HSR versus no HSR Cost Difference** ($ millions/month) (B113-C113)		**$18**		**$38**

	A	B	C	D	E
115		**Maximum Disruption**			
116	***Month One:***	**Scenario 3a**		**Scenario 3b**	
117	***Maximum Disruption Scenarios (3a and 3b)***	No HSR	HSR	No HSR	HSR
118	Highway trips per month on key Bay links[1]	11,382,140	10,585,390	11,382,140	10,585,390
119	**Eliminated or diverted hwy trips** per month due to the earthquake (%)[2]	**20%**	**20%**	**20%**	**20%**
120	Eliminated or diverted hwy trips per month due to the earthquake (Rw118* Rw119)	2,276,428	2,117,078	2,276,428	2,117,078
121	*Business hwy trips* eliminated or diverted per month due to the earthquake[3] (Rw120*25%)	569,107	529,270	569,107	529,270
122	*Non-busi hwy trips* eliminated or diverted per month due to the earthquake[3] (Rw120*75%)	1,707,321	1,587,809	1,707,321	1,587,809
123	Vehicle occupancy for busi travelers per hwy trip (persons/hwy trip)[4]	1.90	1.90	1.90	1.90
124	Vehicle occupancy for non-busi travelers per hwy trip (persons/hwy trip)[4]	2.60	2.60	2.60	2.60
125	**Busi travelers** per month who eliminated or diverted hwy trips due to the earthquake (Rw121*Rw123)	**1,081,303**	**1,005,612**	**1,081,303**	**1,005,612**
126	**Non-busi travelers** per month who eliminated or diverted hwy trips due to the earthquake (Rw122*Rw124)	**4,439,035**	**4,128,302**	**4,439,035**	**4,128,302**
127	**Travelers per month diverted to HSR** (%)[5]	**0%**	**10%**	**0%**	**40%**
128	*Busi travelers* per month diverted to HSR (Rw125*Rw127)	0.00	100,561	0.00	402,245
129	*Non-busi travelers* per month diverted to HSR (Rw126*Rw127)	0.00	412,830	0.00	1,651,321
130	**Travelers per month diverted to other modes** such as carpools, buses and rail (%)[6]	**85%**	**80%**	**75%**	**45%**
131	*Busi travelers* per month diverted to other modes (Rw125*Rw130)	919,108	804,490	810,977	452,525
132	*Non-busi travelers* per month diverted to other modes (Rw126*Rw130)	3,773,179	3,302,642	3,329,276	1,857,736
133	**Travelers per month who eliminated hwy trips** (%)[7]	**15%**	**10%**	**25%**	**15%**
134	*Busi travelers* per month who eliminated hwy trips (Rw125*Rw133)	162,195	100,561	270,326	150,842
135	*Non-busi travelers* per month who eliminated hwy trips (Rw126*Rw133)	665,855	412,830	1,109,759	619,245

	A	B	C	D	E
136		**Maximum Disruption**			
137	***Month One:***	**Scenario 3a**		**Scenario 3b**	
138	***Maximum Disruption Scenarios (3a and 3b) (cont.)***	No HSR	HSR	No HSR	HSR
139	***Cost of Additional Travel Time***				
140	Additional travel time per traveler when using other modes such as buses, rail and carpools (hours/traveler)[8]	0.67	0.67	0.67	0.67
141	*Busi travelers* per month diverted to other modes (same as Rw131)	919,108	804,490	810,977	452,525
142	*Non-busi travelers* per month diverted to other modes (same as Rw132)	3,773,179	3,302,642	3,329,276	1,857,736
143	Additional travel time for busi travelers when using other modes (hours/month) (Rw140*Rw141)	615,802	539,008	543,355	303,192
144	Additional travel time for non-busi travelers when using other modes (hours/month) (Rw140*Rw142)	2,528,030	2,212,770	2,230,615	1,244,683
145	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
146	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
147	Additional costs to busi travelers for using other modes ($/month) (Rw143*Rw145)	$15,629,061	$13,680,025	$13,790,348	$7,695,014
148	Additional costs to non-busi travelers for using other modes ($/month) (Rw144*Rw146)	$37,642,370	$32,948,145	$33,213,856	$18,533,331
149	**Cost of additional travel time to travelers** for using other modes ($/month) (Rw147+Rw148)	**$53,271,430**	**$46,628,170**	**$47,004,203**	**$26,228,345**
150					
151	***Cost of Eliminated Highway Trips***				
152	Value of a highway trip per traveler (hours/traveler)[10]	5.34	5.34	5.34	5.34
153	*Busi travelers* per month who eliminated hwy trips (same as Rw134)	162,195	100,561	270,326	150,842
154	*Non-busi travelers* per month who eliminated hwy trips (same as Rw135)	665,855	412,830	1,109,759	619,245
155	Value of eliminated busi hwy travel per month (hours/month) (Rw152*Rw153)	866,124	536,997	1,443,540	805,495
156	Value of eliminated non-busi hwy travel per month (hours/month) (Rw152*Rw154)	3,555,667	2,204,513	5,926,111	3,306,770
157	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
158	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
159	Cost of eliminated hwy trips to busi travelers ($/month) (Rw155*Rw157)	$21,982,226	$13,628,980	$36,637,043	$20,443,470
160	Cost of eliminated hwy trips to non-busi travelers ($/month) (Rw156*Rw158)	$52,943,877	$32,825,204	$88,239,796	$49,237,806
161	**Cost of eliminated highway trips** ($/month) (Rw159+Rw160)	**$74,926,103**	**$46,454,184**	**$124,876,838**	**$69,681,276**
163	***Summary of Service Interruption Costs***				
164	Cost of Additional Travel Time (same as Rw149)	53,271,430	46,628,170	47,004,203	26,228,345
165	Cost of Eliminated Highway Trips (same as Rw161)	$74,926,103	$46,454,184	$124,876,838	$69,681,276
166	Cost of additional travel time and eliminated hwy trips ($) (Rw164+Rw165)	$128,197,533	$93,082,354	$171,881,042	$95,909,621
167	Cost of additional travel time and eliminated hwy trips ($ millions/month)	**$128**	**$93**	**$172**	**$96**
168	**HSR versus no HSR Cost Difference** ($ millions/month) (B167-C167)		**$35**		**$76**

	A	B	C	D	E
169			**Minimum Disruption**		
170	***Month Two:***	**Scenario 1a**		**Scenario 1b**	
171	***Minimum Disruption Scenarios (1a and 1b)***	No HSR	HSR	No HSR	HSR
172	Highway trips per month on key Bay links[1]	11,382,140	10,585,390	11,382,140	10,585,390
173	**Eliminated or diverted hwy trips** per month due to the earthquake (%)[2]	**1%**	**1%**	**1%**	**1%**
174	Eliminated or diverted hwy trips per month due to the earthquake (Rw172* Rw173)	113,821	105,854	113,821	105,854
175	*Business hwy trips* eliminated or diverted per month due to the earthquake[3] (Rw174*25%)	28,455	26,463	28,455	26,463
176	*Non-busi hwy trips* eliminated or diverted per month due to the earthquake[3] (Rw174*75%)	85,366	79,390	85,366	79,390
177	Vehicle occupancy for busi travelers per hwy trip (persons/hwy trip)[4]	1.90	1.90	1.90	1.90
178	Vehicle occupancy for non-busi travelers per hwy trip (persons/hwy trip)[4]	2.60	2.60	2.60	2.60
179	**Busi travelers** per month who eliminated or diverted hwy trips due to the earthquake (Rw175*Rw177)	**54,065**	**50,281**	**54,065**	**50,281**
180	**Non-busi travelers** per month who eliminated or diverted hwy trips due to the earthquake (Rw176*Rw178)	**221,952**	**206,415**	**221,952**	**206,415**
181	**Travelers per month diverted to HSR** (%)[5]	**0%**	**20%**	**0%**	**50%**
182	*Busi travelers* per month diverted to HSR (Rw179*Rw181)	0.00	10,056	0.00	25,140
183	*Non-busi travelers* per month diverted to HSR (Rw180*Rw181)	0.00	41,283	0.00	103,208
184	**Travelers per month diverted to other modes** such as carpools, buses and rail (%)[6]	**90%**	**75%**	**85%**	**40%**
185	*Busi travelers* per month diverted to other modes (Rw179*Rw184)	48,659	37,710	45,955	20,112
186	*Non-busi travelers* per month diverted to other modes (Rw180*Rw184)	199,757	154,811	188,659	82,566
187	**Travelers per month who eliminated highway trips** (%)[7]	**10%**	**5%**	**15%**	**10%**
188	*Busi travelers* per month who eliminated hwy trips (Rw179*Rw187)	5,407	2,514	8,110	5,028
189	*Non-busi travelers* per month who eliminated hwy trips (Rw180*Rw187)	22,195	10,321	33,293	20,642

	A	B	C	D	E
190		Minimum Disruption			
191	***Month Two:***	**Scenario 1a**		**Scenario 1b**	
192	***Minimum Disruption Scenarios (1a and 1b) (cont.)***	No HSR	HSR	No HSR	HSR
193	***Cost of Additional Travel Time***				
194	Additional travel time per traveler when using other modes such as buses, rail and carpools (hours/traveler)[8]	0.67	0.67	0.67	0.67
195	*Busi travelers* per month diverted to other modes (same as Rw185)	48,659	37,710	45,955	20,112
196	*Non-busi travelers* per month diverted to other modes (same as Rw186)	199,757	154,811	188,659	82,566
197	Additional travel time for busi travelers when using other modes (hours/month) (Rw194*Rw195)	32,601	25,266	30,790	13,475
198	Additional travel time for non-busi travelers when using other modes (hours/month) (Rw194*Rw196)	133,837	103,724	126,402	55,319
199	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
200	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
201	Additional costs to busi travelers for using other modes ($/month) (Rw197*Rw199)	$827,421	$641,251	$781,453	$342,001
202	Additional costs to non-busi travelers for using other modes ($/month) (Rw198*Rw200)	$1,992,831	$1,544,444	$1,882,118	$823,704
203	**Cost of additional travel time to travelers** for using other modes ($/month) (Rw201+Rw202)	**$2,820,252**	**$2,185,695**	**$2,663,572**	**$1,165,704**
204					
205	***Cost of Eliminated Highway Trips***				
206	Value of a highway trip per traveler (hours/traveler)[10]	5.34	5.34	5.34	5.34
207	Busi travelers per month who eliminated hwy trips (same as Rw188)	5,407	2,514	8,110	5,028
208	Non-busi travelers per month who eliminated hwy trips (same as Rw189)	22,195	10,321	33,293	20,642
209	Value of eliminated busi hwy travel per month (hours/month) (Rw206*Rw207)	28,871	13,425	43,306	26,850
210	Value of eliminated non-busi hwy travel per month (hours/month) (Rw206*Rw208)	118,522	55,113	177,783	110,226
211	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
212	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
213	Cost of eliminated hwy trips to busi travelers ($/month) (Rw209*Rw211)	$732,741	$340,724	$1,099,111	$681,449
214	Cost of eliminated hwy trips to non-busi travelers ($/month) (Rw210*Rw212)	$1,764,796	$820,630	$2,647,194	$1,641,260
215	**Cost of eliminated highway trips** ($/month) (Rw213+Rw214)	**$2,497,537**	**$1,161,355**	**$3,746,305**	**$2,322,709**
216					
217	***Summary of Service Interruption Costs***				
218	Cost of Additional Travel Time (same as Rw203)	$2,820,252	$2,185,695	$2,663,572	$1,165,704
219	Cost of Eliminated Highway Trips (same as Rw215)	$2,497,537	$1,161,355	$3,746,305	$2,322,709
220	Cost of additional travel time and eliminated hwy trips ($) (Rw218+Rw219)	$5,317,789	$3,347,050	$6,409,877	$3,488,413
221	Cost of additional travel time and eliminated hwy trips ($ millions/month)	**$5**	**$3**	**$6**	**$3**
222	**HSR versus no HSR Cost Difference** ($ millions/month) (B221-C221)		**$2.0**		**$2.9**

