3. Vehicle Travel: Recent Trends and Environmental Impacts

Vehicle travel has increased substantially in recent decades. Factors contributing to this trend are numerous. Although some new travel can be attributed to shifting demographics and market characteristics, substantial evidence suggests that much of the increase is a direct result of changing development patterns.

As development becomes more dispersed, with increasing numbers of families living on large lots at the urban fringes, and as jobs and housing become increasingly segregated from one another, distances between destinations have increased. Further, people are forced to make more trips by car, since the distances between destinations are often too great to walk or bike.

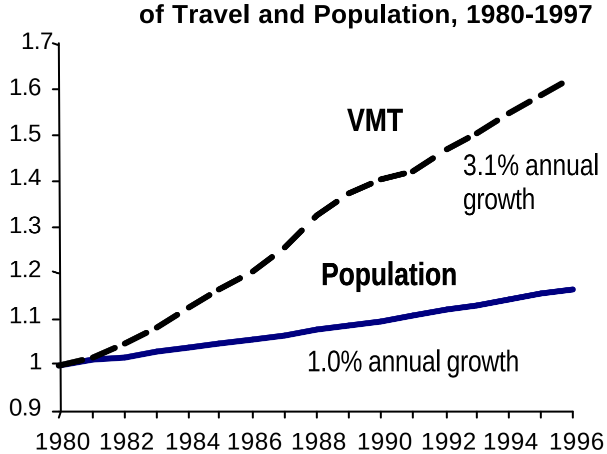
Rapid increases in vehicle travel have negatively affected the environment in numerous ways. The growth in travel degrades air quality, impairs water quality, and increases traffic noise.

3.1 Trends in Vehicle Travel

Vehicle travel increased substantially in recent decades. Total vehicle miles of travel (VMT) in the United States increased 63 percent between 1980 and 1997. VMT has more than doubled since 1970.[57] As shown in Figure 3-1, the rate of growth in VMT has exceeded the rate of population growth significantly over the last decade. VMT growth also outpaced employment growth and economic growth.

VMT is projected to grow considerably into the future. FHWA projects that light-duty VMT will grow at an annual rate of approximately 2.16 percent over the next 20 years, resulting in a 53 percent increase in VMT.[58] (See Figure 3-2.) As a result, FHWA has projected significant increases in annual travel delay times through 2005.

Figure 3-1: Growth in Vehicle Miles of Travel and Population, 1980-1997



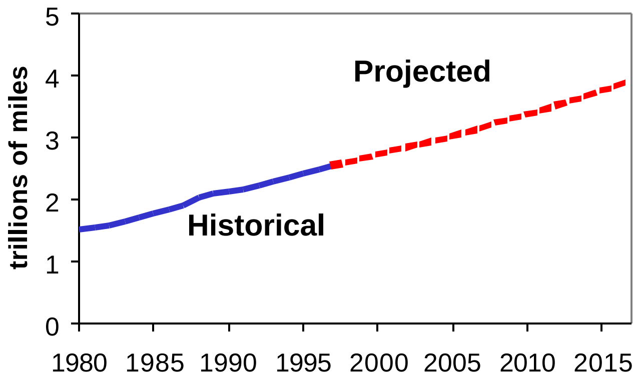
Scale: 1980 value = 1.0

Sources: U.S. Department of Transportation, Federal Highway Administration. *Highway Statistics (Summary to 1995,* and annual editions, *1996* and *1997),* Washington, DC.

[57] U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics (Summary to 1995,* and annual editions, *1996* and *1997.)* Washington, DC.

[58] U.S. Department of Transportation, *1997 Status of the Nation's Surface Transportation System: Condition & Performance Report to Congress,* 1998. p. 60.

Figure 3-2: Projected Growth in VMT



Source: U.S. Department of Transportation. *1995 Status of the Nation's Surface Transportation System: Condition & Performance Report to Congress*, October 1995.

When contrasted against population growth, the VMT increase is particularly high in specific metropolitan areas, as shown in Table 3-1.[59]

Table 3-1: Growth in Daily Vehicle Miles of Travel Exceeds Population Growth, 1982-1996

Urbanized Area	Population Growth, 1982-96	VMT Growth on Freeways and Principal Arterials, 1982-96
Atlanta, GA	53%	119%
Boston, MA	6%	31%
Charlottee, NC	63%	105%
Chicago, IL-IN	11%	79%
Houston, TX	28%	54%
Kansas City, MO-KS	23%	79%
Miami-Hialeah, FL	18%	61%
Nashville, TN	25%	120%
New York, NY-NJ	3%	40%
Pittsburgh, PA	7%	54%
Portland-Vancouver OR-WA	26%	98%
Salt Lake City, UT	32%	129%
San Antonio, TX	29%	77%
Seattle-Everett, WA	35%	59%
Washington, DC-MD-VA	28%	78%

Source: Texas Transportation Institute, *Urban Roadway Congestion, Annual Report 1998.* Tables A-6 and A-7.

