Background Papers on Panel Topics
prepared for

*The Search for Wise Energy Policy*

Conference

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This series of background papers was prepared by a team of graduate students in the School of Public and Environmental Affairs (SPEA) at Indiana University in support of the conference “the Search for Wise Energy Policy.” This conference was organized by SPEA and is scheduled for June 11, 2009 in the Mayflower Hotel in Washington, D.C.

The primary purpose of these papers is to provide background information related to most of the primary topics of the conference. The students were asked to review the appropriate literature and web sites in each of seven areas of energy policy and to prepare fairly concise review articles for use of the panelists. These papers have not yet been subjected to expert peer review. The opinions expressed are those of the individual authors, not the School of Public and Environmental Affairs or Indiana University.

This team of students was supervised by Professors Evan Ringquist and J.C. Randolph. Any omissions or errors are the responsibility of this team.
Panel 3: Changing Patterns in Energy Demand and Use

B. Transportation – Madhavi Gosalia

1.0 The Context for Transportation

Transportation affects vitality, growth and health of a nation’s economic and social systems. In 2007, transportation and related industries made up 10.8% of the US GDP and employed 10% of the labor force (Pocket Guide to Transportation 2009).

In 2007, the transportation sector in the US consumed 28.64% (EIA) of the total energy used and 97.48% of that energy came from petroleum-based fuels (National Transportation Statistics, BTS). The US imported 58% of petroleum that was consumed during 2007 (Energy Information Administration).

The dependence on oil and its environmental effects pose serious challenges for the transportation sector and the US economy. In the light of these challenges, the 21st century requires us to think about transportation as more than a mere means to move goods and people. It forces us to think about the impact of our transportation-related choices on other spheres of our lives – energy security, environmental safety and efficiency.

This paper discusses the behaviors that can be encouraged, as well as the public policy measures that can be used to encourage them, in order to meet the energy security, environmental safety and efficiency goals as they relate to transportation. The behaviors and policy measures are organized along the lines of consumers, vehicles and infrastructure - the components of a transportation system. The paper focuses on surface transportation, primarily on passenger car travel, because that is the largest segment of transportation demand as shown in Table 1.1.

Table 1.1: Vehicle-miles by transportation mode in the United States in 2006.

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Air</td>
<td>6,619</td>
<td>0.22%</td>
</tr>
<tr>
<td>Highway</td>
<td>3,014,116</td>
<td>99.61%</td>
</tr>
<tr>
<td>Transit</td>
<td>4,684</td>
<td>0.15%</td>
</tr>
<tr>
<td>Rail</td>
<td>599</td>
<td>0.02%</td>
</tr>
</tbody>
</table>

Source: National Transportation Statistics, Figure 1-31, Bureau of Transportation Statistics
1.1 Environmental Consequences of Energy Use in the Transportation System

1.1.1 Transportation and Climate Change

Over the last 15 years, transportation has overtaken all other sources as the major contributor of greenhouse gas (GHG) emissions in the environment (US Energy Information Administration). Unless it is addressed, this trend will continue as the demand for transportation grows. In short, addressing energy use in the transportation sector will be a critical element of any effective climate change policy.

1.1.2 Transportation and Air Pollution

According to the Transportation Statistics Annual Report 2007, in 2006 transportation contributed 54% of the nation’s pollution from carbon monoxide, 36% from nitrogen oxides, 22% from volatile organic compounds, and 1.4% from sulfur dioxide.

1.1.3 Overall Environmental Costs of Energy Use in Transportation

The most comprehensive assessment places the cost of environmental externalities from fuel use in motor vehicles at between $38.3 billion and $546.6 billion (Delucchi 2000). These figures, however, reflect fuel use and prices in 1990. Updating fuel use and prices to 2007 figures, the estimated cost of environmental externalities from fuel use in motor vehicles is between $67.8 billion and $965.9 billion (the latter figure being far less credible). Using $67.8 billion as a lower bound, the estimated cost of environmental externalities associated with fuel use in motor vehicles is at least $10 per barrel of oil or 48 cents per gallon of fuel consumed.

1.2 Security Consequences of Energy Use in the Transportation System

1.2.1 Security Concerns Regarding Source of U.S. Petroleum Imports

In 2008, the U.S. imported nearly 60 percent of its petroleum consumption. The sheer volume of imports poses obvious security risks, but the sources of these imports multiply these risks. Table 1.2 reports total petroleum imports to the U.S. in 2008 from the top seven nations. The top two sources of imports, Canada and Mexico, border the U.S., have strong and stable democratic governments, and are staunch U.S. allies. The remaining nations on the list, however, are all located a great distance from the U.S. In addition, each of these nations has unstable governments (e.g., Nigeria, Iraq), governments that are avowedly hostile to the United States (e.g., Venezuela), or significant elements of their population that are hostile to the United States (e.g., Saudi Arabia, Algeria) - and many are located in the volatile Middle East (e.g., Saudi Arabia, Iraq).
Table 1.2: Oil imports to the United States by country in 2008.