	A	B	C	D	E
223		Medium Disruption			
224	***Month Two:***	**Scenario 2a**		**Scenario 2b**	
225	***Medium Disruption Scenarios (2a and 2b)***	No HSR	HSR	No HSR	HSR
226	CA Corridor highway trips per month[1]	11,382,140	10,585,390	11,382,140	10,585,390
227	**Eliminated or diverted hwy trips** per month due to the earthquake (%)[2]	**5%**	**5%**	**5%**	**5%**
228	Eliminated or diverted hwy trips per month due to the earthquake (Rw226* Rw227)	569,107	529,270	569,107	529,270
229	*Business hwy trips* eliminated or diverted per month due to the earthquake[3] (Rw228*25%)	142,277	132,317	142,277	132,317
230	*Non-busi hwy trips* eliminated or diverted per month due to the earthquake[3] (Rw228*75%)	426,830	396,952	426,830	396,952
231	Vehicle occupancy for busi travelers per hwy trip (persons/hwy trip)[4]	1.90	1.90	1.90	1.90
232	Vehicle occupancy for non-busi travelers per hwy trip (persons/hwy trip)[4]	2.60	2.60	2.60	2.60
233	**Busi travelers** per month who eliminated or diverted hwy trips due to the earthquake (Rw229*Rw231)	**270,326**	**251,403**	**270,326**	**251,403**
234	**Non-busi travelers** per month who eliminated or diverted hwy trips due to the earthquake (Rw230*Rw232)	**1,109,759**	**1,032,076**	**1,109,759**	**1,032,076**
235	**Travelers per month diverted to HSR** (%)[5]	**0%**	**20%**	**0%**	**50%**
236	*Busi travelers* per month diverted to HSR (Rw233*Rw235)	0.00	50,281	0.00	125,702
237	*Non-busi travelers* per month diverted to HSR (Rw234*Rw235)	0.00	206,415	0.00	516,038
238	**Travelers per month diverted to other modes** such as carpools, buses and rail (%)[6]	**90%**	**75%**	**85%**	**40%**
239	*Busi travelers* per month diverted to other modes (Rw233*Rw238)	243,293	188,552	229,777	100,561
240	*Non-busi travelers* per month diverted to other modes (Rw234*Rw238)	998,783	774,057	943,295	412,830
241	**Travelers per month who eliminated highway trips** (%)[7]	**10%**	**5%**	**15%**	**10%**
242	*Busi travelers* per month who eliminated hwy trips (Rw233*Rw241)	27,033	12,570	40,549	25,140
243	*Non-busi travelers* per month who eliminated hwy trips (Rw234*Rw241)	110,976	51,604	166,464	103,208

	A	B	C	D	E
244		Medium Disruption			
245	***Month Two:***	**Scenario 2a**		**Scenario 2b**	
246	***Medium Disruption Scenarios (2a and 2b) (cont.)***	No HSR	HSR	No HSR	HSR
247	***Cost of Additional Travel Time***				
248	Additional travel time per traveler when using other modes such as buses, rail and carpools (hours/traveler)[8]	0.67	0.67	0.67	0.67
249	*Busi travelers* per month diverted to other modes (same as Rw239)	243,293	188,552	229,777	100,561
250	*Non-busi travelers* per month diverted to other modes (same as Rw240)	998,783	774,057	943,295	412,830
251	Additional travel time for busi travelers when using other modes (hours/month) (Rw248*Rw249)	163,006	126,330	153,951	67,376
252	Additional travel time for non-busi travelers when using other modes (hours/month) (Rw248*Rw250)	669,184	518,618	632,008	276,596
253	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
254	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
255	Additional costs to busi travelers for using other modes ($/month) (Rw251*Rw253)	$4,137,104	$3,206,256	$3,907,265	$1,710,003
256	Additional costs to non-busi travelers for using other modes ($/month) (Rw252*Rw254)	$9,964,157	$7,722,221	$9,410,592	$4,118,518
257	**Cost of additional travel time to travelers** for using other modes ($/month) (Rw255+Rw256)	**$14,101,261**	**$10,928,477**	**$13,317,858**	**$5,828,521**
258					
259	***Cost of Eliminated Highway Trips***				
260	Value of a highway trip per traveler (hours/traveler)[10]	5.34	5.34	5.34	5.34
261	*Busi travelers* per month who eliminated hwy trips (same as Rw242)	27,033	12,570	40,549	25,140
262	*Non-busi travelers* per month who eliminated hwy trips (same as Rw243)	110,976	51,604	166,464	103,208
263	Value of eliminated busi hwy travel per month (hours/month) (Rw260*Rw261)	144,354	67,125	216,531	134,249
264	Value of eliminated non-busi hwy travel per month (hours/month) (Rw260*Rw262)	592,611	275,564	888,917	551,128
265	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
266	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
267	Cost of eliminated hwy trips to busi travelers ($/month) (Rw263*Rw265)	$3,663,704	$1,703,622	$5,495,556	$3,407,245
268	Cost of eliminated hwy trips to non-busi travelers ($/month) (Rw264*Rw266)	$8,823,980	$4,103,150	$13,235,969	$8,206,301
269	**Cost of eliminated hwy trips** ($/month) (Rw267+Rw268)	**$12,487,684**	**$5,806,773**	**$18,731,526**	**$11,613,546**
270					
271	***Summary of Service Interruption Costs***				
272	Cost of Additional Travel Time (same as Rw257)	$14,101,261	$10,928,477	$13,317,858	$5,828,521
273	Cost of Eliminated Highway Trips (same as Rw269)	$12,487,684	$5,806,773	$18,731,526	$11,613,546
274	Cost of additional travel time and eliminated hwy trips ($) (Rw272+Rw273)	$26,588,945	$16,735,250	$32,049,383	$17,442,067
275	Cost of additional travel time and eliminated hwy trips ($ millions/month)	**$27**	**$17**	**$32**	**$17**
276	**HSR versus no HSR Cost Difference** ($ millions/month) (B275-C275)		**$10**		**$15**

	A	B	C	D	E
277			Maximum Disruption		
278	***Month Two:***	**Scenario 3a**		**Scenario 3b**	
279	***Maximum Disruption Scenarios (3a and 3b)***	No HSR	HSR	No HSR	HSR
280	CA Corridor highway trips per month[1]	11,382,140	10,585,390	11,382,140	10,585,390
281	**Eliminated or diverted hwy trips** per month due to the earthquake (%)[2]	**10%**	**10%**	**10%**	**10%**
282	Eliminated or diverted hwy trips per month due to the earthquake (Rw280* Rw281)	1,138,214	1,058,539	1,138,214	1,058,539
283	*Business hwy trips* eliminated or diverted per month due to the earthquake[3] (Rw282*25%)	284,554	264,635	284,554	264,635
284	*Non-busi hwy trips* eliminated or diverted per month due to the earthquake[3] (Rw282*75%)	853,661	793,904	853,661	793,904
285	Vehicle occupancy for busi travelers per hwy trip (persons/hwy trip)[4]	1.90	1.90	1.90	1.90
286	Vehicle occupancy for non-busi travelers per hwy trip (persons/hwy trip)[4]	2.60	2.60	2.60	2.60
287	**Busi travelers** per month who eliminated or diverted hwy trips due to the earthquake (Rw283*Rw285)	**540,652**	**502,806**	**540,652**	**502,806**
288	**Non-busi travelers** per month who eliminated or diverted hwy trips due to the earthquake (Rw284*Rw286)	**2,219,517**	**2,064,151**	**2,219,517**	**2,064,151**
289	**Travelers per month diverted to HSR** (%)[5]	**0%**	**20%**	**0%**	**50%**
290	*Busi travelers* per month diverted to HSR (Rw287*Rw289)	0.00	100,561	0.00	251,403
291	*Non-busi travelers* per month diverted to HSR (Rw288*Rw289)	0.00	412,830	0.00	1,032,076
292	**Travelers per month diverted to other modes** such as carpools, buses and rail (%)[6]	**90%**	**75%**	**85%**	**40%**
293	*Busi travelers* per month diverted to other modes (Rw287*Rw292)	486,586	377,105	459,554	201,122
294	*Non-busi travelers* per month diverted to other modes (Rw288*Rw292)	1,997,566	1,548,113	1,886,590	825,660
295	**Travelers per month who eliminated hwy trips** (%)[7]	**10%**	**5%**	**15%**	**10%**
296	*Busi travelers* per month who eliminated hwy trips (Rw287*Rw295)	54,065	25,140	81,098	50,281
297	*Non-busi travelers* per month who eliminated hwy trips (Rw288*Rw295)	221,952	103,208	332,928	206,415

	A	B	C	D	E
298		Maximum Disruption			
299	***Month Two:***	**Scenario 3a**		**Scenario 3b**	
300	***Maximum Disruption Scenarios (3a and 3b) (cont.)***	No HSR	HSR	No HSR	HSR
301	***Cost of Additional Travel Time***				
302	Additional travel time per traveler when using other modes such as buses, rail and carpools (hours/traveler)[8]	0.67	0.67	0.67	0.67
303	*Busi travelers* per month diverted to other modes (same as Rw293)	486,586	377,105	459,554	201,122
304	*Non-busi travelers* per month diverted to other modes (same as Rw294)	1,997,566	1,548,113	1,886,590	825,660
305	Additional travel time for busi travelers when using other modes (hours/month) (Rw302*Rw303)	326,013	252,660	307,901	134,752
306	Additional travel time for non-busi travelers when using other modes (hours/month) (Rw302*Rw304)	1,338,369	1,037,236	1,264,015	553,192
307	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
308	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
309	Additional costs to busi travelers for using other modes ($/month) (Rw305*Rw307)	$8,274,209	$6,412,512	$7,814,530	$3,420,006
310	Additional costs to non-busi travelers for using other modes ($/month) (Rw306*Rw308)	$19,928,313	$15,444,443	$18,821,185	$8,237,036
311	**Cost of additional travel time to travelers** for using other modes ($/month) (Rw309+Rw310)	**$28,202,522**	**$21,856,955**	**$26,635,715**	**$11,657,042**
312					
313	***Cost of Eliminated Highway Trips***				
314	Value of a highway trip per traveler (hours/traveler)[10]	5.34	5.34	5.34	5.34
315	Busi travelers per month who eliminated hwy trips (same as Rw296)	54,065	25,140	81,098	50,281
316	Non-busi travelers per month who eliminated hwy trips (same as Rw297)	221,952	103,208	332,928	206,415
317	Value of eliminated busi hwy travel per month (hours/month) (Rw314*Rw315)	288,708	134,249	433,062	268,498
318	Value of eliminated non-busi hwy travel per month (hours/month) (Rw314*Rw316)	1,185,222	551,128	1,777,833	1,102,257
319	Value of busi traveler time per hour for highway travel ($/hr)[9]	$25.38	$25.38	$25.38	$25.38
320	Value of non-busi traveler time per hour for highway travel ($/hr)[9]	$14.89	$14.89	$14.89	$14.89
321	Cost of eliminated hwy trips to busi travelers ($/month) (Rw317*Rw319)	$7,327,409	$3,407,245	$10,991,113	$6,814,490
322	Cost of eliminated hwy trips to non-busi travelers ($/month) (Rw318*Rw320)	$17,647,959	$8,206,301	$26,471,939	$16,412,602
323	**Cost of eliminated highway trips** ($/month) (Rw321+Rw322)	**$24,975,368**	**$11,613,546**	**$37,463,052**	**$23,227,092**
324					
325	***Summary of Service Interruption Costs***				
326	Cost of Additional Travel Time (same as Rw311)	$28,202,522	$21,856,955	$26,635,715	$11,657,042
327	Cost of Eliminated Highway Trips (same as Rw323)	$24,975,368	$11,613,546	$37,463,052	$23,227,092
328	Cost of additional travel time and eliminated hwy trips ($) (Rw326+Rw327)	$53,177,890	$33,470,500	$64,098,767	$34,884,134
329	Cost of additional travel time and eliminated hwy trips ($ millions/month)	**$53**	**$33**	**$64**	**$35**
330	**HSR versus no HSR Cost Difference** ($ millions/month) (B329-C329)		**$20**		**$29**

Earthquake Assumptions

1. According to the *Post-Earthquake Commute Summary-Daily Trips* by the California Department of Transportation, travelers during normal conditions used 517,370 highway vehicles per weekday on five bridges that link the San Francisco Bay. When considering the number of highway vehicles per month on weekdays, the figure totals 11.4 million highway vehicles per month. Since the Loma Prieta earthquake occurred in an urban setting, intercity highway trips are not as affected meaning that HSR would not play a major role in diverting highway trips after the earthquake.