59 U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics*, 1990 and 1997.

3.2 Sources of VMT Growth

VMT growth can be attributed to a variety of factors, including the following:

- Demographic and market changes that allow more families to own multiple cars and lead more individuals to drive on a regular basis
- Development patterns that lead to increases in the number and average distance of trips
- The ability of increased road capacity to encourage additional travel—"induced travel"

Demographic and Market Changes

VMT growth has occurred in response to a number of factors, including recent changes in the profile of the workforce and in general demographics. As the baby boom generation came of age, large numbers of people were thrown into the driving population at one time, causing VMT numbers to escalate. Female participation in the labor force has increased dramatically in recent decades, putting more drivers on the road in general, and during peak commute times in particular. According to the Nationwide Personal Transportation Survey (NPTS), women workers as a percentage of women aged 16 or older grew from 37 percent to 59 percent between 1969 and 1995. By 1995, women were driving approximately 60-70 percent as many miles as men do. This gap continues to close as women's participation in the workforce increases.[60]

A combination of rising incomes and falling fuel prices also affected VMT. As household incomes increased and fuel prices fell over the past several decades, families became better able to afford one or more cars. In 1969, 48 percent of all households owned one vehicle. By 1995, the figure dropped to 32 percent, while the proportion of households with two and three cars increased.[61]

Development Patterns

Observed VMT growth can be only partially attributed to demographic factors; changing development and commuting patterns also play a significant role. The 1990 NPTS found that between 1983 and 1990, only 36 percent of VMT growth was associated with demographic change. The remainder can be attributed to changes in land use patterns that have led to increases in average trip distances (38 percent) and in the number of trips made (25 percent).[62]

As discussed in Chapter 4 of this report, numerous studies have found a direct relationship between development patterns and the amount of driving done. On a national level, from 1983 to 1995, the average length of work trips increased by 36 percent (from 8.5 to 11.6 miles), reflecting the fact that jobs and housing have become increasingly segregated from one another in recent years.[63]

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[60] U.S Department of Transportation, Federal Highway Administration. "1995 Nationwide Personal Transportation Survey." September, 1997.

[61] *Ibid*.

[62] U.S. Department of Transportation, Federal Highway Administration, "1990 Nationwide Personal Transportation Survey".

[63] United States Department of Transportation, Federal Highway Administration. *Our Nation's Travel: 1995 NPTS Early Results Report*, 1997. Note that some of the increase in work trip lengths could be associated with trip chaining or other methodological issues associated with measuring trip lengths.

Induced Traffic and VMT Growth

"Induced traffic" is a term for traffic growth produced by the addition of highway capacity. The theory behind induced travel is that of supply and demand. Adding highway capacity (supply) reduces the cost of vehicle travel, particularly the costs associated with travel time. Demand is inversely related to cost. When cost goes down, demand goes up. As travel time and monetary costs fall, people travel more.

Expansion in road capacity can have multiple effects on behavior. An increase in capacity may result in changes in travel route, timing, vehicle occupancy, or mode choice for any given trip. It may also result in changes in trip frequency and switches to alternative destinations. Of these effects, increases in trip making and mode switches clearly contribute to induced travel. Other effects, such as switching routes or changing travel times, may occur as well. Although these effects may reduce some of the expected improvement in traffic flow and savings in travel time associated with the road project, they do not constitute new vehicle travel.

Different types of induced traffic are believed to occur in the short term and long term. In the short term, people may make more trips or switch from transit or carpools to driving alone because of improved traffic conditions. In the long term, reduced travel costs encourage more dispersed land use patterns that, in turn, can increase trip lengths and vehicle dependency.[64]

A Regression Analysis on Impacts of New Lane-Miles

Probably the best-known quantification of induced travel using U.S. data is a study by a University of California-Berkeley team led by Mark Hansen. Using time-series data and multiple regression, Hansen *et al.* estimated the auto traffic effects of changes in road capacity. Hansen studied relatively long-run time-series data—up to 16 years—and cross-sectional data to overcome difficulties in other studies that used only cross-sectional data and limited time periods.[65] The peer-reviewed results are statistically robust and quite clear: induced travel can occur and can absorb all new capacity.[66]

According to the study, vehicle miles traveled on state highways increase, on average, by 0.6 to 0.7 percent at the county level for each 1 percent increase in highway miles, and by 0.9 percent at

[64] See discussion in section 2.2 of this paper. Also refer to: Litman, Todd. "Incorporating Generated Travel in Transportation Economic Analysis." Paper presented at the 75th Annual Meeting of the Transportation Research Board. Washington, DC: January 1996; Cohen, H., "Review of Empirical Studies of Induced Traffic." *Expanding Metropolitan Highways: Implications for Air Quality and Energy Use.* Transportation Research Board Special Report 245, Washington, DC: National Academy Press, 1995.

[65] Hansen *et al.*'s 1993 study has been widely cited. He and his team have since improved on it, and we present here the updated results from Mark Hansen and Yuanlin Huang, "Road Supply and Traffic in California Urban Areas," *Transportation Research-A*, 31:3 (1997), pp. 205-218. The Hansen team used data from 30 California urban counties. "The populations of the regions ranged over two orders of magnitude, from 150,000 to 15 million." Because of the wide variety of urban sizes and types included in the sample, the findings are applicable beyond California. Because the 1997 journal article was much shorter than the 1993 report, the article did not go into as much detail about the mechanisms of induced travel. In some cases we have quoted and cited the 1993 report to fill in detail.