<table>
<thead>
<tr>
<th>Country</th>
<th>US Oil Imports in 2008 in Millions of Barrels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>9222</td>
</tr>
<tr>
<td>Mexico</td>
<td>4810</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>5700</td>
</tr>
<tr>
<td>Venezuela</td>
<td>4430</td>
</tr>
<tr>
<td>Nigeria</td>
<td>4050</td>
</tr>
<tr>
<td>Iraq</td>
<td>2400</td>
</tr>
<tr>
<td>Algeria</td>
<td>1880</td>
</tr>
</tbody>
</table>

Source: EIA 2009

1.2.2 Costs of Securing Access to U.S. Petroleum Imports

Several observers have noted that the US spends a great deal of money securing access to petroleum from the Middle East and elsewhere. Several economists have attempted to estimate this “oil import premium.” Delucchi and Murphy (2008) estimate that the security costs of oil imports range between $7 and $20 per barrel of oil, or 17 cents to 48 cents per gallon of gasoline. Leiby (2005) provides a 90% confidence interval of $6.70 - $23.25 per barrel, with a best estimate of $13.60 per barrel of oil, or roughly 33 cents per gallon of gasoline.

1.3 Affordability and Energy Use in the Transportation System

1.3.1 Private Costs of Energy Use in Transportation

Total spending for petroleum makes up a small but meaningful percentage of US GDP. In 1981, total spending on petroleum and petroleum products constituted roughly 5 percent of GDP, the highest figure on record. Since that time, the share of GDP allocated to petroleum expenditures has fallen to around 2 percent of GDP. This trend is due in part to reductions in the real price of petroleum, and in part to the decreased energy intensity if the US economy. Since only 60% of US petroleum consumption goes to transportation, the total private cost of petroleum consumption for transportation is just over 1% of GDP.

One might also measure the private cost of energy consumption in transportation at the level of individual households. According to the most recent figures available, the average US household spent $1289 on gasoline and motor oil in 2004 (in 2000$; U.S. Bureau of Transportation Statistics 2006). This figure has not changed meaningfully over the past decade. These expenditures are not equally distributed across households. According to the US Energy Information Administration (2001), transportation fuel
expenses for households in the lowest income category ($620 for household with incomes below $5000) were less than half that of households in the highest income category ($1549 for households with incomes above $75,000). For most households, then, significant increases in transportation fuel costs will have little effect on aggregate expenditures or quality of life. For the very poorest households, however, these price increases might amount to several percentage points of income. If federal policies substantially increase the price of gasoline, therefore, these policies should be designed to limit the hardship experienced by these households.

1.3.2 Social Costs of Energy Use in Transportation

The private costs of energy use in transportation are generally estimated to be far below the social costs. One element of this social cost increment is the environmental externalities produced by petroleum combustion. Section 1.1.3 estimates these costs at $10 per barrel. A second element of the social cost increment is the military cost of securing access to imported oil. Section 1.2.2 estimates these costs at $7 - $14 per barrel.

The final element of social cost addressed here are the costs associated with (a) the market power of oil producers and consumers in the international system (i.e., monopoly and monopsony power) and (b) the macroeconomic adjustment costs associated with dramatic fluctuations in the price of oil. The best estimates of this social cost of oil dependence vary widely. Parry and Darmstadter (2003) estimate these costs at $5 per barrel with a 50 percent confidence interval between $2.50 and $15 per barrel (or 6 cents to 36 cents per gallon of gasoline). Green and Ahmad (2008), however, place a far larger estimate on these costs: $40 per barrel of oil or nearly $1 per gallon of gasoline (see Figure 1).

If we take the lower bound estimate of the cost of environmental externalities ($10 per barrel), the security costs of petroleum imports ($7 per barrel), and the costs associated with market power, wealth transfer, and macroeconomic adjustment ($5 per barrel), we obtain an estimate of the social cost premium of petroleum use in transportation of $22 per barrel, or roughly 51 cents per gallon of gasoline. This figure might be a reasonable starting point for a gasoline tax that seeks to match private costs of petroleum use with social costs.

Figure 1: Direct economic costs of U.S. oil dependence, 1970-2008

![Figure 1: Direct economic costs of U.S. oil dependence, 1970-2008](source: Oil Security Metrics Model, David L. Greene, Oak Ridge National Laboratory, April 2008)
1.4 Policy Goals and Targets Regarding Energy Use in the Transportation System

The overarching goal of transportation policy is a transportation system that meets the needs of users at an affordable cost, but that reduces the dependence of the transportation system on petroleum. This goal can be achieved through increasing the efficiency of current elements of the transportation system, and by moving the transportation system toward using alternative (especially reduced carbon) fuels. These changes in the transportation system will simultaneously address the environmental and security effects of the current system, and should also be designed with an eye toward affordability effects as well.

When considering barriers and opportunities for reshaping energy use in the transportation section, this paper will focus on what we view as the three most critical elements of the transportation system: consumers of transportation services; the vehicles used by these consumers; and the infrastructure that allows for the use of these vehicles.

2.0 Consumers

As seen in Figure 2.1, between 1970 and 1997 passenger vehicle miles traveled (VMT) grew as disposable income and population grew (BTS Special Report, October 2007). However, gasoline consumption was closely linked to oil prices. Between 1950 and 1973 gasoline consumption grew at an average annual rate of 4.3%, between 1970 and 1997 it grew at an average annual rate of 0.8% and post 1997 at an average annual rate of 1.5%. The difference between gasoline consumption and highway mileage increase can be explained by improvements in fuel efficiency of about 2% in the period between 1970 – 1997 (Source: Motor Gasoline Consumption 2008, EIA).

Figure 2.1: Vehicle miles traveled, real personal income, and population growth in the United States, 1970-205.
Government policy can address consumer energy use in transportation by (1) stimulating the market penetration of energy efficient vehicles, (2) encouraging the use of energy efficient modes of transportation, and (3) managing or structuring consumer demand for travel.