   For the "HSR" analyses, the *Draft California HSR Economic Impact* study states that HSR would divert approximately seven percent of highway trips during normal conditions. Thus, if HSR existed, about 10.6 million highway vehicles per month would use the bridges that link the Bay.

2. According to *Competing Against Time* by George W. Housner, the percentage of eliminated or diverted highway trips after the Loma Prieta earthquake totaled 12.5 percent. The maximum mobility disruption is expected to occur during the first month when travelers are learning about other traveling options. For the first month, the percentage of eliminated or diverted highway trips is assumed to range from five percent to 20 percent. For the second month, the percentage of eliminated or diverted highway trips is assumed to range from one percent to 10 percent.

3. According to the *Draft California HSR Economic Impact* study, 25 percent of the highway trips are business trips and 75 percent are non-business trips.

4. According to the *Draft California HSR Economic Impact* study, vehicle occupancy rates total 1.9 persons per vehicle for intercity highway business trips and 2.6 persons per vehicle for intercity highway non-business trips.

5. Highway trips that are diverted to high-speed rail generate no extra costs because these travelers view the service as comparable to private autos, and as an optimal choice when comparing it to carpools and conventional rail. Even though the HSR service is considered to be optimal in some cases, this analysis does not give credit for its time savings when present. The percentage of diverted trips to HSR is assumed to vary between 10 percent and 40 percent for the first month and between 20 percent and 50 percent for the second month. The HSR service is assumed to be more responsive to service disruptions in the analyses labeled "B" than in the analyses labeled "A." Implicit in this analysis is that short and long trips are diverted to high-speed rail at the same rate.

6. The term "other modes" considers buses, conventional rail and carpools. "Other modes" are assumed to be more responsive to service disruptions in the analyses labeled "A" than in the analyses labeled "B." For the "HSR" analyses, the percentage of diverted trips to "other modes" is assumed to vary between 45 percent and 80 percent for the first month and between 40 percent and 75 percent for the second month. For the "No HSR" analyses, the percentage of diverted trips to "other modes" is assumed to vary between 75 percent and 85 percent for the first month and between 85 percent and 90 percent for the second month. Implicit in this analysis is that short and long trips are diverted to "other modes" at the same rate.

7. Fewer travelers are expected to eliminate a trip when a HSR service exists and during the second month of an earthquake-related disruption. For the "HSR" analyses, the percentage of eliminated trips is assumed to vary between 10 percent and 15 percent for the first month and between five percent and 10 percent for the second month. For the "No HSR" analyses, the percentage of eliminated trips is assumed to vary between 15 percent and 25 percent for the first month and between 10 percent and 15 percent for the second month. Implicit in this analysis is that short and long trips are eliminated at the same rate.

8. The mean highway trip time is assumed to be 3.34 hours per trip during service interruptions and 2.67 hours per trip during regular conditions (i.e., periods without service interruptions). Thus, the additional cost of traveling by highway during service interruptions equals .67 hours per trip, the difference between the two travel times. The additional cost of traveling via conventional rail is expected to be even higher, so .67 hours represents a conservative estimate. The trip time estimates are derived from a weighted average of highway trip distance along the corridor, which totals 147 miles. An assumed average rate of travel of 55 mph for highway vehicles is used to calculate an average highway trip time of 2.67 hours. A 25 percent increase in travel time is assumed to occur during service interruptions. This time increase is an arbitrary number that was assigned in order to bracket the benefits of HSR.

9. According to Charles River Associates estimates in the *Draft California HSR Economic Impact* study, the value of business traveler time for highway travel equals $25.38 per hour and the value of non-business traveler time for highway travel equals $14.89 per hour.

10. The mean highway travel time is estimated to be 2.67 hours per trip. (See #8 for analysis.) Travel time acts as a proxy for the cost of a trip. The value of a trip must be greater than its cost. A highway trip value of 5.34 hours is selected as an arbitrary estimate, which is double the cost of an average highway trip. The value selected for highway trips is less than the value for air travel because air travelers pay more to use these services.

High-Speed Rail Contributions:
Reduction of Strike-Related Economic and Social Dislocation Costs

Month One	**Reduction of Disruption Costs due to HSR ($ millions/month)**
Minimum Disruption: Low HSR Contribution (1a)	$14
Minimum Disruption: High HSR Contribution (1b)	$19
Medium Disruption: Low HSR Contribution (2a)	$56
Medium Disruption: High HSR Contribution (2b)	$78
Maximum Disruption: Low HSR Contribution (3a)	$105
Maximum Disruption: High HSR Contribution (3b)	$146

	A	B	C	D	E
1	**High-Speed Rail Contributions:**				
2	**Reduction of Strike-Related Economic and Social Dislocation Costs**				
3					
4	A labor strike causes air travelers to reduce trips for *one month* , which is an average duration for strikes related to air travel when compared				
5	to the 1981 air traffic controllers strike (two months) and the 1995 strikes in France (three weeks).				
6					
7		**Minimum Disruption**			
8	***Month One:***	**Scenario 1a**		**Scenario 1b**	
9	***Minimum Disruption Scenarios (1a and 1b)***	No HSR	HSR	No HSR	HSR
10	CA Corridor air travel per month[1]	1,821,609	1,456,609	1,821,609	1,456,609
11	**Eliminated or diverted air travel** per month due to strikes (%)[2]	**10%**	**10%**	**10%**	**10%**
12	Eliminated or diverted air travel per month due to strikes (Rw10*Rw11)	182,161	145,661	182,161	145,661
13	**Busi travelers** per month who eliminated or diverted air travel due to strikes (Rw12*50%)[3]	**91,080**	**72,830**	**91,080**	**72,830**
14	**Non-busi travelers** per month who eliminated or diverted air travel due to strikes (Rw12*50%)[3]	**91,080**	**72,830**	**91,080**	**72,830**
15	**Travelers per month diverted to HSR** (%)[4]	**0%**	**25%**	**0%**	**50%**
16	*Busi travelers* per month diverted to HSR (Rw13*Rw15)	0	18,208	0	36,415
17	*Non-busi travelers* per month diverted to HSR (Rw14*Rw15)	0	18,208	0	36,415
18	**Travelers per month diverted to other modes** such as autos, buses and rail (%)[5]	**85%**	**65%**	**75%**	**45%**
19	*Busi travelers* per month diverted to other modes (Rw13*Rw18)	77,418	47,340	68,310	32,774
20	*Non-busi travelers* per month diverted to other modes (Rw14*Rw18)	77,418	47,340	68,310	32,774
21	**Travelers per month who eliminated air travel** (%)[6]	**15%**	**10%**	**25%**	**5%**
22	*Busi travelers* per month who eliminated air travel (Rw13*Rw21)	13,662	7,283	22,770	3,642
23	*Non-busi travelers* per month who eliminated air travel (Rw14*Rw21)	13,662	7,283	22,770	3,642

	A	B	C	D	E
24		Minimum Disruption			
25	***Month One:***	**Scenario 1a**		**Scenario 1b**	
26	***Minimum Disruption Scenarios (1a and 1b) (cont.)***	No HSR	HSR	No HSR	HSR
27	***Cost of Additional Travel Time***				
28	Additional travel time per air traveler when using other modes such as buses, rail and autos (hours/traveler)[7]	5.35	5.35	5.35	5.35
29	*Busi travelers* per month diverted to other modes (same as Rw19)	77,418	47,340	68,310	32,774
30	*Non-busi travelers* per month diverted to other modes (same as Rw20)	77,418	47,340	68,310	32,774
31	Additional travel time for busi travelers when using other modes (hours/month) (Rw28*Rw29)	414,188	253,268	365,460	175,339
32	Additional travel time for non-busi travelers when using other modes (hours/month) (Rw28*Rw30)	414,188	253,268	365,460	175,339
33	Value of busi traveler time per hour for air travel ($/hr)[8]	$42.42	$42.42	$42.42	$42.42
34	Value of non-busi traveler time per hour for air travel ($/hr)[8]	$30.84	$30.84	$30.84	$30.84
35	Additional costs to busi travelers for using other modes ($/month) (Rw31*Rw33)	$17,569,870	$10,743,624	$15,502,826	$7,437,893
36	Additional costs to non-busi travelers for using other modes ($/month) (Rw32*Rw34)	$12,773,569	$7,810,782	$11,270,796	$5,407,464
37	**Cost of additional travel time to travelers** for using other modes ($/month) (Rw35+Rw36)	**$30,343,438**	**$18,554,406**	**$26,773,622**	**$12,845,358**
38					
39	***Cost of Eliminated Air Travel***				
40	Value of an airplane trip per traveler (hours/traveler)[9]	3.75	3.75	3.75	3.75
41	Busi travelers per month who eliminated air travel (same as Rw22)[6]	13,662	7,283	22,770	3,642
42	Non-busi travelers per month who eliminated air travel (same as Rw23)[6]	13,662	7,283	22,770	3,642
43	Value of eliminated busi air travel per month (hours/month) (Rw40*Rw41)	51,233	27,311	85,388	13,656
44	Value of eliminated non-busi air travel per month (hours/month) (Rw40*Rw42)	51,233	27,311	85,388	13,656
45	Value of busi traveler time per hour for air travel ($/hr)[8]	$42.42	$42.42	$42.42	$42.42
46	Value of non-busi traveler time per hour for air travel ($/hr)[8]	$30.84	$30.84	$30.84	$30.84
47	Cost of eliminated air travel to busi travelers ($/month) (Rw43*Rw45)	$2,173,293	$1,158,550	$3,622,156	$579,275
48	Cost of eliminated air travel to non-busi travelers ($/month) (Rw44*Rw46)	$1,580,018	$842,284	$2,633,364	$421,142
49	**Cost of eliminated air travel** ($/month) (Rw47+Rw48)	**$3,753,311**	**$2,000,835**	**$6,255,519**	**$1,000,417**
50					
51	***Summary of Service Interruption Costs***				
52	Cost of Additional Travel Time (same as Rw37)	$30,343,438	$18,554,406	$26,773,622	$12,845,358
53	Cost of Eliminated Air Travel (same as Rw49)	$3,753,311	$2,000,835	$6,255,519	$1,000,417
54	Cost of additional travel time and eliminated air travel ($) (Rw52+Rw53)	$34,096,750	$20,555,240	$33,029,141	$13,845,775
55	Cost of additional travel time and eliminated air travel ($ millions/mnth)	**$34**	**$21**	**$33**	**$14**
56	**HSR versus no HSR Cost Difference** ($ millions/month) (B55-C55)		**$14**		**$19**

	A	B	C	D	E
57		Medium Disruption			
58	***Month One:***	Scenario 2a		Scenario 2b	
59	***Medium Disruption Scenarios (2a and 2b)***	No HSR	HSR	No HSR	HSR
60	CA Corridor air travel per month[1]	1,821,609	1,421,609	1,821,609	1,421,609
61	**Eliminated or diverted air travel** per month due to strikes (%)[2]	**40%**	**40%**	**40%**	**40%**
62	Eliminated or diverted air travel per month due to strikes (Rw60*Rw61)	728,644	568,644	728,644	568,644
63	**Busi travelers** per month who eliminated or diverted air travel due to strikes (Rw62*50%)[3]	**364,322**	**284,322**	**364,322**	**284,322**
64	**Non-busi travelers** per month who eliminated or diverted air travel due to strikes (Rw62*50%)[3]	**364,322**	**284,322**	**364,322**	**284,322**
65	**Travelers per month diverted to HSR** (%)[4]	**0%**	**25%**	**0%**	**50%**
66	*Busi travelers* per month diverted to HSR (Rw63*Rw65)	0	71,080	0	142,161
67	*Non-busi travelers* per month diverted to HSR (Rw64*Rw65)	0	71,080	0	142,161
68	**Travelers per month diverted to other modes** such as autos, buses and rail (%)[5]	**85%**	**65%**	**75%**	**45%**
69	*Busi travelers* per month diverted to other modes (Rw63*Rw68)	309,674	184,809	273,241	127,945
70	*Non-busi travelers* per month diverted to other modes (Rw64*Rw68)	309,674	184,809	273,241	127,945
71	**Travelers per month who eliminated air travel** (%)[6]	**15%**	**10%**	**25%**	**5%**
72	*Busi travelers* per month who eliminated air travel (Rw63*Rw71)	54,648	28,432	91,080	14,216
73	*Non-busi travelers* per month who eliminated air travel (Rw64*Rw71)	54,648	28,432	91,080	14,216