[66] The explanatory power of the models is quite high, at R^2 = .92 - .99. Unless noted otherwise, we report here only statistically significant results.

the metropolitan level. The full increase in VMT materializes within five years of the change in road supply. [67]

New road capacity does not simply affect travel on the new road or new lanes. It may also affect traffic outside its own corridor. People might use the new road rather than an older, more congested route. People may choose new destinations. A decision to use the new road probably means a decision to use a road connecting to it. Thus, capacity increase can lead to travel growth on other roads as well as on new roads highway lanes.

Hansen found that:

> …adding lane miles in a given county increases VMT throughout the wider region. This will occur if, for example, increasing the capacity of a highway in a given county induces commuting to or through that county from other counties in the region. [68]

Hansen found that capacity additions have different impacts in different metropolitan areas. An additional lane mile in San Francisco, Los Angeles, or San Diego metro areas produces roughly 12,000 additional daily VMT. In smaller Stockton, just over 8,000 additional daily VMT are produced per new lane mile. In much smaller Redding, roughly 3,000 additional VMT occur per new lane mile. "Greater quantities of induced traffic are predicted for larger urban regions because such regions have higher ratios of VMT to state highway lane miles."[69]

Hansen does acknowledge that other factors (specifically, population growth, income level, and gasoline prices) also affect VMT. However, his findings call into question whether communities can relieve congestion through new road construction. Transportation decisions can produce travel changes over a wide area, and local capacity additions can increase VMT system-wide.

LITERATURE REVIEW AND SYNTHESIS OF EVIDENCE ON INDUCED TRAFFIC

Goodwin's paper, "Empirical Evidence on Induced Traffic: A Review and Synthesis," is useful in surveying additional evidence for induced traffic. Where Hansen used a traditional multiple regression approach in his study, Goodwin assembled evidence for induced travel from studies in several fields.[70]

Goodwin drew the evidence from studies on several subjects: the cost of car use, travel time budgets, the value of time, and other multiple regression studies. Together, those studies supported "an elasticity of traffic volume with respect to travel speed of about –0.5 in the short term and up to –1.0 in the long term." That is, in the short term, a 1 percent decrease in travel time will result in a 0.5 percent increase in vehicle travel. Over the long term, a 1 percent improvement in travel time will cause a 1 percent increase in VMT.

[67] Hansen investigates whether and how the effect grows over time, using lagged and unlagged models. He finds that the effect does grow. For further discussion, see both the 1993 report and the 1997 article.

[68] Hansen, Mark and Yuanlin Huang. "Road Supply and Traffic in California Urban Areas," *Transportation Research*, Volume 31, Number 3. Great Britain: Elsevier Science Ltd, 1997. p. 213.

[69] Hansen, Mark and Yuanlin Huang. "Road Supply and Traffic in California Urban Areas," *Transportation Research*, Volume 31, Number 3. Great Britain: Elsevier Science Ltd, 1997. p. 217.

[70] "The approach taken is that inferences are to be judged on the basis of 'the balance of probability' rather than conclusive rejection of a formal hypothesis." Goodwin 1996.

Goodwin's review led in part to a significant change in British national policy on the evaluation of road projects. The British government announced in December 1994 that "there is likely to be a significant proportion of schemes where there is a real possibility of extra traffic," and ordered re-review of construction proposals to take into account the induced travel.

OTHER STUDIES OF INDUCED TRAVEL

Hansen and the U.S. Transportation Research Board (TRB), a unit of the National Academy of Sciences, have, like Goodwin, reviewed various empirical studies of induced travel. *Our Built and Natural Environments* does not analyze the empirical studies in the level of detail that Goodwin did, but our review of the studies found estimated elasticities of VMT with respect to road supply ranging from 0.1 to 0.8. Most of the U.S. studies collected were older than those reviewed by Goodwin. Nonetheless, the two reviews are fundamentally in agreement in finding consistent evidence for induced travel in response to road improvements.

Transportation demand forecasting models that estimate the likelihood of choosing a specific mode for a trip, such as transit or motor vehicle, typically use a measure of travel cost as a determinant of mode choice. The statistical significance of travel cost in these models suggests that changes in travel costs associated with highway development typically will result in mode shifts from transit to personal vehicle use. There is a wide literature on travel price elasticities.[71] Stated preference surveys also have found that people plan to make more auto trips in response to added capacity.[72]

A recent statistical study analyzing the issue of how additions of highway lane miles can increase vehicle miles of travel found elasticities within the ranges of previous research, with short-run elasticities of about 0.5 and long-run elasticities of about 0.8.[73]

The 1995 TRB Report, *Expanding Metropolitan Highways: Implications for Air Quality and Energy Use*, stated:

> The evidence from the studies reviewed here supports the view that highway capacity additions can induce new trips, longer trips, and diversions from transit.[74]

The study suggests that land use and pricing policies may be more effective than efforts to restrain the growth in highway capacity to achieve long-run improvements in air quality.