2.1 Stimulate the market penetration of energy efficient vehicles

2.1.1 Trends in Vehicle Fuel Efficiency

Consumers choose vehicles on the basis of a number of criteria, though performance, cost, and fuel economy are generally among the top criteria for selection. As figure 2.1 shows, after significant increases between 1975 and 1985, the average fuel efficiency of the US vehicle fleet has remained flat, or even declined slightly, over the past 20 years. Part of this decline is due to consumers purchasing more light duty trucks and SUVs, and part is due to consumers placing more emphasis on performance (i.e., size and power) in their vehicle purchase decisions. (Figure 2.2 shown as Figure 7 below).

![Figure 7. Light Truck Market Share and Fuel Efficiencies, 1975-2006](image)

2.1.2 Policies to Encourage Market Penetration of Fuel Efficient Vehicles

Government can play a key role in the diffusion of fuel efficient, environmentally friendly vehicles. The surest way to increase the proportion of consumers choosing fuel efficient vehicles is to increase the price of fuel, and the surest way to increase the price of fuel is through an increase in the tax on gasoline and diesel fuel. Compared with other policy tools for increasing fuel efficiency, such as increasing Corporate Automobile Fuel Efficiency (CAFÉ) standards (discussed below), increased gasoline taxes are generally more effective and less costly at encouraging the purchase of fuel efficient vehicles (e.g., Kleit 1990). Gasoline taxes would have to be increased substantially to effect meaningful change in consumer purchasing decisions, however, and are politically unpopular. A similar but less objectionable policy option might be to revise the current “gas guzzler tax” on the purchase of new vehicles, substantially increasing the tax and applying it on a sliding scale to all vehicles with below average fuel economy. This instrument would have the added benefit of sending a clearer signal to consumers regarding the cost
of choosing an inefficient vehicle. Alternatively, the federal government might provide tax incentives or other subsidies for the purchase of fuel efficient vehicles.

Consumers are often reluctant to purchase the new technology associated with efficient vehicles because there is no track record of performance and reliability. The government can lead the market by replacing its fleet with fuel efficient vehicles over time. This would serve the purpose of creating a market for fuel efficient vehicles and demonstrating the effectiveness of newer models of vehicles to consumers.

2.2 Encouraging the use of energy efficient modes of transport

There are two requirements for increasing the proportion of consumers choosing more efficient modes of transport; (1) providing alternative modes of transport, and (b) inducing consumers to select these modes. The need for alternate modes of transit and related matters are discussed in greater detail in the section on infrastructure. Here we emphasize policies to induce consumers to choose these modes.

In 2001, the Surface Transportation Policy Project created a Transportation Choice Ratio that examined not just the traffic congestion present in an area, but also the transit options available to travelers to avoid it. Convenience and cost are the primary considerations affecting the choice of transit mode, though the purpose of the trip, the availability of transit, and socioeconomic and demographic characteristics matter as well. In 2006, passengers paid an average of $1.12 per trip, using transit for an average trip length of 5.2 miles (this figure does not include subsidies for public transit: Public Transportation Fact Book, 2008). In the same year, the cost of owning and operating a vehicle was $0.52 per mile assuming an annual mileage of 15,000 miles (Source: BTS); this translates to $2.70 for a trip of 5.2 miles. Broadly speaking, economics favor the use of public transit when available and convenient.

The government can induce consumers to use public transit by using various pricing and supply management strategies. These include increasing the cost of passenger car travel whenever high frequency, well-routed transit is available by implementing area-pricing; charging high parking fees; and implementing congestion tolls. Non-monetary strategies include creating park and ride lots near railway and bus stations, creating awareness about the availability and convenience of public transport, and ensuring the reliability of public transit systems. Several analyses illustrate that the most effective strategies for reducing energy consumption in private transportation is a combination of tools that target consumer vehicle choices (e.g., a gasoline tax) and tools that target consumer mode choices (e.g., congestion tolls: see Kleit 2004).

2.3 Managing the demand for travel

The government has an important role to play in managing the demand for travel as well. It can help reduce the demand for transportation by encouraging companies to promote telecommuting, flex-working hours, car-pooling or rideshare.

Table 2.1 (shown as Table 5 below) lists several options for managing consumer demand for travel. A 2003 report by the Pew Center on Global Climate Change concludes that these non-monetary traffic control measures can be expected to yield a 6% reduction in vehicular travel. Therefore, these strategies are worth looking into as options for managing consumer demand for transportation.
2.4 Barriers to Implementation of Policy Measures or to their Effectiveness

2.4.1 Social Status of Fuel Efficient Vehicles and Public Transportation

Until recently, vehicles with higher fuel economy have been viewed as symbols of thrift, and are therefore viewed with derision by large groups of consumers. Public transport is held in low esteem by even larger groups of consumers, who view this transport option as reserved for the working class (Garrett and Taylor 1999). This perception is changing as climate change awareness increases; fuel efficient vehicles are slowly being viewed as a means of resource conservation. Until the ideas of fuel efficiency and resource conservation become socially acceptable and trendy, adoption of fuel efficient vehicles will continue at a slow pace.

2.4.2 Incompletely Rational Consumer Decision Making

Households do not keep track of gasoline expenses on a day-to-day basis. They also have little idea about scientifically determining the discount rate or creating a payback period model for evaluating the cost-effectiveness of vehicles. Instead, consumer vehicle choices are usually driven by day-to-day changes in gas prices (Car Buyers and Fuel Economy 2006). This lack of complete information results in over- or under-estimating fuel consumption and savings of fuel efficient vehicles, and provides a barrier to the purchase of more efficient vehicles.