	A	B	C	D	E
74			Medium Disruption		
75	***Month One:***	**Scenario 2a**		**Scenario 2b**	
76	***Medium Disruption Scenarios (2a and 2b) (cont.)***	No HSR	HSR	No HSR	HSR
77	***Cost of Additional Travel Time***				
78	Additional travel time per traveler when using other modes such as buses, rail and autos (hours/traveler)[7]	5.35	5.35	5.35	5.35
79	*Busi travelers* per month diverted to other modes (same as Rw69)	309,674	184,809	273,241	127,945
80	*Non-busi travelers* per month diverted to other modes (same as Rw70)	309,674	184,809	273,241	127,945
81	Additional travel time for busi travelers when using other modes (hours/month) (Rw78*Rw79)	1,656,753	988,729	1,461,841	684,505
82	Additional travel time for non-busi travelers when using other modes (hours/month) (Rw78*Rw80)	1,656,753	988,729	1,461,841	684,505
83	Value of busi traveler time per hour for air travel ($/hr)[8]	$42.42	$42.42	$42.42	$42.42
84	Value of non-busi traveler time per hour for air travel ($/hr)[8]	$30.84	$30.84	$30.84	$30.84
85	Additional costs to busi travelers for using other modes ($/month) (Rw81*Rw83)	$70,279,479	$41,941,887	$62,011,305	$29,036,691
86	Additional costs to non-busi travelers for using other modes ($/month) (Rw82*Rw84)	$51,094,274	$30,492,404	$45,083,183	$21,110,126
87	**Cost of additional travel time to travelers** for using other modes ($/month) (Rw85+Rw86)	**$121,373,753**	**$72,434,291**	**$107,094,488**	**$50,146,817**
88					
89	***Cost of Eliminated Air Travel***				
90	Value of an airplane trip per traveler (hours/traveler)[9]	3.75	3.75	3.75	3.75
91	Busi travelers per month who eliminated air travel (same as Rw72)[6]	54,648	28,432	91,080	14,216
92	Non-busi travelers per month who eliminated air travel (same as Rw73)[6]	54,648	28,432	91,080	14,216
93	Value of eliminated busi air travel per month (hours/month) (Rw90*Rw91)	204,931	106,621	341,552	53,310
94	Value of eliminated non-busi air travel per month (hours/month) (Rw90*Rw92)	204,931	106,621	341,552	53,310
95	Value of busi traveler time per hour for air travel ($/hr)[8]	$42.42	$42.42	$42.42	$42.42
96	Value of non-busi traveler time per hour for air travel ($/hr)[8]	$30.84	$30.84	$30.84	$30.84
97	Cost of eliminated air travel to busi travelers ($/month) (Rw93*Rw95)	$8,693,174	$4,522,849	$14,488,623	$2,261,425
98	Cost of eliminated air travel to non-busi travelers ($/month) (Rw94*Rw96)	$6,320,072	$3,288,182	$10,533,454	$1,644,091
99	**Cost of eliminated air travel** ($/month) (Rw97+Rw98)	**$15,013,246**	**$7,811,031**	**$25,022,077**	**$3,905,515**
100					
101	***Summary of Service Interruption Costs***				
102	Cost of Additional Travel Time (same as Rw87)	$121,373,753	$72,434,291	$107,094,488	$50,146,817
103	Cost of Eliminated Air Travel (same as Rw99)	$15,013,246	$7,811,031	$25,022,077	$3,905,515
104	($)(Rw102+Rw103)	$136,386,999	$80,245,322	$132,116,565	$54,052,332
105	Cost of additional travel time and eliminated air travel ($ millions/mnth)	**$136**	**$80**	**$132**	**$54**
106	**HSR versus no HSR Cost Difference** ($ millions/month) (B105-C105)		**$56**		**$78**

	A	B	C	D	E
107		**Maximum Disruption**			
108	***Month One:***	**Scenario 3a**		**Scenario 3b**	
109	***Maximum Disruption Scenarios (3a and 3b)***	No HSR	HSR	No HSR	HSR
110	CA Corridor air travel per month[1]	1,821,609	1,421,609	1,821,609	1,421,609
111	**Eliminated or diverted air travel** per month due to strikes (%)[2]	**75%**	**75%**	**75%**	**75%**
112	Eliminated or diverted air travel per month due to strikes (Rw110* Rw111)	1,366,207	1,066,207	1,366,207	1,066,207
113	**Busi travelers** per month who eliminated or diverted air travel due to strikes (Rw112*50%)[3]	**683,103**	**533,103**	**683,103**	**533,103**
114	**Non-busi travelers** per month who eliminated or diverted air travel due to strikes (Rw112*50%)[3]	**683,103**	**533,103**	**683,103**	**533,103**
115	**Travelers per month diverted to HSR** (%)[4]	**0%**	**25%**	**0%**	**50%**
116	*Busi travelers* per month diverted to HSR (Rw113*Rw115)	0	133,276	0	266,552
117	*Non-busi travelers* per month diverted to HSR (Rw114*Rw115)	0	133,276	0	266,552
118	**Travelers per month diverted to other modes** such as autos, buses and rail (%)[5]	**85%**	**65%**	**75%**	**45%**
119	*Busi travelers* per month diverted to other modes (Rw113*Rw118)	580,638	346,517	512,328	239,897
120	*Non-busi travelers* per month diverted to other modes (Rw114*Rw118)	580,638	346,517	512,328	239,897
121	**Travelers per month who eliminated air travel** (%)[6]	**15%**	**10%**	**25%**	**5%**
122	*Busi travelers* per month who eliminated air travel (Rw113*Rw121)	102,466	53,310	170,776	26,655
123	*Non-busi travelers* per month who eliminated air travel (Rw114*Rw121)	102,466	53,310	170,776	26,655

	A	B	C	D	E
124		Maximum Disruption			
125	***Month One:***	**Scenario 3a**		**Scenario 3b**	
126	***Maximum Disruption Scenarios (3a and 3b) (cont.)***	No HSR	HSR	No HSR	HSR
127	***Cost of Additional Travel Time***				
128	Additional travel time per traveler when using other modes such as buses, rail and autos (hours/traveler)[7]	5.35	5.35	5.35	5.35
129	*Busi travelers* per month diverted to other modes (same as Rw119)	580,638	346,517	512,328	239,897
130	*Non-busi travelers* per month diverted to other modes (same as Rw120)	580,638	346,517	512,328	239,897
131	Additional travel time for busi travelers when using other modes (hours/month) (Rw128*Rw129)	3,106,413	1,853,867	2,740,952	1,283,446
132	Additional travel time for non-busi travelers when using other modes (hours/month) (Rw128*Rw130)	3,106,413	1,853,867	2,740,952	1,283,446
133	Value of busi traveler time per hour for air travel ($/hr)[8]	$42.42	$42.42	$42.42	$42.42
134	Value of non-busi traveler time per hour for air travel ($/hr)[8]	$30.84	$30.84	$30.84	$30.84
135	Additional costs to busi travelers for using other modes ($/month) (Rw131*Rw133)	$131,774,022	$78,641,038	$116,271,196	$54,443,795
136	Additional costs to non-busi travelers for using other modes ($/month) (Rw132*Rw134)	$95,801,765	$57,173,258	$84,530,969	$39,581,486
137	**Cost of additional travel time to travelers** for using other modes ($/month) (Rw135+Rw136)	**$227,575,787**	**$135,814,295**	**$200,802,165**	**$94,025,281**
138					
139	***Cost of Eliminated Air Travel***				
140	Value of an airplane trip per traveler (hours/traveler)[9]	3.75	3.75	3.75	3.75
141	Busi travelers per month who eliminated air travel (same as Rw122)[6]	102,466	53,310	170,776	26,655
142	Non-busi travelers per month who eliminated air travel (same as Rw123)[6]	102,466	53,310	170,776	26,655
143	Value of eliminated busi air travel per month (hours/month) (Rw140*Rw141)	384,246	199,914	640,409	99,957
144	Value of eliminated non-busi air travel per month (hours/month) (Rw140*Rw142)	384,246	199,914	640,409	99,957
145	Value of busi traveler time per hour for air travel ($/hr)[8]	$42.42	$42.42	$42.42	$42.42
146	Value of non-busi traveler time per hour for air travel ($/hr)[8]	$30.84	$30.84	$30.84	$30.84
147	Cost of eliminated air travel to busi travelers ($/month) (Rw143*Rw145)	$16,299,700	$8,480,342	$27,166,167	$4,240,171
148	Cost of eliminated air travel to non-busi travelers ($/month) (Rw144*Rw146)	$11,850,136	$6,165,341	$19,750,226	$3,082,670
149	**Cost of eliminated air travel** ($/month) (Rw147+Rw148)	**$28,149,836**	**$14,645,682**	**$46,916,394**	**$7,322,841**
150					
151	***Summary of Service Interruption Costs***				
152	Cost of Additional Travel Time (same as Rw137)	$227,575,787	$135,814,295	$200,802,165	$94,025,281
153	Cost of Eliminated Air Travel (same as Rw149)	$28,149,836	$14,645,682	$46,916,394	$7,322,841
154	($)(Rw152+Rw153)	$255,725,623	$150,459,978	$247,718,559	$101,348,123
155	Cost of additional travel time and eliminated air travel ($ millions/mnth)	**$256**	**$150**	**$248**	**$101**
156	**HSR versus no HSR Cost Difference** ($ millions/month) (B155-C155)		**$105**		**$146**

Labor Strike Assumptions

1. The *Draft California HSR Economic Impact* study states that annual air travel in the California Corridor totals 15.3 million trips (1994) and 28.4 million (2020). This analysis uses a mean estimate of these two figures (21.9 million air travelers per year) and then disaggregates it to a monthly level of about two million air travelers per month. The air travel that is considered for this analysis includes Los Angeles-Fresno, Los Angeles-Sacramento, Los Angeles-San Diego, Los Angeles-San Francisco, San Francisco-San Diego, and San Francisco-Sacramento.

   For the "HSR" analyses: the *Draft California HSR Economic Impact* study states that HSR would divert about 20 percent of air travel during normal conditions. When considering the impact of HSR on air travel, an additional 4.38 million trips per year (or 365,000 per month) are subtracted from the corridor air travel figure. These numbers correspond with the expected HSR contributions as stated in the *Economic Impact* study.

2. Air travel reductions range from 10 percent to 75 percent over one month. The 1981 Professional Air Traffic Controllers Strike reduced air travel between 60 percent and 75 percent while the 1995 strikes in France decreased air travel by about 15 percent over three weeks.[1][2]

3. According to the *Draft California HSR Economic Impact* study, there is a one-to-one ratio between business and non-business air travelers.

4. Air travel that is diverted to high-speed rail generates no extra costs because these travelers view the service as comparable to air travel and as an optimal choice when comparing it to highway vehicles and conventional rail. Air travel that is diverted to high-speed rail is assumed to vary from 25 percent in the scenarios labeled "A" to 50 percent in the scenarios labeled "B" in order to show a range of responses to the service interruption. Even though the HSR service is considered to be optimal in some cases, this analysis does not give credit for its time savings when present. Implicit in the analysis is that short and long trips are diverted to high-speed rail at the same rate.

5. The term "other modes" considers buses, conventional rail and carpools. "Other modes" are assumed to be more responsive to service disruptions in the analyses labeled "A" than in the analyses labeled "B." For the "HSR" analyses, the percentage of diverted trips to "other modes" is assumed to vary between 45 percent and 65 percent for the "B" and "A" analyses, respectively. For the "No HSR" analyses, the percentage of diverted trips to "other modes" is assumed to vary between 75 percent and 85 percent for the "B" and "A" analyses, respectively. Implicit in the analysis is that short and long trips are diverted to "other modes" at the same rate.