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[71] Many of these studies estimate elasticities based on fuel prices. See: Dahl C., and T. Sterner. "Analyzing Gasoline Demand Elasticities: A Survey." *Energy Economics* 13, 1991, No. 3:203-210. Dahl, C.A. 1986. "Gasoline Demand Survey." *The Energy Journal* 7, no. 1:67-82. Gately, D. 1990. "The U.S. Demand for Highway Travel and Motor Fuel." *The Energy Journal* 11, no 3:59-73. Greene, D.L. "Vehicle Use and Fuel Economy: How Big is the Rebound Effect?" *The Energy Journal* 13, 1992, No. 1:117-143. Southworth, F. "VMT Forecasting for National Highway Planning: A Review of Existing Approaches." Oak Ridge, TN: Center for Transportation Analysis, Oak Ridge National Laboratory, 1986.

[72] Dowling, Richard G. and Steven Colman. "Effects of Increased Highway Capacity: Results of a Household Travel Behavior Survey." Transportation Research Board paper No. 95-0409, presented at the 74th Annual TRB meeting, January 22-28, 1995.

[73] Noland, Robert. "Relationships between Highway Capacity and Induced Vehicle Travel." Paper presented at the 78th Annual Meeting of the Transportation Research Board, January 1999.

[74] Transportation Research Board, *Expanding Metropolitan Highways: Implications for Air Quality and Energy Use*, TRB Special Report 245, Washington, DC: National Academy Press, 1995, p. 162.

Trends in Vehicle Travel – Conclusion

Literature on trends in vehicle travel indicate that numerous factors including demographic and market shifts, contributed to recent increases in VMT. Studies also show that increases in VMT cannot be entirely explained by those factors and that changes in development patterns have had a particularly significant impact on VMT growth. Furthermore, because additional road capacity can be absorbed quickly by induced traffic, adding capacity alone is not likely to solve the problem of rapidly rising VMT.

Section 3.3 discusses how these increases in vehicle travel affect our natural environment.

3.3 Environmental Consequences of Vehicle Travel

Although vehicle travel produces benefits in terms of mobility, convenience, and flexibility, it also creates unintended environmental consequences. Outcomes include:

- Degradation of air quality
- Impairment of water quality associated with deposition of air pollutants
- Greenhouse gas emissions and global climate change
- Increased traffic noise
- Upstream impacts from activities associated with vehicle use, such as oil spills and water quality impacts from road de-icing.

Many of these consequences have severe effects on environmental quality. [75] The following subsections review these problems.

Degradation of Air Quality

Motor vehicles emit pollution through fuel combustion (exhaust) during operation and fuel evaporation during and between periods of operation. EPA established National Ambient Air Quality Standards (NAAQS) to protect public health, including the health of sensitive populations such as children and the elderly, from adverse effects of poor air quality. Pollutants covered by NAAQS (so-called "criteria pollutants") include carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), particulate matter less than or equal to 10 micrometers in diameter (PM_{10}), particulate matter less than or equal to 2.5 micrometers in diameter ($PM_{2.5}$), and lead (Pb). Volatile organic compounds (VOC) and oxides of nitrogen (NO_X) are precursors to the formation of ozone. Motor vehicles emit each of these pollutants, and contribute a large portion of CO and ozone precursors in particular. Vehicle travel also kicks up large quantities of particulate matter from roads (especially on unpaved roads in rural areas). Table 3-2 presents emissions from motor vehicles in 1997, and Figure 3-3 shows the share of air pollutants emitted by motor vehicles.

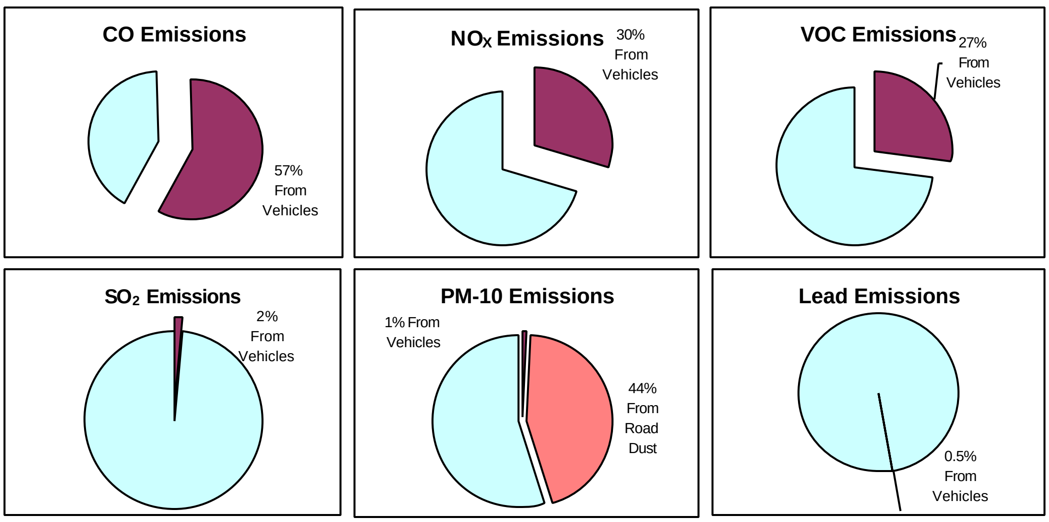
[75] For complete data on transportation's impacts on the environment, see: U.S. Environmental Protection Agency, Office of Policy. *Indicators of the Environmental Impacts of Transportation: Highway, Rail, Aviation, and Maritime Transport.* October, 1999, EPA 230-R-99-001.