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Table 5

<table>
<thead>
<tr>
<th>Transportation Control Measure</th>
<th>Percent Reduction in Vehicle Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employer trip reduction</td>
<td>0.2% to 3.3%</td>
</tr>
<tr>
<td>Area-wide ridesharing</td>
<td>0.1 to 2.0</td>
</tr>
<tr>
<td>Transit improvements</td>
<td>0.0 to 2.6</td>
</tr>
<tr>
<td>HOV lanes</td>
<td>0.2 to 1.4</td>
</tr>
<tr>
<td>Park-and-ride lots</td>
<td>0.1 to 0.5</td>
</tr>
<tr>
<td>Bicycle/pedestrian facilities</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>Parking pricing</td>
<td></td>
</tr>
<tr>
<td>Work</td>
<td>0.5 to 4.0</td>
</tr>
<tr>
<td>Non-work</td>
<td>3.1 to 4.2</td>
</tr>
<tr>
<td>Congestion pricing</td>
<td>0.2 to 5.7</td>
</tr>
<tr>
<td>Compressed work week</td>
<td>0.0 to 0.6</td>
</tr>
<tr>
<td>Telecommuting</td>
<td>0.0 to 3.4</td>
</tr>
<tr>
<td>Land use planning</td>
<td>0.0 to 5.2</td>
</tr>
<tr>
<td>Signal timing</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>Incident management</td>
<td>0.0 to a 0.1 increase</td>
</tr>
<tr>
<td>Emissions/VMT tax</td>
<td>0.2 to 0.6</td>
</tr>
<tr>
<td>Buy-backs of older cars</td>
<td>&gt; 0.0</td>
</tr>
</tbody>
</table>

Source: Greene, 1996, Table 7.3.
2.4.3 Relative inelasticity to fuel prices

Figure 2.3 shows a three-month moving average of the percentage change of monthly data from one year to the next (i.e., February 2001 data were compared with February 2000 data). In 2008, when gasoline prices were 20-30% higher, VMT declined nearly 5% from the previous year. When gasoline prices fell dramatically in late 2008, VMT increased slightly. This demonstrates that it takes large price increases in fuel to cause any meaningful reduction in the number of vehicle miles travelled.

Figure 2.3: three-month moving average of vehicle miles traveled and gasoline price.

3.0 Vehicles

Vehicle manufacturers are driven by profit motive and competitive forces. US automakers have focused on developing bigger, more powerful vehicles (light duty vehicles) to meet consumer demand. Another reason for US automakers to aggressively market light duty vehicles is profitability. With their comparatively high labor cost structure, US automakers face stiff competition from foreign carmakers in the passenger cars segment. This results in low profit margins. However, US automakers have enjoyed a more protected market in the light duty truck segment because (a) few foreign manufacturers emphasized these vehicles in their product lines, and (b) a 25% import duty is levied on light duty trucks not manufactured in Canada or Mexico. Consequently, light trucks have captured an increasingly large share of the US vehicle market. One consequence of this shift has been the leveling off and reduction in the fuel efficiency of the US vehicle fleet (see Figure 2.2 shown as Figure 7 above).
One approach to improving energy efficiency in transportation is for government policies to target the fuel efficiency of vehicles. The current economic downturn and the structural changes in the US auto industry make this a propitious time for government to encourage vehicle manufacturers to make fuel efficient and environmentally friendly vehicles. In this context, the government can promote the following behaviors among manufacturers through the use of public policy to reach its goals:

3.1 Encourage the production of more fuel efficient vehicles

The federal government could encourage manufacturers to produce more fuel efficient vehicles by setting rigorous fuel efficiency standards for new vehicles or by mandating the sale of minimum percentage of fuel efficient vehicles. In practice, the CAFÉ standards do both.

While improving fuel efficiency reduces CO₂ emissions through reduction in fuel consumption per mile, it does not ensure lower emissions per gallon of fuel consumed. An alternative approach, therefore, would be to set greenhouse gas emissions standards for motor vehicles that take into consideration lifecycle emissions of fuel from production to consumption. By focusing on emissions standards, this low carbon fuel standard (LCFS) approach avoids having to adjust emissions standards each time technology changes or vehicle model changes occur. It is also technology-neutral, and therefore limits the role of the government to achieving outcomes, while the market determines the most efficient way to get there. This standard allows the government to achieve difficult goals without having to impose direct taxes such as carbon taxes.

The new fuel economy standards proposed by the Obama administration merge the CAFÉ standards with a greenhouse gas emission standard. Since manufacturers will be able to meet this standard by increasing fuel economy or decreasing the carbon footprint of the vehicle, it is unclear just how much fuel economy will improve under the new regulations. It is clear that average fuel economy will rise above the current standard of 27.5 miles per gallon (mpg) for passenger cars and 24mpg for light duty trucks.

In addition to establishing stringent fuel economy standards, the government might offer subsidies, tax incentives, or monetary “prizes” to manufacturers who produce larger number of more fuel efficient vehicles.

3.2 Encourage the Development and Diffusion of Alternate Vehicle Technologies
Alternate technologies to the current internal combustion engine (ICE) need to be developed both to reduce reliance on foreign sources for fuel and to reduce GHG emissions, but vehicle manufacturers are conservative when it comes to investing in changing technologies unless they are certain that a market exists. Research, development, production and marketing of new technologies are capital- and labor-intensive. Heavy capital investments result in high ownership cost for the early adopters of new technology. The high initial cost of ownership of new vehicles with no history of performance and reliability results in slow adoption. As illustrated by Fig. 3.1, it takes 10 – 15 years before new technologies attain a market share of 40% or more.