6. The percentage of eliminated air travel is assumed to vary between 5 percent and 10 percent for the "HSR" analyses and between 15 percent and 25 percent for the "No HSR" analyses. Thus, fewer travelers are expected to eliminate a trip when a HSR service exists. Implicit in the analysis is that short and long trips are eliminated at the same rate.

7. Assuming that air travel between San Francisco and Los Angeles represents a typical air trip taken in the California corridor, the mean air travel time for the corridor is estimated to be 1.25 hours. The mean highway travel time for this same trip equals about 6.60 hours. During an air service interruption, travelers would be forced to use highways or conventional rail. The additional cost of traveling by highway during an air service interruption equals 5.35 hours, the difference between the two travel times.

8. According to Charles River Associates estimates in the *Draft California HSR Economic Impact* study, the value of business air traveler time is estimated at $42.42 per hour and the value of non-business air traveler time is estimated at $30.84 per hour.

9. The mean air travel time is estimated to be one hour, which approximates the air travel time between San Francisco and Los Angeles. Travel time acts as a proxy for the cost of a trip. The value of a trip must be greater than its cost. An air travel value of three hours is selected as an arbitrary estimate, which is triple the cost of an average air trip. The value selected for highway trips is less than the value for air travel because air travelers pay more to use these services.

[1] Bert A. Spector, *Air Traffic Controllers*, Harvard Business School, Boston, MA, 1982.

[2] Alexandre Polozoff, *The French Strikes (en Greve) of 1995*, World Wide Web, December 21, 1995.

High-Speed Rail Contributions:
Reduction of Terrorist-Related Economic and Social Dislocation Costs

Year 1	Reduction of Disruption Costs due to HSR ($ millions/yr)
Minimum Disruption: Low HSR Contribution (1a)	$11
Minimum Disruption: High HSR Contribution (1b)	$20
Medium Disruption: Low HSR Contribution (2a)	$122
Medium Disruption: High HSR Contribution (2b)	$203
Maximum Disruption: Low HSR Contribution (3a)	$243
Maximum Disruption: High HSR Contribution (3b)	$406

	A	B	C	D	E
1	**High-Speed Rail Contributions:**				
2	**Reduction of Terrorist-Related Economic and Social Dislocation Costs**				
3					
4	This analysis assumes that air-related terrorist activities cause air travelers to reduce trips between one percent and 20 percent for one year.				
5					
6					
7			**Minimum Disruption**		
8	***Year One:***	**Scenario 1a**		**Scenario 1b**	
9	***Minimum Disruption Scenarios (1a and 1b)***	No HSR	HSR	No HSR	HSR
10	CA Corridor annual air travel[1]	21,859,305	17,479,305	21,859,305	17,479,305
11	**Eliminated or diverted air travel** per year due to terrorist activities (%)[2]	**1%**	**1%**	**1%**	**1%**
12	Eliminated or diverted air travel per year due to terrorist activities (Rw10* Rw11)	218,593	174,793	218,593	174,793
13	**Busi travelers** per year who eliminated or diverted air travel due to terrorist activities (Rw12*50%)[3]	**109,297**	**87,397**	**109,297**	**87,397**
14	**Non-busi travelers** per year who eliminated or diverted air travel due to terrorist activities (Rw12*50%)[3]	**109,297**	**87,397**	**109,297**	**87,397**
15	**Travelers per year diverted to HSR** (%)[4]	**0%**	**10%**	**0%**	**40%**
16	*Busi travelers* per year diverted to HSR (Rw13*Rw15)	0	8,740	0	34,959
17	*Non-busi travelers* per year diverted to HSR (Rw14*Rw15)	0	8,740	0	34,959
18	**Travelers per year diverted to other modes** such as autos, buses and rail (%)[5]	**85%**	**80%**	**75%**	**55%**
19	*Busi travelers* per year diverted to other modes (Rw13*Rw18)	92,902	69,917	81,972	48,068
20	*Non-busi travelers* per year diverted to other modes (Rw14*Rw18)	92,902	69,917	81,972	48,068
21	**Travelers per year who eliminated air travel** (%)[6]	**15%**	**10%**	**25%**	**5%**
22	*Busi travelers* per year who eliminated air travel (Rw13*Rw21)	16,394	8,740	27,324	4,370
23	*Non-busi travelers* per year who eliminated air travel (Rw14*Rw21)	16,394	8,740	27,324	4,370

	A	B	C	D	E
24			**Minimum Disruption**		
25	***Year One:***	**Scenario 1a**		**Scenario 1b**	
26	***Minimum Disruption Scenarios (1a and 1b) (cont.)***	No HSR	HSR	No HSR	HSR
27	***Cost of Additional Travel Time***				
28	Additional travel time per traveler when using other modes such as buses, rail and autos (hours/traveler)[7]	5.35	5.35	5.35	5.35
29	*Busi travelers* per year diverted to other modes (same as Rw19)	92,902	69,917	81,972	48,068
30	*Non-busi travelers* per year diverted to other modes (same as Rw20)	92,902	69,917	81,972	48,068
31	Additional travel time for busi travelers when using other modes (hours/yr) (Rw28*Rw29)	497,026	374,057	438,552	257,164
32	Additional travel time for non-busi travelers when using other modes (hours/yr) (Rw28*Rw30)	497,026	374,057	438,552	257,164
33	Value of busi traveler time per hour for air travel ($/hr)[8]	$42.42	$42.42	$42.42	$42.42
34	Value of non-busi traveler time per hour for air travel ($/hr)[8]	$30.84	$30.84	$30.84	$30.84
35	Additional costs to busi travelers for using other modes ($/yr) (Rw31*Rw33)	$21,083,841	$15,867,503	$18,603,389	$10,908,909
36	Additional costs to non-busi travelers for using other modes ($/yr) (Rw32*Rw34)	$15,328,280	$11,535,922	$13,524,953	$7,930,946
37	**Cost of additional travel time to travelers** for using other modes ($/yr) (Rw35+Rw36)	**$36,412,121**	**$27,403,425**	**$32,128,342**	**$18,839,855**
38					
39	***Cost of Eliminated Air Travel***				
40	Value of an airplane trip per traveler (hours/traveler)[9]	3.75	3.75	3.75	3.75
41	Busi travelers per year who eliminated air travel (same as Rw22)[6]	16,394	8,740	27,324	4,370
42	Non-busi travelers per year who eliminated air travel (same as Rw23)[6]	16,394	8,740	27,324	4,370
43	Value of eliminated busi air travel per year (hours/yr) (Rw40*Rw41)	61,479	32,774	102,465	16,387
44	Value of eliminated non-busi air travel per year (hours/yr) (Rw40*Rw42)	61,479	32,774	102,465	16,387
45	Value of busi traveler time per hour for air travel ($/hr)[8]	$42.42	$42.42	$42.42	$42.42
46	Value of non-busi traveler time per hour for air travel ($/hr)[8]	$30.84	$30.84	$30.84	$30.84
47	Cost of eliminated air travel to busi travelers ($/yr) (Rw43*Rw45)	$2,607,952	$1,390,260	$4,346,586	$695,130
48	Cost of eliminated air travel to non-busi travelers ($/yr) (Rw44*Rw46)	$1,896,021	$1,010,741	$3,160,036	$505,370
49	**Cost of eliminated air travel** ($/yr) (Rw47+Rw48)	**$4,503,973**	**$2,401,001**	**$7,506,622**	**$1,200,501**
50					
51	***Summary of Service Interruption Costs***				
52	Cost of Additional Travel Time (same as Rw37)	$36,412,121	$27,403,425	$32,128,342	$18,839,855
53	Cost of Eliminated Air Travel (same as Rw49)	$4,503,973	$2,401,001	$7,506,622	$1,200,501
54	Cost of additional travel time and eliminated air travel ($) (Rw52+Rw53)	$40,916,094	$29,804,426	$39,634,964	$20,040,355
55	Cost of additional travel time and eliminated air travel ($ millions/yr)	**$41**	**$30**	**$40**	**$20**
56	**HSR versus no HSR Cost Difference** ($ millions/yr) (B55-C55)		**$11**		**$20**

	A	B	C	D	E
57		**Medium Disruption**			
58	***Year One:***	**Scenario 2a**		**Scenario 2b**	
59	***Medium Disruption Scenarios (2a and 2b)***	No HSR	HSR	No HSR	HSR
60	CA Corridor annual air travel[1]	21,859,305	16,859,305	21,859,305	16,859,305
61	**Eliminated or diverted air travel** per year due to terrorist activities (%)[2]	**10%**	**10%**	**10%**	**10%**
62	Eliminated or diverted air travel per year due to terrorist activities (Rw60* Rw61)	2,185,931	1,685,931	2,185,931	1,685,931
63	**Busi travelers** per year who eliminated or diverted air travel due to terrorist activities (Rw62*50%)[3]	**1,092,965**	**842,965**	**1,092,965**	**842,965**
64	**Non-busi travelers** per year who eliminated or diverted air travel due to terrorist activities (Rw62*50%)[3]	**1,092,965**	**842,965**	**1,092,965**	**842,965**
65	**Travelers per year diverted to HSR** (%)[4]	**0%**	**10%**	**0%**	**40%**
66	*Busi travelers* per year diverted to HSR (Rw63*Rw65)	0	84,297	0	337,186
67	*Non-busi travelers* per year diverted to HSR (Rw64*Rw65)	0	84,297	0	337,186
68	**Travelers per year diverted to other modes** such as autos, buses and rail (%)[5]	**85%**	**80%**	**75%**	**55%**
69	*Busi travelers* per year diverted to other modes (Rw63*Rw68)	929,020	674,372	819,724	463,631
70	*Non-busi travelers* per year diverted to other modes (Rw64*Rw68)	929,020	674,372	819,724	463,631
71	**Travelers per year who eliminated air travel** (%)[6]	**15%**	**10%**	**25%**	**5%**
72	*Busi travelers* per year who eliminated air travel (Rw63*Rw71)	163,945	84,297	273,241	42,148
73	*Non-busi travelers* per year who eliminated air travel (Rw64*Rw71)	163,945	84,297	273,241	42,148

	A	B	C	D	E
74		**Medium Disruption**			
75	***Year One:***	**Scenario 2a**		**Scenario 2b**	
76	***Medium Disruption Scenarios (2a and 2b) (cont.)***	No HSR	HSR	No HSR	HSR
77	***Cost of Additional Travel Time***				
78	Additional travel time per traveler when using other modes such as buses, rail and autos (hours/traveler)[7]	5.35	5.35	5.35	5.35
79	*Busi travelers* per year diverted to other modes (same as Rw69)	929,020	674,372	819,724	463,631
80	*Non-busi travelers* per yr diverted to other modes (same as Rw70)	929,020	674,372	819,724	463,631
81	Additional travel time for busi travelers when using other modes (hours/yr) (Rw78*Rw79)	4,970,259	3,607,891	4,385,523	2,480,425
82	Additional travel time for non-busi travelers when using other modes (hours/yr) (Rw78*Rw80)	4,970,259	3,607,891	4,385,523	2,480,425
83	Value of busi traveler time per hour for air travel ($/hr)[8]	$42.42	$42.42	$42.42	$42.42
84	Value of non-busi traveler time per hour for air travel ($/hr)[8]	$30.84	$30.84	$30.84	$30.84
85	Additional costs to busi travelers for using other modes ($/yr) (Rw81*Rw83)	$210,838,407	$153,046,748	$186,033,888	$105,219,639
86	Additional costs to non-busi travelers for using other modes ($/yr) (Rw82*Rw84)	$153,282,802	$111,267,367	$135,249,531	$76,496,315
87	**Cost of additional travel time to travelers** for using other modes ($/yr) (Rw85+Rw86)	**$364,121,209**	**$264,314,114**	**$321,283,420**	**$181,715,954**
88					
89	***Cost of Eliminated Air Travel***				
90	Value of a air trip per traveler (hours/traveler)[9]	3.75	3.75	3.75	3.75
91	*Busi travelers* per year who eliminated air travel (same as Rw72)[6]	163,945	84,297	273,241	42,148
92	*Non-busi travelers* per year who eliminated air travel (same as Rw73)[6]	163,945	84,297	273,241	42,148
93	Value of eliminated busi air travel per year (hours/yr) (Rw90*Rw91)	614,793	316,112	1,024,655	158,056
94	Value of eliminated non-busi air travel per year (hours/yr) (Rw90*Rw92)	614,793	316,112	1,024,655	158,056
95	Value of busi traveler time per hour for air travel ($/hr)[8]	$42.42	$42.42	$42.42	$42.42
96	Value of non-busi traveler time per hour for air travel ($/hr)[8]	$30.84	$30.84	$30.84	$30.84
97	Cost of eliminated air travel to busi travelers ($/yr) (Rw93*Rw95)	$26,079,517	$13,409,470	$43,465,862	$6,704,735
98	Cost of eliminated air travel to non-busi travelers ($/yr) (Rw94*Rw96)	$18,960,215	$9,748,893	$31,600,358	$4,874,447
99	**Cost of eliminated air travel** ($/yr) (Rw97+Rw98)	**$45,039,732**	**$23,158,363**	**$75,066,220**	**$11,579,181**
100					
101	***Summary of Service Interruption Costs***				
102	Cost of Additional Travel Time (same as Rw87)	$364,121,209	$264,314,114	$321,283,420	$181,715,954
103	Cost of Eliminated Air Travel (same as Rw99)	$45,039,732	$23,158,363	$75,066,220	$11,579,181
104	(Rw102+Rw103)	$409,160,941	$287,472,477	$396,349,639	$193,295,135
105	Cost of additional travel time and eliminated air travel ($ millions/yr)	**$409**	**$287**	**$396**	**$193**
106	**HSR versus no HSR Cost Difference** ($ millions/year) (B105-C105)		**$122**		**$203**