Table 3-2: Motor Vehicle Emissions, 1997

Pollutant	Quantity Emitted (thousand short tons)
Carbon monoxide (CO)	50,257
Nitrogen oxides (NO_X)	7,035
Volatile organic compounds (VOC)	5,230
Sulfur dioxide (SO_2)	320
Particulate matter (PM_{10}):	
From exhaust	268
From road dust	14,820
Lead (Pb)	0.019

Source: U.S. Environmental Protection Agency. *National Air Pollutant Emissions Trends, 1900-1997*. 1999.

Figure 3-3: Highway Share of Air Pollutants Emitted, 1997



Note: percentages are based on anthropogenic emissions, except for PM-10, which includes natural emissions.
Source: U.S. Environmental Protection Agency. *National Air Pollutant Emissions Trends, 1900-1997*. 1999.

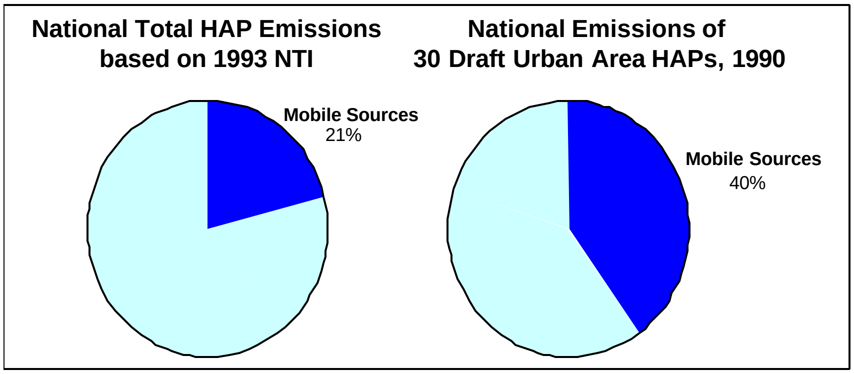
Since 1970, per mile motor vehicle emissions have been decreasing as a result of vehicle emissions control systems and cleaner fuels. However, increasing VMT threatens to reverse this trend in the near future for carbon monoxide, sulfur dioxide, and particulate matter (PM_{10}). The share of total emissions attributable to on-road mobile sources varies greatly by location. The share of NO_x can range from 20 to 60 percent of total emissions (including biogenic) in most ozone nonattainment areas, and on-road VOC emissions can range from 10 to 40 percent of the total.[76]

Motor vehicles also emit hazardous air pollutants (HAPs), sometimes referred to as air toxics. HAPs are pollutants known or suspected to cause cancer or other serious human health effects or ecosystem damage. Persistent air toxics are of particular concern in aquatic ecosystems, as toxic levels can magnify up the food chain. Compared with the criteria pollutants, less information is available concerning the health and environmental impacts of individual HAPs. According to EPA's 1993 National Toxics Inventory (NTI), mobile sources released about 21 percent of the

[76] Apogee Research, Inc. and Sierra Research. "Strategic Analysis of Mobile Source Options for Air Quality: Regional Differences and Implications for Ozone Policy." Prepared for the Federal Highway Administration. August 1996.

8.1 million tons of air toxics released nationwide.[77] EPA also compiled an interim 1990 emissions inventory of 30 proposed urban HAPs that pose the greatest threat to public health in urban areas. Of these, about 40 percent of emissions come from mobile sources, as shown in Figure 3-4.

Figure 3-4: Mobile Source Contribution to HAPs, 1993



Source: U.S. Environmental Protection Agency. *National Air Quality and Emissions Trends Report, 1997,* December 1998.

Table 3-3 shows the quantity and share of individual toxic emissions that were emitted by motor vehicles in 1993.

Table 3-3: Toxic Emissions Due to Highway Vehicle Operations, 1993

Pollutant	Quantity Emitted (1993, metric tons)	Percent of Total Emission
Benzene	158,149	60%
1,3 Butadiene	27,972	56%
Formaldehyde	73,874	33%

Source: U.S. Environmental Protection Agency. *Motor Vehicle-Related Air Toxics Study,* April 1993.

IMPACT: HEALTH PROBLEMS

In 1997, approximately 113 million people lived in counties that had failed to attain the NAAQS for at least one criteria pollutant.[78] As shown in Table 3-4, these pollutants are associated with numerous public health problems.

[77] EPA National Toxics Inventory. 1993.

[78] U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. *National Air Quality and Emission Trends Report, 1997.* Research Triangle Park, NC, December 1998.