Another challenge that manufacturers face while rolling-out new vehicle technologies is the need for refueling and maintenance infrastructure to build product acceptance in the market. Here, the bar for convenience is set by the infrastructure for the ICE. Often the challenge with infrastructure can be explained in terms of a chicken-and-egg situation where it is not financially viable to develop large refueling and maintenance infrastructure for a vehicle technology that hasn’t gained market share - and in turn a vehicle will not gain market share unless consumers are assured that they will have access to refueling and maintenance support as needed.

Alternatives to the current ICE are, in order of maturity of development, advanced ICE (including ethanol and high efficiency diesel engines), hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV), vehicle to grid PHEV (V2G), and fuel cell vehicles (FCV). Recent assessments conclude that both high efficiency diesel ICEs and hybrid engines are cost-effective alternatives to the traditional ICE, while ethanol fueled engines are not (Keefe, Griffin, and Graham 2008). A similar assessment of plug in hybrid electric vehicles (PHEVs)
concluded that these vehicles are cost effective only under conditions of high fuel costs and low battery costs. PHEVs can, however, reduce gasoline consumption by 45%. Given the substantial social costs of transportation dependence on petroleum (see section 1.3), the analysis concludes that there is sufficient justification for governmental efforts to encourage this technology (Simpson 2008).

The direction the industry takes with technology is influenced by government policies, as evidenced in the case of zero emission electric vehicles in California. Another example would be the impetus that hydrogen based FCV received in 2003 under the leadership of former President Bush. The industry is experiencing yet another shift in government backing for technologies under the new administration, which has reduced funding by 60% to FCV projects and is promoting the development of advanced battery-powered cars and advanced ICE and biofuels. Such shifts lead to inefficiencies in the productivity of research dollars, as money keeps shifting from one technology to another.

The government may be more effective in promoting the development and diffusion of alternate technologies or fuels by adopting a neutral, outcomes-based approach. As with other industries where winning technologies are determined by market forces, the government should allow market forces to determine which technologies to support. It could adopt a SEMATECH type model of collaborative development. SEMATECH is a consortium of semiconductor companies that works together to develop and promote semiconductor technologies. The government could promote development of technological excellence centers in which manufacturers work towards developing promising future technologies. Collaborating on technologies may help manufacturers pool resources to build infrastructure and promote technologies they believe will thrive in the market. This will lead to constructive competition within the industry and help achieve energy policy goals through focused efforts.

Government support of such centers of excellence should be based on outcomes and performance. Support for these organizations can take the form of subsidies, grants etc. Manufacturers who are the first to market viable technologies should also incentivized through tax breaks, incentives, subsidies etc. The support program should be designed to encourage manufacturers to produce vehicles that meet energy policy goals and discourage any other development. The program goals have to be carefully planned and phased in to allow manufacturers, their suppliers, customers and other stakeholders to bring about changes in infrastructure and develop skills among the labor base. This ‘push’ strategy combined with the ‘pull’ strategy which encourages consumers to purchase fuel efficient vehicles will help adoption of viable technologies without placing government in the difficult spot of deciding between many vested technological interests.

3.3 Barriers to Vehicle Improvements

3.3.1 More Efficient Vehicles May Compromise Safety

One common criticism is that increasing fuel efficiency standards requires the production of smaller and lighter cars that are unsafe. A substantial amount of evidence supports this perspective. Other studies, however, show that higher fuel efficiency can be achieved by designing and building smaller and lighter cars that have similar crashworthiness as bigger and heavier cars (Bandivadekar et al., 2008).
Reduction in vehicle size and weight can significantly reduce fuel consumption. Every 10% of weight reduced from the average new car or light truck can cut fuel consumption by around 7%. The three strategies to reduce weight are (1) aggressive material substitution using aluminum and high-strength steel which can cut vehicle weight by up to 20%, (2) vehicle design changes, which can reduce vehicle weight by redesigning or reconfiguring the vehicle, and (3) vehicle downsizing which has the potential to reduce the vehicle’s weight by 9% to 12% for cars and up to 26% for SUVs, minivans and pickups. Together these can lead to vehicle weight reduction of 20-35% by 2035. These approaches are expected to cost $2 to $3.50 per kilogram of weight saved in the average vehicle. (Bandivadekar et al. 2008)

3.3.2 The Rebound Effect

More fuel-efficient vehicles make travel less expensive, which encourages consumers to drive more. This “rebound effect” partially offsets the environmental and security benefits from increases in fuel efficiency. Figure 3.2 shows that as fuel efficiency increases, consumers drive more miles per vehicle, thus consuming more fuel. In addition, an increase in the total miles travelled can lead to higher wear and tear, lower vehicle life and increased vehicle scrapping. These effects can be mitigated through higher fuel taxes, pay-at-pump insurance, and carbon taxes for higher fuel usage, thereby increasing the cost per mile of driving. Of course, these measures will negatively affect lower income groups. However, when such taxes are used in conjunction with measures to increase ownership of fuel efficient vehicles, they may balance each other out.

3.3.3 Fuel Efficiency Standards are Relatively Inefficient

One benefit of fuel efficiency standards is that they target the behavior of a small number of vehicle manufacturers, rather than targeting the behavior of millions of drivers, as the gasoline tax does. Consequently, fuel efficiency standards tend to be more popular among citizens. Most assessments of these instruments, however, show that increasing vehicle mpg using CAFÉ standards is far more expensive than increasing mpg using a gasoline tax. For example, Kleit (2004) estimates that an 11 cent per gallon gasoline tax would increase average vehicle fleet efficiency as much as a 3mpg increase in the CAFÉ standard, and at a cost saving of $290 million per year.