	A	B	C	D	E
107		**Maximum Disruption**			
108	***Year One:***	**Scenario 3a**		**Scenario 3b**	
109	***Maximum Disruption Scenarios (3a and 3b)***	No HSR	HSR	No HSR	HSR
110	CA Corridor annual air travel[1]	21,859,305	16,859,305	21,859,305	16,859,305
111	**Eliminated or diverted air travel** per year due to terrorist activities (%)[2]	**20%**	**20%**	**20%**	**20%**
112	Eliminated or diverted air travel per year due to terrorist activities (Rw110* Rw111)	4,371,861	3,371,861	4,371,861	3,371,861
113	**Busi travelers** per year who eliminated or diverted air travel due to terrorist activities (Rw112*50%)[3]	**2,185,931**	**1,685,931**	**2,185,931**	**1,685,931**
114	**Non-busi travelers** per year who eliminated or diverted air travel due to terrorist activities (Rw112*50%)[3]	**2,185,931**	**1,685,931**	**2,185,931**	**1,685,931**
115	**Travelers per year diverted to HSR** (%)[4]	**0%**	**10%**	**0%**	**40%**
116	*Busi travelers* per year diverted to HSR (Rw113*Rw115)	0	168,593	0	674,372
117	*Non-busi travelers* per year diverted to HSR (Rw114*Rw115)	0	168,593	0	674,372
118	**Travelers per year diverted to other modes** such as autos, buses and rail (%)[5]	**85%**	**80%**	**75%**	**55%**
119	*Busi travelers* per year diverted to other modes (Rw113*Rw118)	1,858,041	1,348,744	1,639,448	927,262
120	*Non-busi travelers* per year diverted to other modes (Rw114*Rw118)	1,858,041	1,348,744	1,639,448	927,262
121	**Travelers per year who eliminated air travel** (%)[6]	**15%**	**10%**	**25%**	**5%**
122	*Busi travelers* per year who eliminated air travel (Rw113*Rw121)	327,890	168,593	546,483	84,297
123	*Non-busi travelers* per year who eliminated air travel (Rw114*Rw121)	327,890	168,593	546,483	84,297

	A	B	C	D	E
124		**Maximum Disruption**			
125	***Year One:***	**Scenario 3a**		**Scenario 3b**	
126	***Maximum Disruption Scenarios (3a and 3b) (cont.)***	No HSR	HSR	No HSR	HSR
127	***Cost of Additional Travel Time***				
128	Additional travel time per traveler when using other modes such as buses, rail and autos (hours/traveler)[7]	5.35	5.35	5.35	5.35
129	*Busi travelers* per year diverted to other modes (same as Rw119)	1,858,041	1,348,744	1,639,448	927,262
130	*Non-busi travelers* per yr diverted to other modes (same as Rw120)	1,858,041	1,348,744	1,639,448	927,262
131	Additional travel time for busi travelers when using other modes (hours/yr) (Rw128*Rw129)	9,940,519	7,215,783	8,771,046	4,960,850
132	Additional travel time for non-busi travelers when using other modes (hours/yr) (Rw128*Rw130)	9,940,519	7,215,783	8,771,046	4,960,850
133	Value of busi traveler time per hour for air travel ($/hr)[8]	$42.42	$42.42	$42.42	$42.42
134	Value of non-busi traveler time per hour for air travel ($/hr)[8]	$30.84	$30.84	$30.84	$30.84
135	Additional costs to busi travelers for using other modes ($/yr) (Rw131*Rw133)	$421,676,814	$306,093,495	$372,067,777	$210,439,278
136	Additional costs to non-busi travelers for using other modes ($/yr) (Rw132*Rw134)	$306,565,604	$222,534,734	$270,499,063	$152,992,629
137	**Cost of additional travel time to travelers** for using other modes ($/yr) (Rw135+Rw136)	**$728,242,418**	**$528,628,229**	**$642,566,840**	**$363,431,907**
138					
139	***Cost of Eliminated Air Travel***				
140	Value of a air trip per traveler (hours/traveler)[9]	3.75	3.75	3.75	3.75
141	Busi travelers per year who eliminated air travel (same as Rw122)[6]	327,890	168,593	546,483	84,297
142	Non-busi travelers per year who eliminated air travel (same as Rw123)[6]	327,890	168,593	546,483	84,297
143	Value of eliminated busi air travel per year (hours/yr) (Rw140*Rw141)	1,229,586	632,224	2,049,310	316,112
144	Value of eliminated non-busi air travel per year (hours/yr) (Rw140*Rw142)	1,229,586	632,224	2,049,310	316,112
145	Value of busi traveler time per hour for air travel ($/hr)[8]	$42.42	$42.42	$42.42	$42.42
146	Value of non-busi traveler time per hour for air travel ($/hr)[8]	$30.84	$30.84	$30.84	$30.84
147	Cost of eliminated air travel to busi travelers ($/yr) (Rw143*Rw145)	$52,159,034	$26,818,939	$86,931,724	$13,409,470
148	Cost of eliminated air travel to non-busi travelers ($/yr) (Rw144*Rw146)	$37,920,429	$19,497,786	$63,200,716	$9,748,893
149	**Cost of eliminated air travel** ($/yr) (Rw147+Rw148)	**$90,079,463**	**$46,316,726**	**$150,132,439**	**$23,158,363**
150					
151	***Summary of Service Interruption Costs***				
152	Cost of Additional Travel Time (same as Rw137)	$728,242,418	$528,628,229	$642,566,840	$363,431,907
153	Cost of Eliminated Air Travel (same as Rw149)	$90,079,463	$46,316,726	$150,132,439	$23,158,363
154	(Rw152+Rw153)	$818,321,882	$574,944,955	$792,699,279	$386,590,270
155	Cost of additional travel time and eliminated air travel ($ millions/yr)	**$818**	**$575**	**$793**	**$387**
156	**HSR versus no HSR Cost Difference** ($ millions/yr) (B155-C155)		**$243**		**$406**

Terrorism Assumptions

1. The *Draft California HSR Economic Impact* study states that annual air travel in the California Corridor totals 15.3 million trips (1994) and 28.4 million (2020). This analysis uses a mean estimate of these two figures (21.9 million air travelers per year). The air travel that is considered for this analysis includes Los Angeles-Fresno, Los Angeles-Sacramento, Los Angeles-San Diego, Los Angeles-San Francisco, San Francisco-San Diego, and San Francisco-Sacramento.

   For the "HSR" analyses: the Dr*aft California HSR Economic Impact* study states that HSR would divert about 20 percent of air travel during normal conditions. Thus, when considering the impact of HSR on air travel, an additional 4.38 million trips per year are subtracted from the total volume of air travel in the corridor.

2. Terrorist threats and attacks are expected to dissuade an estimated range of one percent to 20 percent of air travelers from traveling for one year.

3. According to the *Draft California HSR Economic Impact* study, there is a one-to-one ratio between business and non-business air travelers.

4. Air travel that is diverted to high-speed rail generates no extra costs because these travelers view the service as comparable to air travel and as an optimal choice when comparing it to highway vehicles and conventional rail. Air travel that is diverted to high-speed rail is assumed to vary from 10 percent in the scenarios labeled "A" to 40 percent in the scenarios labeled "B" in order to show a range of responses to the service interruption. The HSR service is not expected to assist with terrorism as much as other incidents because the tracks, trains and stations also are exposed to threats and attacks, making travelers hesitate before switching to this mode. Even though the HSR service is considered to be optimal in some cases, this analysis does not give credit for its time savings. Implicit in the analysis is that short and long trips are diverted to high-speed rail at the same rate.

5. The term "other modes" considers buses, conventional rail and carpools. "Other modes" are assumed to be more responsive to service disruptions in the analyses labeled "A" than in the analyses labeled "B." For the "HSR" analyses, the percentage of diverted trips to "other modes" is assumed to vary between 55 percent and 80 percent for the "B" and "A" analyses, respectively. For the "No HSR" analyses, the percentage of diverted trips to "other modes" is assumed to vary between 75 percent and 85 percent for the "B" and "A" analyses, respectively. Implicit in the analysis is that short and long trips are diverted to "other modes" at the same rate.

6. The percentage of air travel that is eliminated is assumed to vary between five percent and ten percent for the "HSR" analyses and between 15 percent and 25 percent for the "No HSR" analyses. Thus, fewer travelers are expected to eliminate a trip when a HSR service exists. Implicit in the analysis is that short and long trips are eliminated at the same rate.

7. Assuming that air travel between San Francisco and Los Angeles represents a typical air trip taken in the California corridor, the mean air travel time for the corridor is estimated to be 1.25 hours. The mean highway travel time for this same trip equals about 6.60 hours. During an air service interruption, travelers would be forced to use highways or conventional rail. The additional cost of traveling by highway during an air service interruption equals 5.35 hours, the difference between the two travel times.

8. According to Charles River Associates estimates in the *Draft California HSR Economic Impact* study, the value of business air traveler time is estimated at $42.42 per hour and the value of non-business air traveler time is estimated at $30.84 per hour.

9. The mean air travel time is estimated to be one hour, which approximates the air travel time between San Francisco and Los Angeles. Travel time acts as a proxy for the cost of a trip. The value of a trip must be greater than its cost. An air travel value of three hours is selected as an arbitrary estimate, which is triple the cost of an average air trip. The value selected for highway trips is less than the value for air travel because air travelers pay more to use these services.