Table 3-4: Health Impacts of Criteria Pollutants

Pollutant	Health Impacts
CO	Interferes with the absorption of oxygen by hemoglobin in the blood. Lack of oxygen impairs the cardiovascular and nervous system, with symptoms including chest pain, headaches, dizziness, nausea, fatigue, and slower reflexes. In addition, impairs visual perception, work capacity, manual dexterity, learning ability and performance of complex tasks. Affects fetal growth and tissue development. Results in mortality at extremely high concentrations.
Ozone	May cause temporary lung irritation, minor eye irritation, coughing, pain upon inhalation with short-term exposure. Heavy exercise becomes difficult. Long-term exposure to ambient ozone may cause structural lung damage leading to chronic lung disease, lung cancer, and increased susceptibility to respiratory infections, such as bronchitis and pneumonia. May interfere w/ the immune system. May be agent for infectious disease since produces more receptors for viruses. Exacerbates allergies.
Particulate Matter	May cause coughing, lung tissue damage, alteration in immune system, and respiratory and cardiovascular diseases. Effects on breathing and respiratory symptoms, aggravation of existing respiratory and cardiovascular disease, alterations in the body's defense systems, damage to lung tissue, carcinogenesis. Raises risk of cancer (since particulates adhere to carcinogens).
SO_2	Constricts bronchial passages and alters the lungs' defenses, with symptoms including effects on breathing, asthma, and respiratory illness. People with pre-existing chronic lung and heart diseases are at increased risk of acute illness or premature death during episodes of combination of SO_2 and particulate matter. Also important since it contributes to particulate formation by reacting in the atmosphere to form sulfates, which are believed to be a significant portion of PM-10 in terms of both volume and effect on humans.
Lead	May cause increased blood pressure and heart disease. Impairment of children's mental functioning. Neurological impairments, such as seizures, mental retardation, and/or behavioral disorders.

Source: Apogee Research, Inc. *Incorporating Additional Effects into the HERS Model for National Highway Investment Analysis.* Prepared for the Federal Highway Administration. January 1996. Based on reviews from various health studies.

There is strong evidence that air pollution from highways causes a significant number of public health problems. A detailed analysis of the costs of motor vehicle travel concluded that in 1991 motor vehicle pollution was responsible for the following health problems:[79]

- Roughly 50-70 million respiratory-related restricted activity days, of which approximately 43-60 million can be attributed to particulate matter alone
- About 852 million headaches from CO
- Approximately 20,000-46,000 cases of chronic respiratory illness (chronic cough, phlegm, wheezing, chest illness, and bronchitis)
- An estimated 530 cases of cancer from air toxins (estimates of cancer risk, however, are highly uncertain)
- An estimated 40,000 premature deaths in the United States.

[79] McCubbin, D. and M. Delucchi. *Health Effects of Motor Vehicle Air Pollution.* 1995.

IMPACT: IMPAIRMENT OF WATER QUALITY FROM AIR POLLUTANTS

Air pollution can significantly affect water quality, as illustrated by the following statistics:[80]

- Estimates of atmospheric nitrogen input to water bodies such as the Chesapeake Bay and other major East Coast estuaries range from 5 percent to 50 percent of the controllable load of nitrogen (most estimates are in the range of 30 percent). The error in such estimates, however, is cited as at least plus or minus 20 percent and up to a factor of two or three, depending on location and pollutant considered.
- Atmospheric loadings of metals to water bodies such as the Chesapeake Bay may range from more than 95 percent of total loadings in the case of lead to about 10 percent in the case of cadmium.
- Annual fluxes from wet deposition reported at various coastal locations range from under 5 mg per square meter for copper, nickel, and lead to 15-30 mg per square meter for iron and zinc.
- Wet deposition of various polycyclic aromatic hydrocarbons such as benzo[ghi]perylene (including some carcinogenic products of incomplete combustion) is in the range of 1-10 micrograms per square meter per year.

EPA and others are in the process of modeling the source contribution of each pollutant for the Chesapeake Bay and the Great Lakes.

IMPACT: ECONOMIC COSTS

In addition to causing health problems, air pollution causes damage to building materials, agriculture, and visibility. These impacts have large costs to society. A comprehensive study of air pollution from motor vehicles estimated annual costs of $28.7 to $531 billion in health damage, $2.5 to $4.6 billion in crop damage, and $6.0 to $43.54 billion in damage to visibility.[81] Another study estimated $36.6 billion (1990 dollars converted to 1999 dollars) in annual air pollution health and property costs due to roadway transportation.[82] A 1993 study calculated air pollution health costs as ranging from $146 to $271.6 billion (1990 dollars converted to 1999 dollars) and building damage to cost another $365.6 million (1990 dollars converted to 1999 dollars).[83]

Greenhouse Gas Emissions and Global Climate Change

Greenhouse gases from human sources threaten to alter Earth's atmosphere, since the planet's ecosystems cannot absorb such elevated levels of these gases. Carbon dioxide (CO_2) is one of the primary greenhouse gases emitted by humans.

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[80] Air deposition data from AQCG/STAC 1994/95, and Valigura *et al*., 1994/1995.

[81] Delucchi, M. et al. *The Annualized Social Cost of Motor-Vehicle Use in the U.S., based on 1990-1991 Data, June 1997.* Converted into 1999 dollars. (UCD-ITS-RR-96-3).

[82] Ketcham, B. and C. Komanoff. Win-Win Transportation: A No-Losers Approach to Financing Transport in New York City and the Region. 1992.