3.3.4 Conflicting Interests

New technologies may disrupt the way the vehicle manufacturing, maintenance and refueling industries have worked. An electric vehicle does not have nearly as many moving parts as an ICE, so this would
affect the supplier base; it does not require the oil change, filter replacement, coolant replacement and such other maintenance associated with ICE, so this affects the maintenance technicians; it does not need gasoline, so it eliminates the need for gasoline-related infrastructure. These industry segments - manufacturing, maintenance, refueling – together employ millions of people. A sudden switch towards new technologies that disenfranchise those currently employed will lead to resistance to change. The vision for future vehicle technologies includes advanced plug-in hybrids which will generate, store and send electricity back to the power grids. This disrupts the way utilities operate. Over time utilities could transform from large centralized power generation centers to smaller, more distributed networks with customers also playing the role of suppliers. Such a vision changes the market dynamics and could lead to utilities joining forces with other sectors to encourage resistance to change and maintenance of the status quo.

3.3.5 Energy security concerns and environmental concerns

While the security advantages of biofuels are obvious, the environmental advantages are less so. Estimates of the net energy value and fuel energy ratios associated with biofuels range widely, suggesting that biofuels either outperform or underperform traditional fossil fuel-based transportation fuels. Various analyses also conclude that greenhouse gas production from biofuels is both greater and less than that produced by fossil fuels. To the extent that we can draw general conclusions from this conflicting research, it suggests that (a) biodiesel produces less pollution and fewer greenhouse gasses than does corn ethanol (Hill et al. 2006), and that (b) the better, more comprehensive assessments conclude that biofuels produce fewer greenhouse gasses than do fossil fuels (Davis et al. 2009). Still, biofuels do generate substantial pollution, and their production consumes large quantities of water – by some estimates as much as 50 gallons of water for each gallon of ethanol (Domínguez-Faus et al. 2009). Moreover, current production of corn and soybeans is only sufficient to generate a small percentage of liquid fuels consumed in the US without a dramatic increase in the cultivation of marginal croplands, which would substantially increase the environmental consequences of biofuel production. The environmental effects of biofuels would be reduced if feedstocks could be shifted from grains to cellulose.

The current emphasis on advanced plug-in hybrids that rely on battery power also raises important questions with respect to environmental and security concerns. For example, while the air pollution and climate change benefits of hybrid technology are substantial, there have been very few lifecycle assessments of the environmental implications of manufacturing and disposing of the hundreds of millions of batteries necessary to support a national fleet of hybrid automobiles. In addition, reliance upon lithium batteries in hybrids may substitute one form of energy dependence for another. The US leads the world in battery technology research but does not have a manufacturing base. Virtually all lithium batteries are manufactured in Asia. In addition, the USGS reports that the US contains less than 4% of world lithium reserves. By contrast, Bolivia, Chile, and China contain 86% of world reserves (USGS 2006). Like oil, lithium is a commodity controlled by few countries.

These facts demonstrate that the pathway to energy security and environmental safety involves striking the right balance with technologies rather than switching dependence from one technology to another.
4.0 Transportation Infrastructure

4.1 Stresses on Transportation Infrastructure

4.1.1 Passenger Travel and Commuting

According to the Federal Highway Administration (2007), between 1980 and 1999, vehicle miles of travel grew by 76% while the number of new roads or lanes increased only 1.5%. In short, infrastructure growth has not kept pace with the growth in vehicle miles traveled. One consequence is longer travel times for commuters. Between 1983 and 2001, average commuting times increased while average commuting speeds decreased, and both changed at a faster rate than average commuting distances (US Federal Highway Administration 2007).

A second consequence is increased traffic congestion. In 1982 the national travel time index was 1.09. By 2005 it rose to 1.26. This means that a trip which took 60 minutes in 1982 took 65 minutes in 1985 and 75 minutes in 2005 during peak traffic hours. In addition to being frustrating and inconvenient for travelers, congestion has real economic costs. During 2005, congestion cost the nation 2.9 billion gallons in wasted fuel, 4.2 billion hours in total delay and $78.2 billion in total cost (Schrank and Lomax 2007). According to the Texas Travel Institute, between 1982 and 2005, the congestion costs increased from $16.2 billion to $78.2 billion (2005$). Per traveler this translates to an increase of $450, from $260 to $710 (Schrank and Lomax 2007).

4.1.2 Freight Shipments

Over the last 50 years, manufacturing has shifted overseas, and both the demand for transportation and the level of US imports have increased rapidly. Since 1970, the import share of GDP has tripled, while the export share has doubled. The projected growth in container imports is shown in Figure 4.1 below. (Transportation For Tomorrow, 2007)

Figure 4.1: Projected growth in container imports to the United States, 2000-2015.
An increasing share of the domestic freight system is also serving international trade shipments. According to forecasts by Global Insight, Inc., total freight movement (measured by ton-miles) is projected to increase by 92 percent in the next 30 years (Transportation For Tomorrow, 2007).

In 2006, trucks carried 84%, the railways carried 7.1%, and air freight carried 3.2% of the commercial freight business. The remaining was business was carried by water and pipelines (Industry Surveys, S&P, January 2009). While VMT by trucks has remained fairly constant as a percentage of total VMT since 1995, the FHWA’s freight analysis framework forecasts a 2.5% annual increase truck VMT until 2035. (Transportation For Tomorrow, 2007). The projected traffic at US ports is shown in Figure 4.2.