Appendix B:

Intercity Highway Travel along the California High-Speed Rail Corridor Alignment

Appendix B

Intercity Highway Travel along the California HSR Corridor Alignment

Intercity City Pairs	Miles	PTRIPS (1994) (000)	Trip %	Weighted Share	PTRIPS (2020) (000)	Trip %	Weighted Share	Busn %
Bakersfield-Fresno	118	1,095	0.86%	1.02	1,742	1.01%	1.19	44%
Bakersfield-Los Angeles	112	6,872	5.42%	6.07	9,614	5.55%	6.22	23%
Bakersfield-Merced	179	54	0.04%	0.08	86	0.05%	0.09	43%
Bakersfield-Modesto	222	201	0.16%	0.35	320	0.18%	0.41	42%
Bakersfield-Monterey	244	42	0.03%	0.08	64	0.04%	0.09	36%
Bakersfield-Sacramento	288	413	0.33%	0.94	608	0.35%	1.01	22%
Bakersfield-San Diego	232	407	0.32%	0.75	569	0.33%	0.76	9%
Bakersfield-San Francisco	284	697	0.55%	1.56	903	0.52%	1.48	27%
Bakersfield-Stockton	242	79	0.06%	0.15	119	0.07%	0.17	43%
Bakersfield-Visalia	80	199	0.16%	0.13	308	0.18%	0.14	41%
Fresno-Los Angeles	227	2,294	1.81%	4.11	3,209	1.85%	4.21	21%
Fresno-Merced	62	956	0.75%	0.47	1,483	0.86%	0.53	45%
Fresno-Modesto	105	465	0.37%	0.39	721	0.42%	0.44	43%
Fresno-Monterey	185	243	0.19%	0.35	367	0.21%	0.39	10%
Fresno-Sacramento	185	947	0.75%	1.38	1,395	0.81%	1.49	25%
Fresno-San Diego	347	238	0.19%	0.65	341	0.20%	0.68	8%
Fresno-San Francisco	193	3,036	2.40%	4.62	3,932	2.27%	4.38	26%
Fresno-Stockton	137	334	0.26%	0.36	504	0.29%	0.40	45%
Fresno-Visalia	45	542	0.43%	0.19	839	0.48%	0.22	36%
Los Angeles-Merced	288	293	0.23%	0.67	409	0.24%	0.68	19%
Los Angeles-Modesto	331	658	0.52%	1.72	921	0.53%	1.76	19%
Los Angeles-Monterey	330	777	0.61%	2.02	1,087	0.63%	2.07	18%
Los Angeles-Sacramento	384	2,677	2.11%	8.11	3,745	2.16%	8.31	14%
Los Angeles-San Diego	121	32,609	25.73%	31.14	45,623	26.36%	31.89	34%
Los Angeles-San Francisco	380	7,851	6.20%	23.54	10,705	6.18%	23.50	11%
Los Angeles-Stockton	338	519	0.41%	1.38	726	0.42%	1.42	19%
Los Angeles-Visalia	189	174	0.14%	0.26	244	0.14%	0.27	23%
Merced-Modesto	43	2,224	1.76%	0.75	3,537	2.04%	0.88	44%
Merced-Monterey	144	180	0.14%	0.20	259	0.15%	0.22	10%
Merced-Sacramento	123	531	0.42%	0.52	762	0.44%	0.54	25%
Merced-San Diego	408	29	0.02%	0.09	41	0.02%	0.10	7%
Merced-San Francisco	131	1,337	1.06%	1.38	1,688	0.98%	1.28	26%
Merced-Stockton	75	378	0.30%	0.22	557	0.32%	0.24	46%
Merced-Visalia	106	40	0.03%	0.03	60	0.03%	0.04	46%
Modesto-Monterey	164	228	0.18%	0.30	336	0.19%	0.32	10%
Modesto-Sacramento	80	2,186	1.73%	1.38	3,219	1.86%	1.49	25%
Modesto-San Diego	451	53	0.04%	0.19	74	0.04%	0.19	7%
Modesto-San Francisco	88	6,144	4.85%	4.27	7,756	4.48%	3.94	30%
Modesto-Stockton	32	4,949	3.91%	1.25	7,477	4.32%	1.38	10%
Modesto-Visalia	149	59	0.05%	0.07	92	0.05%	0.08	45%
Monterey-Sacramento	213	557	0.44%	0.94	779	0.45%	0.96	13%
Monterey-San Diego	451	111	0.09%	0.40	156	0.09%	0.41	7%
Monterey-San Francisco	143	9,416	7.43%	10.63	11,886	6.87%	9.82	20%
Monterey-Stockton	169	87	0.07%	0.12	126	0.07%	0.12	21%
Monterey-Visalia	216	9	0.01%	0.02	13	0.01%	0.02	8%
Sacramento-San Diego	504	679	0.54%	2.70	950	0.55%	2.77	14%
Sacramento-San Francisco	87	18,781	14.82%	12.89	24,326	14.05%	12.23	31%
Sacramento-Stockton	52	3,100	2.45%	1.27	4,449	2.57%	1.34	25%
Sacramento-Visalia	229	109	0.09%	0.20	156	0.09%	0.21	26%
San Diego-San Francisco	500	2,195	1.73%	8.66	2,843	1.64%	8.21	14%
San Diego-Stockton	458	64	0.05%	0.23	90	0.05%	0.24	8%
San Diego-Visalia	309	26	0.02%	0.06	37	0.02%	0.07	8%
San Francisco-Stockton	82	8,361	6.60%	5.41	10,555	6.10%	5.00	28%
San Francisco-Visalia	238	138	0.11%	0.26	175	0.10%	0.24	26%
Stockton-Visalia	182	71	0.06%	0.10	105	0.06%	0.11	43%
		126,714	100%	147.04	173,088	100%	146.63	

Bibliography

General References

Smith, F. *Transportation in America.* Eno Transportation Foundation, Lansdowne, VA, 1993.

Transportation Research Board, National Research Council, *A Look Ahead: Year 2020,* Special Report 220, Washington, D.C. 1988.

United States General Accounting Office, *Traffic Congestion: Trends, Measures, and Effects,* Report to the Chairman, Subcommittee on Transportation and Related Agencies, Committee on Appropriations, United States Senate, November 1989.

Air Quality References

Richard W. Boubel, Donald L. Fox, D. Bruce Turner, and Arthur C. Stern, *Fundamentals of Air Pollution,* Third Edition, Academic Press, New York, 1994.

Michael Cameron, *Transportation Efficiency: Tackling Southern California's Air Pollution and Congestion,* Environmental Defense Fund, Regional Institute of Southern California, Washington, D.C., March 1991.

Arnold M. Howitt, Joshua P. Anderson, Alan A. Altshuler, *The New Politics of Clean Air and Transportation,* A. Alfred Taubman Center for State and Local Government, John F. Kennedy School of Government, Harvard University, Cambridge, MA, November 1994.

Alan J. Krupnick, *Vehicle Emissions, Urban Smog, and Clean Air Policy,* JEL Classification No(s): 722, 933, 1993.

Diversification References

Michael D. Meyer and Peter Belobaba, "Contingency Planning for Response to Urban Transportation System Disruptions," *APA Journal,* Autumn 1982, pp. 454 - 465.

Public Law 85-767 - August 27, 1958, Title 23-Highways, *United States Statutes at Large,* 85th Congress, 2nd Session, Volume 72, Part I, Chapter 1: Federal-Air Highways, Section 101, p. 887.

United States Committee on Banking, Finance and Urban Affairs, *New Urban Rail Transit: How Can its Development and Growth-Shaping Potential be Realized?,* 96th Congress, 1st Session, U.S. Government Printing Office, December 1979.

Earthquake References

_______ , "Raleigh Beltline Project Wins First National Quality Initiative Award: Projects Promoting Quality, Teamwork Honored," *The Urban Transportation Monitor*, November 24, 1995.

Siamak A. Ardekani and Anup K. Shah, "Post-Quake Transportation Operations Following the 1994 Northridge Earthquake," *Transportation Research Board*, 74th Annual Meeting, Washington, D.C., January 22-28, 1995.

Siamak A. Ardekani, "Transportation Operations Following The 1989 Loma Prieta Earthquake," *Transportation Quarterly*, Eno Transportation Foundation, Inc., Vol. 46, No. 2, April 1992, pp. 219-233.

Siamak A. Ardekani and Antoine G. Hobeika, "Logistics Problems in the Aftermath of the 1985 Mexico City Earthquake," *Transportation Quarterly*, Vol. 42, No. 1, Eno Transportation Foundation, Inc., Westport, CT, January 1988.

G. Lennis Berlin, *Earthquakes and the Urban Environment*, Volume II, CRC Press, Inc., Boca Raton, Florida, 1981.

California Department of Transportation, District 7, Office of Operations, *Northridge Earthquake Recovery: Interim Transportation Report #2: April 1 - June 30, 1994*, prepared by Barton-Aschman Associates, Inc., September 8, 1994.

California Department of Transportation, *Post-Earthquake Commute Summary-Daily Trips*, December 19, 1989.

Earthquake Spectra, *Loma Prieta Earthquake Reconnaissance Report*, The Professional Journal of the Earthquake Engineering Research Institute, Vol. 6, Chapter 8: Lifelines, May 1990, pp. 270-281.

Dr. William Ellsworth, "The San Andreas Fault System, California," *United States Geological Survey Professional Paper 1515*, Menlo Park, CA, 1994.

Richard M. Fahey and George E. Gray, "Bay Area Emergency Ferry Service: Transportation Relief After the October 17, 1989, Earthquake," *Transportation Research Record 1297*, pp. 148-161.

Virginia Fairweather, "Northridge: Questioning our Codes," *Civil Engineering*, June 1994, pp. 60-63.

Egill Hauksson, "The Northridge Earthquake and the 'Earthquake Deficit'," *Engineering & Science*, Summer 1994, pp. 13-22.

George W. Housner, Chairman, *Competing Against Time*, Report to Governor George Deukmejian from The Governor's Board of Inquiry on the 1989 Loma Prieta Earthquake, State of California, Office of Planning and Research, May 1990, pp. 19 - 41.

Insurance Services Office, Inc., *Catastrophic Insurance Issues Surrounding the Northridge Earthquake and Other Natural Disasters,* 1994.

Denis Mitchell, Michel Bruneau, Martin Williams, Donald Anderson, Murat Saatcioglu, and Robert Sexsmith, "Performance of bridges in the 1994 Northridge earthquake," *Canadian Journal of Civil Engineering,* Vol. 22, 1995, pp. 415-427.

Elliott Mittler, M. EERI, "The California Earthquake Insurance Program: Developments in 1990," *Earthquake Spectra,* Vol. 7, No. 3, 1991.

National Research Council, *Practical Lessons from the Loma Prieta Earthquake,* Report from a Symposium Sponsored by the Geotechnical Board and the Board on Natural Disasters of the National Research Council, National Academy Press, Washington, D.C., 1994.

Northridge Earthquake: Lifeline Performance and Post-Earthquake Response, Technical Council on Lifeline Earthquake Engineering, Monograph No. 8, edited by Anshel J. Schiff, published by the American Society of Civil Engineers, New York, August 1995.

Risa Palm, *Earthquake Insurance: A Longitudinal Study of California Homeowners,* Westview Press, San Francisco, 1995.

Anshel J. Schiff, "Earthquakes in Transportation Contingency Planning," *Energy,* Vol. 8, No. 8-9, 1983, pp. 689-693.

Technical Council on Lifeline Earthquake Engineering Monograph No. 8, *Northridge Earthquake: Lifeline Performance and Post-Earthquake Response,* edited by Anshel J. Schiff, American Society of Civil Engineers, August 1995.

Charles C. Thiel, Jr., M. EERI, "Book Review," *U.S. Geological Survey Open File Report 88-398,* Menlo Park, California, 1988; Earthquake Spectra, Vol. 6, No. 4, 1990, pp. 811-814.

Urban Transportation Monitor, "Raleigh Beltline Project Wins First National Quality Initiative Award," November 24, 1995, p.6.

United States Department of Commerce, *Earthquake History of the United States,* Publication 41-1, edited by Jerry L. Coffman and Carl A. von Hake, Washington, D.C., 1973.

United States Geological Survey, National Earthquake Information Center, World Wide Web page, January 1996.

United States Geological Survey, "Probabilities of Large Scale Earthquakes Occurring in California on the San Andreas Fault," Working Group on California Earthquake Probabilities, *United States Geological Survey Open File Report 88-398,* Menlo Park, CA, 1988.

United States Office of Science and Technology Policy, *Earthquake Hazards Reduction: Issues for an Implementation Plan*, Working Group on Earthquake Hazards Reduction, Executive Office of the President, Washington, D.C., 1978.

Ray Zelinski, "Road to Recovery," *Civil Engineering*, April 1994, pp. 36-39.

Energy References

William P. Barrett, "Domestic blockade?" *Forbes*, September 3, 1990.

Choosing A Sustainable Future: The Report of the National Commission on the Environment, Island Press, Washington, D.C., 1993.

M. DeLuchi, D. Sperling, and R.A. Johnson, *A Comparative Analysis of Future Transportation Fuels*. Report UCB-ITS-RR-87-13. University of California, Berkeley, 1987.

Pierre Desprairies, "The outlook for oil: New shocks? New remedies?" *Natural Resources Forum*, August 1990, pp. 222-226.