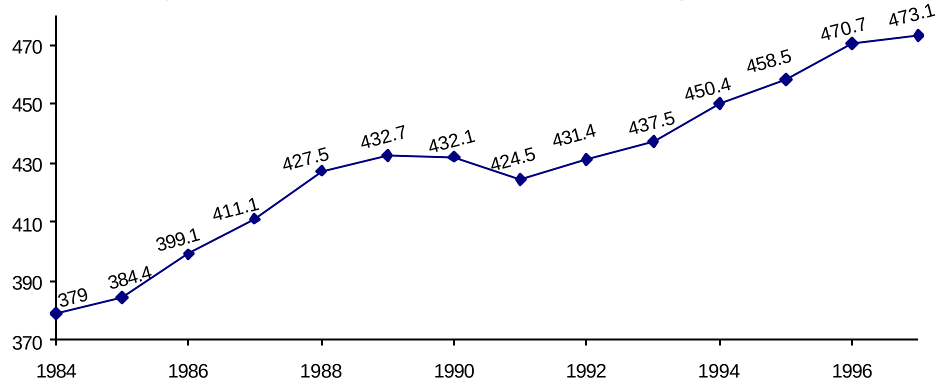
[83] Miller, P. and J. Moffet. *The Price of Mobility: Uncovering the Hidden Costs of Transportation.* Natural Resources Defense Council, 1993.

The accumulation of greenhouse gases in the atmosphere can lead to global climate change (also called "global warming," since one outcome is an increase in the *average* atmospheric temperature). The results of global climate change are potentially dramatic. Increases in atmospheric and oceanic temperatures might raise sea levels and alter associated weather patterns, which in turn could increase the frequency and severity of extreme weather events worldwide. Such changes might alter current patterns of land use and human activity, as well as ecosystems and natural habitats.[84]

Even an increase of a few degrees can lead to dramatic changes in climate. The total global warming since the peak of the last ice age—18,000 years ago—was only about 5°C. In 1990 EPA estimated that a doubling of atmospheric levels of CO_2 would lead to an increase in average temperatures of anywhere from 1.5 to 5.5°C.[85] The Intergovernmental Panel on Climate Change (IPCC) in 1995 predicted an increase of about 2 to 3.5°C between 1990 and 2100.[86]

Transportation is a significant source of greenhouse gas emissions. In 1997, for example, the transportation sector emitted 32 percent of U.S. CO_2 emissions from fossil fuels, or 473.1 million metric tons of carbon. As indicated by Figure 3-5, carbon emissions from transportation have increased significantly over time.[87]

Figure 3-5: US Carbon Dioxide Emissions from Transportation



The transportation sector is projected to be the fastest growing contributor to carbon emissions in the next 20 years. Carbon emissions from transportation are projected to grow by 47.5 percent over the period 1996-2020. Projected carbon emissions from transportation (based on modeling by the U.S. Department of Energy) are shown in Table 3-5.

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[84] U.S. Congress Office of Technology Assessment. *Preparing for an Uncertain Climate.* Washington, DC, 1993.

[85] U.S. Environmental Protection Agency. *Policy Options for Stabilizing Global Climate: Report to Congress*. Washington, DC, December, 1990.

[86] Intergovernmental Panel on Climate Change. *Second Scientific Assessment of Climate Change, Summary and Report.* World Meteorological Organization/U.N. Environment Program. Cambridge, MA: Cambridge University Press, 1995.

[87] U.S. Department of Energy, Energy Information Administration. *Emissions of Greenhouse Gases in the United States, 1997.* October 1998.

Table 3-5: Projected Carbon Emissions from Transportation

Year	Million metric tons per year
1996 est.	472.8
1997 est.	475.3
2000	515.8
2005	572.8
2010	626.3
2015	662.3
2020	697.3

Source: U.S. Department of Energy, Energy Information Administration. *Annual Energy Outlook 1999: With Projections to 2020.* DOE/EIA-0383(98), December 1998, Table A-19. Reference Case Forecast.

In addition to carbon emissions, vehicle travel contributes to emissions of two other greenhouse gases, methane and nitrous oxide. Emissions for these gases for 1997 are tabulated in Table 3-6:

Table 3-6: Greenhouse Gas Emissions Due to Highway Vehicle Travel

Pollutant	Quantity Emitted (1997, thousand metric tons)
Methane (CH_4)	213
Nitrous Oxide (N_2O)	205

Source: U.S. Department of Energy. *Emissions of Greenhouse Gas in the US 1997,* October 1998, Table 26.

Global climate change may have severe consequences for ecosystems and economies around the globe. IPCC models predict a rise in sea level over the next 100 years of 20 to 86 centimeters, with the most likely case of a rise of 50 centimeters.[88] EPA predicts a median estimate of 45 centimeters. Such a rise would inundate wetlands and lowlands, accelerate coastal erosion, worsen coastal flooding, threaten coastal structures, raise water tables, and increase salinity of rivers, bays, and aquifers.[89] Low-lying coastal areas would be the hardest hit, since a small sea level rise could put large areas under water. EPA estimated that a 50-centimeter sea level rise would inundate 5,000 square miles of dry land and 4,000 square miles of wetlands in the United States.[90] Total monetary losses caused by a 1-meter rise are estimated to be between $270 and $475 billion, not including future development.[91]

The rises in global average temperature predicted by EPA, the IPCC, and the U.S. Congress Office of Technology Assessment could increase average global precipitation by as much as 7 to 15 percent. Predictions suggest that precipitation would increase at high latitudes and decrease at low to middle latitudes, increasing the potential for more severe and longer-lasting droughts.[92]

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[88] Intergovernmental Panel on Climate Change, *Second Scientific Assessment of Climate Change, Summary and Report.* World Meteorological Organization/UN Environment Program. Cambridge, UK: Cambridge University Press, 1995.