**Figure 4.2: Projected growth in container shipments to U.S. ports, 2004-2020.**

The average haul length of trucks has gone up from 398 miles in 1991 to 485 miles in 2001, and that of rail has gone up from 751 miles in 1991 to 859 miles in 2001. Companies are also using air freight over shorter distances; the average length of haul for air has gone down from 1346 miles in 1991 to 973 miles in 2001 (Bureau of Transportation Statistics).

**4.1.3 Implications**

This information indicates that the roadway transportation infrastructure in the US is under increasing pressure. This presents the government with a unique opportunity to dramatically change the infrastructure required to meet the challenges of the 21st century, through the use of public policy to reach the goals of energy security and environmental safety.
4.1 Expanding the Capacity of the Transportation Infrastructure

The Texas Travel Institute concludes that in order to ease congestion at 2005 VMT levels, 16,203 lane miles need to be added every year. In its 2007 report Transportation For Tomorrow, the National Surface Transportation Policy and Revenue Study Commission estimated the dollar range of capital investment needed to upgrade the US transportation infrastructure. These estimates are shown in Table 4.1. The government will have to use innovative approaches to fund infrastructure capacity expansion at this level.

**Table 4.1: Capital investment needed to upgrade the U.S. transportation infrastructure**

<table>
<thead>
<tr>
<th></th>
<th>Currently Sustainable</th>
<th>Range Through 2020</th>
<th>Range Through 2035</th>
<th>Range Through 2055</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>From</td>
<td>To</td>
<td>From</td>
<td>To</td>
</tr>
<tr>
<td>Highway</td>
<td>$68</td>
<td>$207</td>
<td>$240</td>
<td>$182</td>
</tr>
<tr>
<td>Transit</td>
<td>$13</td>
<td>$21</td>
<td>$32</td>
<td>$23</td>
</tr>
<tr>
<td>Freight Rail</td>
<td>$4</td>
<td>$5</td>
<td>$7</td>
<td>$5</td>
</tr>
<tr>
<td>Passenger Rail</td>
<td>$1</td>
<td>$7</td>
<td>$7</td>
<td>$9</td>
</tr>
<tr>
<td>All Modes Combined²</td>
<td>$86</td>
<td>$241</td>
<td>$286</td>
<td>$220</td>
</tr>
</tbody>
</table>

Such an expansion is required to meet the increasing demand for passenger travel, and more importantly, to ensure competitiveness of the US economy in the new global economic system.

Increasing the capacity of the US transportation infrastructure will have substantial benefits for the efficiency and productivity of the US economy. These improvements will also have real benefits for travelers in the area of convenience, comfort, and cost. On the other hand, it is not at all clear that increasing the capacity of the transportation infrastructure in a manner consistent with the design of the current system will do much, if anything, to promote the goals of environmental protection and security associated with energy use in this system. Stated differently, attaining the goals of security and environmental protection may require that federal policy emphasize improvements in the efficiency and the design of the transportation infrastructure over increases in capacity.

4.2 Harmonizing Intermodal Transport

Companies are using ever more sophisticated technology to manage their supply chain in terms of inventory turns, optimal distribution and cost of transport. These changes have transformed the role of transportation within corporate supply chains. There is growing pressure on international gateways
(including seaports, airports, and land border crossings) and the surface transportation infrastructure feeding into and leading out of those gateways to ensure timely connectivity. Despite the growing importance of intermodal connectivity, intermodal port connections have been called orphans of the freight transportation system. According to a DOT report to Congress, intermodal connectors have significant mileage with pavement deficiencies, and suffer from general lack of public agency awareness and coordination (Source: Brookings Institute). As the demand for freight transport increases there will be greater need for coordination between different modes of transport. The government can play a key role in encouraging research on the gaps between intermodal connectivity and solutions to bridge the same. These studies can inform the infrastructure expansion that needs to take place in the coming decades, thereby ensuring competitiveness of the US economy, reducing the economic costs of congestion and lost productivity, and reducing emissions that emanate while vehicles are idling.

The government can also improve transportation efficiency by making operational improvements on the roads that manage traffic through the use of intelligent transportation systems, better incident response and management, better traffic light signal coordination, ramp metering etc. In addition, it can manage the demand for traffic by implementing area-wide ridesharing, HOV lanes, park and ride lots, bicycle/pedestrian facilities parking fees, congestion pricing, carbon tax, tolls and such other programs. It can also manage the timing of traffic on roads and ports through the use of pricing schemes to ensure more even demand over a 24-hour period. Together such initiatives can bring about 6% to 10% reduction in VMT.

4.3 Provide More Efficient and Environmentally Friendly Transport Modes

In 2003, 290.8M people lived in the US. Of these, 241.4M lived in metropolitan areas (83%); 29.9M (10.3%) in micropolitan areas and 19.5M (6.7%) in territories outside core based statistical areas. Between 2000 and 2003, the US population grew 3.3 percent. The population in metro areas grew by 3.8%, in micro-areas by 1.6% and outside these territories by 0.5%. This trend will continue in the coming years. Within metropolitan areas the suburbs have seen a faster growth in population than central city areas.

Of the over 3.02B vehicle miles travelled (VMT), 66% were in urban areas and 34% were in rural areas (National Transportation Statistics, BTS Table 1-33). Metros are the fastest growing regions of the country and will place new demands on transportation needs as the population grows.

According to the “Commuting in America” report by the Transportation Research Board, between 1990 – 2000 there were significant changes in travel patterns as shown in Figure 4.4 (adjacent). Suburb-to-suburb commuting is the most dominant pattern, followed by intra-city flows. The concentration of traffic flows provides an opportunity for developing transit. This is borne out by the relationships between transit availability and use and density and modal usage as shown in Figures 4.5 and 4.6.