Energy Information Administration, *Annual Energy Outlook*, 1994 with Projection to 2010, Department of Energy, 1994.

Energy Information Administration, *Annual Energy Review 1993*, U.S. Department of Energy, Washington, D.C., 1993.

_______, "Energy: Pipe Dreams in Central Asia," *The Economist*, May 4, 1996, p. 37.

_______, "The Future of Energy: The Battle for World Power," *The Economist*, October 7, 1995.

General Accounting Office, *Other Nations' Policies to Reduce Oil and Coal Use in Transport and Industry*, Washington, D.C., May 1993.

Micha Gisser and Thomas H. Goodwin, "Crude Oil and the Macroeconomy: Tests of Some Popular Notions," *Money, Credit, and Banking*, pp. 95-103.

David L. Greene and Yuehui Fan, "Transportation Energy Intensity Trends: 1972-1992," *Transportation Research Record 1475*, 1994.

Michael M. Hutchison, "Structural change and the macroeconomic effects of oil shocks: empirical evidence from the United States and Japan." *Journal of International Money and Finance* (1993), 12, pp. 587-606.

International Symposium on the Effects of Energy Shortage on Transportation Balance, Proceedings, Transportation Res., Vol. 8, Pergamon Press, 1974.

Making National Energy Policy, edited by Hans H. Landsberg, Resources for the Future, Washington D.C., 1993.

Klaus Matthies, "Lessons from Three Oil Shocks," *Intereconomics*, March/April 1993, pp. 55-60.

Martin V. Melosi, *Coping with Abundance: Energy and Environment in Industrial America*, University of Houston, Temple University Press, 1985.

Phillip S. Myers, "Reducing Transportation Fuel Consumption: How Far Should We Go?" *Automotive Engineering*, September 1992.

Pietro S. Nivola and Robert W. Crandall, *The Extra Mile: Rethinking Energy Policy for Automotive Transportation*, The Brookings Institution, Washington D.C., 1995.

Oak Ridge National Laboratory, *Transportation Data Energy Book*, 13th ed., Oak Ridge, TN, 1993.

Ernest J. Oppenheimer, *Solving the U.S. Energy Problem*, Pen & Podium, Inc., New York, 1984.

Resources for the Future, *Making National Energy Policy*, edited by Hans H. Landsberg, Washington D.C., 1993.

Karl M. Ruppenthal, *Energy for Transportation - Its Availability, its Cost, and its Conservation*, Centre for Transportation Studies, University of British Columbia, Vancouver, Canada, 1981.

Jeffrey Sachs, "The Oil Shocks and Macroeconomic Adjustment in the United States," *European Economic Review 18* (1982), pp. 243-248.

D.J. Santini, "Past and Future of the Petroleum Problem: The Increasing Need to Develop Alternative Transportation Fuels," Transportation Research Record, No. 1175.

Zachary A. Smith, *The Environmental Policy Paradox*, Northern Arizona University, Prentice Hall, Englewood Cliffs, New Jersey, 1992.

John A. Tatom, "The 1990 Oil Price Hike in Perspective," *Federal Reserve Bank of St. Louis*, November/December 1991, pp. 3-18.

Philip K. Verleger, Jr., "Understanding the 1990 Oil Crisis," *The Energy Journal*, pp. 15-33.

Global Warming References

President William J. Clinton, Vice President Albert Gore, Jr., *The Climate Change Action Plan*, Washington, D.C., October 1993.

Samuel Fankhauser, *Valuing Climate Change: the Economics of the Greenhouse,* Economic and Social Research Council, Earthscan Publications Ltd, London, 1995.

Samuel Fankhauser, "The Social Costs of Greenhouse Gas Emissions: An Expected Value Approach", *The Energy Journal,* Vol. 15, No. 2, 1994, pp. 157-184.

James J. MacKenzie, Michael P. Walsh, *Driving Forces: Motor Vehicle Trends and their Implications for Global Warming,* Energy Strategies, and Transportation Planning, World Resources Institute, Washington, D.C., December 1990.

United Nations Conference on Trade and Development, Combating Global Warming: Study on a Global System of Tradable Carbon Emission Entitlements, United Nations, New York, 1992.

Michael P. Walsh, "Motor Vehicle Trends and their Implications for Global Warming," *Transport Policy and Global Warming,* European Conference of Ministers of Transport, 1992, pp. 73-74.

Labor Strikes

Steve Beroldo, "Effects of Golden Gate Transit Strike on Highway 101 Corridor," *Transportation Quarterly,* Vol. 43, No. 2, Eno Foundation for Transportation, Inc., April 1989, pp. 225-238.

Michael D. Meyer and Peter Belobaba, "Contingency Planning for Response to Urban Transportation System Disruptions," *APA Journal,* pp. 454-465.

Bert A. Spector, "Air Traffic Controller," *Harvard Business School,* HBS Case Services, Boston, MA, 1982.

Rail References

The 21st Century Limited: Celebrating a Decade of Progress. High Speed Rail/Maglev Association, Alexandria, VA. Reichman Frankle, Englewood Cliffs, N.J., 1994.

Tony R. Eastham, "High-Speed Ground Transportation Development Outside the United States," in *Journal of Transportation Engineering,* Vol. 121, No. 5, pages 411-416; September-October 1995.

Tony R. Eastham, "High-Speed Rail: Another Golden Age?" in Scientific American, September 1995, 150th Anniversary Issue: Key Technologies for the 21st Century.

Sharon Greene and Associates, Candidate High-Speed Rail Stations and Intermodal Connectivity, California Intercity High-Speed Rail Study, February 15, 1996, pp. 1-5.

J.A. Harrison, "High-Speed Ground Transportation is Coming to America - Slowly," in *Journal of Transportation Engineering,* Vol. 121, No. 2, pages 117-123; March-April 1995.

A High Speed Rail Revolution in the U.S.? Lessons from the French and Texas TGV, by Helen Ng, Sloan School of Management, Center for Transportation Studies, Massachusetts Institute of Technology, July 8, 1994

Intercity Passenger Traffic and Economic Analysis of ISTEA Corridors: a GIS Approach, 1995

Marcia D. Lowe, *Back on Track: The Global Rail Revival*, Worldwatch Paper 118, Worldwatch Institute, Washington, D.C., April 1994.

Kenneth M. Mead, "High-Speed Ground Transportation and Transportation Decision-Making A New Perspective," *High Speed Ground Transportation Systems I: Planning and Engineering*, Proceedings of the First International Conference on High Speed Ground Transportation (HSGT) Systems, 1992.

William D. Middleton, "Freight railroads welcome commuters-sort of," *Railway Age*, November 1994.

Daniel Roth, "Incremental High-Speed Rail Issues," *Transportation Quarterly*, Vol. 49, No. 2, Spring 1995.

Daniel Roth, *Incremental High-Speed Rail in the U.S.: Economic and Institutional Issues*, Thesis, Massachusetts Institute of Technology, September 1994.

James Rozek and John A. Harrison, "Grade Crossing Safety and Economic Issues in Planning for High-Speed Rail Systems," *Transportation Research Record*, No. 1177.

Transportation Research Board, *In Pursuit of Speed: New Options for Intercity Passenger Transport*, National Research Council, Special Report 233, Washington, D.C., 1991.

United States Army Corps of Engineers, 1990. *National Maglev Initiative: Preliminary Implementation Plan*. Washington D.C., June 1990.

United States Committee on Banking, Finance and Urban Affairs, *New Urban Rail Transit: How Can its Development and Growth-Shaping Potential be Realized?*, 96th Congress, 1st Session, U.S. Government Printing Office, Washington, D.C., December 1979, p.207.

United States Congress. Senate. 1990. *Magnetic Levitation Transportation Act of 1990, Hearing before the Subcommittee on Surface Transportation of the Committee on Commerce, Science, and Transportation*. Report 101-665. 101st Congress, Second Session, Washington, D.C., March 21, 1990.

United States General Accounting Office, *High-Speed Ground Transportation: Issues Affecting Development in the United States*, Report of the Chairman, Committee on Energy and Commerce, House of Representatives, Washington, D.C., November 1993, GAO/RCED-94-29

Urban Mass Transit Administration, *Policy Toward Rail Transit*, Department of Transportation, Federal Register, Appendix, Tuesday, March 7, 1978, Part III.

Joseph Vranich, *Supertrains: Solutions to America's Transportation Gridlock*, St. Martin's Press, 1993.

Michael Walrave, "High-Speed Rail: An Important Asset Reconciling Mobility, Energy Saving and Environmental Requirements," In: *Reconciling Transportation, Energy and Environmental Issues: The Role of Public Transport*, Conference Proceedings, European Conference of Ministers of Transport, European Commission. May - June, 1994.

Wilbur Smith Associates, with Flight Transportation Associates, J. R. Ramos Associates, *draft Working Paper #3: Cost Comparison of Mode Alternatives, California HSR Economic Impact*, San Francisco, February 19, 1996.

Risk References

Frank S. Glendening, CPA, *Business Interruption Insurance*, what is covered, The National Underwriter Company, Cincinnati, Ohio, 1980.

Peter G. Moore, *The Business of Risk*, Cambridge University Press, New York, 1983.

Joseph G. Morone and Edward J. Woodhouse, *Averting Catastrophe: Strategies for Regulating Risky Technologies*, University of California Press: Berkeley, Los Angeles, London, 1986, p. 148.

Risk and Chance: selected readings, edited by Jack Dowie and Paul Lefrere, The Open University Press, Milton Keynes, Stony Stratford, England, 1980.

K. S. Shrader-Frechette, *Risk and Rationality: Philosophical Foundations for Populist Reforms*, University of California Press, Berkeley, 1991.

The Social and Cultural Construction of Risk: Essays on Risk Selection and Perception, edited by Branden B. Johnson and Vincent T. Covello, D. Reidel Publishing Company, Boston, 1987.

Emmett J. Vaughan, *Fundamentals of Risk and Insurance*, 5th Edition, University of Iowa, John Wiley & Sons, New York, 1989.

Severe Weather References

Desda Moses and Lori Sharn, "Economic Cost of the '96 Blizzard," *USA Today*, January 11, 1996.

The Unesco Press, World Catalogue of Very Large Floods, A Contribution to the International Hydrological Programme, Paris, 1976, pp. 415-423.

William C. Vantuono, "Blizzard of '96 stops passenger trains cold - almost," North America in Transit, *Railway Age,* February 1996, p. 14.

Terrorism References

Center for National Security Studies, "Recent Trends in Domestic and International Terrorism," CDT World Wide Web home page: http://www.cdt.org/, Washington, D.C., April 26, 1995.

William C. Chmelir, "Terrorism and Transportation in the 1990s," *Defense Transportation Journal,* August 1990, pp. 22-24.

Theodore Downes-Le Guin, Bruce Hoffman, *The Impact of Terrorism on Public Opinion, 1988 to 1989,* RAND, Santa Monica, California, 1993.

Karen Gardela, Bruce Hoffman, *The RAND Chronology of International Terrorism for 1986,* RAND, Santa Monica, CA, 1990.

Karen Gardela, Bruce Hoffman, *The RAND Chronology of International Terrorism for 1987,* RAND, Santa Monica, CA, 1991.

Karen Gardela, Bruce Hoffman, *The RAND Chronology of International Terrorism for 1988,* RAND, Santa Monica, CA, 1992.

Dennis Hevesi, "Small Blast Damages Detector Serving La Guardia Airport: A Note Left at the Scene Refers to Waco Incident," *New York Times,* Sunday, October 15, 1995.

Bruce Hoffman, *Recent Trends and Future Prospects of Terrorism in the United States,* RAND, Santa Monica, CA, May 1988.

Kevin Jack Riley, Bruce Hoffman, *Domestic Terrorism: A National Assessment of State and Local Preparedness,* RAND, Santa Monica, California, 1995.

Jeffrey D. Simon, *The Terrorist Trap: America's Experience with Terrorism,* Indiana University Press, Bloomington, Indiana, 1994.

"Terrorism: What is terrorism?" *The Economist,* March 2, 1996, pp. 23-25.

United States Department of State, *Patterns of Global Terrorism 1994,* Office of the Secretary of State, Office of the Coordinator for Counterterrorism, April 1995.