![Figure 4.4: Metropolitan flow map](image)
Transit development is justified by the growth of metropolitan and megapolitan areas, the changes in commuting patterns, and the congestion cost and pollution savings it brings. According to the 2007 Urban Mobility Report, in 2005 public transportation helped save 541 million hours, 340 million gallons of fuel and $10.2 billion. The government can play an active role in the development of public transit to achieve the congestion cost savings, which would lead to less demand for individual passenger car travel and reduce demand for petroleum. It will also help reduce emissions. The government can use its ability to cross-subsidize transit with revenue from other modes of transport as a demand management strategy.

Section 2.2 reports that consumers choose transport modes depending upon convenience and the purpose of the trip. This section reports that the choice of transport mode is affected by population density. Both of these factors are affected by land development patterns. Governments play an important role in determining land use, zoning rules, and town planning. Often planning is centered around the use of passenger cars as the primary mode of transport. Bicycling, walking, and public transit are not considered as potential travel options. Development is carried out over large areas (conventional development), rather than compact area (mixed-use) development, which results in increased efficiencies in terms of land use and transportation (Nelson Nygaard Consulting Associates). Higher residential densities and increases in mixed-use development might be aided by greater coordination between land use and transportation planning officials.

4.4 Barriers to Infrastructure Improvement

4.4.1 Financing

A serious constraint to the development of infrastructure is lack of adequate funding. The gap between financing available and investment required is shown in Table 4.2 below (Transportation for Tomorrow).
Traditionally, the government has relied on motor fuel taxes as the primary source revenue for highway development activity and to support other modes of transport. A recent study by the Transportation Research Board estimated that a 20% reduction in fuel consumption per vehicle mile is possible through government regulation or sustained fuel price increases. Reducing energy consumption has clear environmental and security benefits. Indeed, reducing fuel use, or increasing efficiency, are key goals of the policy instruments that target consumers and vehicle manufacturers. Improvements in fuel efficiency, however, will exacerbate the funding problem facing transportation infrastructure investments. In terms of motor fuel taxes, the gap in financing and required investment is estimated as shown in Table 4.3 below.

**Table 4.3: Investment gaps in transportation infrastructure.**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Currently Sustainable</th>
<th>Range Through 2020</th>
<th>Range Through 2035</th>
<th>Range Through 2055</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>From</td>
<td>To</td>
<td>From</td>
<td>To</td>
</tr>
<tr>
<td>Highway</td>
<td>$0.71</td>
<td>$0.88</td>
<td>$0.54</td>
<td>$0.85</td>
</tr>
<tr>
<td>Transit</td>
<td>$0.04</td>
<td>$0.10</td>
<td>$0.05</td>
<td>$0.10</td>
</tr>
<tr>
<td>Freight Rail</td>
<td>$0.01</td>
<td>$0.02</td>
<td>$0.01</td>
<td>$0.01</td>
</tr>
<tr>
<td>Passenger Rail</td>
<td>$0.03</td>
<td>$0.03</td>
<td>$0.04</td>
<td>$0.04</td>
</tr>
<tr>
<td>All Modes Combined</td>
<td>$0.79</td>
<td>$1.02</td>
<td>$0.63</td>
<td>$1.00</td>
</tr>
</tbody>
</table>
A comprehensive evaluation by the National Surface Transportation Policy and Revenue Study Commission evaluated various options for increasing revenues available for transportation infrastructure based upon their desirability and acceptability. This evaluation, presented in Figure 4.7 below, shows that indexed fuel taxes may be the best of the available options.

**Figure 4.7: Potential transportation revenue sources**

This chart provides a subjective evaluation of a series of alternative revenue sources against a set of criteria.

Source: Commission Staff analysis.
5.0 Conclusions

Of the total highways in the US, local governments own a 76%, states own 21%, and the federal government owns the remaining 3% (Our Nation’s Highways, 2008). Of the total funding for highways, the federal share has declined from 2% in 1970 to 1.4% in 2006. While the federal government provides a portion of the funding for highway development, most of the decisions for investment are made at state and local levels. There is little national level coordination of transportation development.

Barriers are even greater to integrating land use and transportation policy at the federal level, since virtually all land use policy decisions are the province of state and local governments. Viewed in this light, the barrier is more than an absence of a national policy – it is the absence of federal power required to craft such a policy.

The limited federal funding for transportation is apportioned through two different accounts, one for highway development and another for transit development. Highway funds are transferred to states on a pre-determined basis without any restrictions on how they are used, so long as they are used for highway related work. On the other hand, any funding for transit development requires detailed plans and justifications.

The 21st century challenges demand a national vision for transportation as a complete system. This vision should have a bias for environmentally friendly, cost-effective and time-efficient transport modes and means. By articulating a national vision the federal government provides strategic guidance and enables state and local governments to make politically risky decisions in the area of transportation infrastructure. For its part, the federal government should focus on ensuring smooth, well-integrated interstate, intermodal transport systems to ensure economic competitiveness and growth.

State level planning should be based on the need to develop various regions within its boundaries, and at the same time incorporate the national vision. It should also work closely with local governments, especially in large metropolitan areas, to help with planning and fundraising. State governments also have a key role to play in coordinating the development of megapolitan areas and in connecting large metro areas with each other through development of intercity transit options.

Local governments should focus on congestion management, town planning and development of multiple modes of transport to reduce travel time and vehicle miles within their jurisdiction.
References Cited


Laboratory for Energy and the Environment, Massachusetts Institute of Technology: Cambridge, MA.