[89] Titus, J. and V. Narayanan. “Greenhouse Effect and Sea Level Rise: The Cost of Holding Back the Sea,” *Coastal Management*. Volume 19, 1991.

[90] Gardiner, David. “Global Climate Change Negotiations.” Testimony before the House Commerce Committee, Subcommittee on Energy and Power. June, 1996.

[91] Titus, J. and V. Narayanan. “Greenhouse Effect and Sea Level Rise: The Cost of Holding Back the Sea,” *Coastal Management*. Volume 19, 1991.

[92] U.S. Office of Technology Assessment. *Preparing for an Uncertain Climate Volume 1*. Washington, DC: U.S. Government Printing Office, 1993.

Human health also could be significantly affected by global climate change, due to extended heat waves and a marked increase in vector-borne diseases such as malaria (due to the extension of the hospitable geographical range and seasons for these organisms).[93] Although costs of mitigating these problems are uncertain, they may be in the billions of dollars per year. Two 1992 studies estimated the annual social costs of greenhouse gas emissions to the United States to be $25 billion (1990 dollars) to $27 billion (1989 dollars).[94]

Noise

Automobile travel creates noise from engine operations, pavement-wheel contact, and wind noise. As a result, increased vehicle travel is likely to cause increased noise disturbances to communities. Because noise diminishes with distance from its source, the most serious transportation noise problems are experienced along major transportation corridors. The passage of the federal Noise Control Act of 1972 marked the recognition of noise as a major problem in urban living. As shown in Table 3-7, an estimate for 1980 indicated that 37 percent of the U.S. population was exposed to noise from road use great enough to cause annoyance—defined at Leq greater than 55 dB (A).[95]

Table 3-7: Percent of U.S. Population Exposed to Road Transportation Noise

(Outdoor Sound Level in Leq [dB(A)])

>55 dB(A) Annoyance	>60 dB(A) Normal Speech Level	>65 dB(A) Communication Interference	>70 dB(A) Muscle/Gland Reaction	>75 dB(A) Changed Motor Coordination
37.0%	18.0%	7.0%	2.0%	0.4%

Source: Organization for Economic Cooperation and Development. *Indicators for the Integration of EnvironmentalConcerns into Transport Policies,* OECD Publications, 1993.

Numerous research projects for Organization for Economic Cooperation and Development (OECD) countries on the effects of noise and its wider repercussions indicate that an outdoor sound level of 65 dB(A) is "unacceptable," and an outdoor level of less than 55 dB(A) is desirable.[96] Studies have estimated the annual social costs of vehicle-related noise to be anywhere from $2.7 to $9 billion.[97]

Other Environmental Impacts of Motor Vehicle Use

Activities associated with the use of motor vehicles can create pollution that affects water quality and damages ecosystems. Upstream impacts associated with fuel production and distribution, in particular, are associated with adverse impacts to the environment, such as oil spills. About 1.6

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[93] McMichael, Antony. "Global Health Watch: Monitoring Impacts of Environmental Change," *The Lancet.* Volume 342, December, 1993.

[94] Lower estimate from Ketcham and Komanoff (*Win-Win Transportation: A No-Losers Approach to Financing Transport in New York City and the Region*. 1992). Upper estimate from MacKenzie, et al. (*The Going Rate: What it Really Costs to Drive.* Washington, DC: World Resources Institute, 1992).

[95] Leq stands for Equivalent Sound Level and is a measure of a steady sound that has the same sound energy as an amplitude-varying sound of the same duration. Sound pressure levels are expressed in decibels (dB).

[96] Organization for Economic Cooperation and Development. *Indicators for the Integration of Environmental Concerns into Transport Policies.* OECD Publications. 1993.

[97] Lower estimate from Miller and Moffet. *The Price of Mobility: Uncovering the Hidden Costs of Transportation.* Natural Resources Defense Council, 1993. Upper estimate from MacKenzie, et al. (*The Going Rate: What it Really Costs to Drive.* Washington, DC: World Resources Institute, 1992).

million gallons of oil were spilled in U.S. navigable waters from vessel incidents during 1996.[98] One study estimates that large oil spills from vehicles transporting fuel cause water pollution that costs society $2.36 to $5.9 billion annually.[99] Leaking underground storage tanks at gas stations and other facilities can cause groundwater contamination with associated environmental and health costs estimated at $0.12 to 0.59 billion annually.[100]

Motor vehicle manufacture is associated with environmental impacts including air pollutant emissions, toxic releases, and the generation of various solid and liquid wastes. Highway maintenance to support vehicle travel also involves activities that can adversely affect the environment, such as road salting, use of solvents, and pesticides. Highway de-icing can adversely affect roadside vegetation, soil structure, drinking water supplies, and aquatic life. Highway de-icing is estimated to cost society $0.826 to $2 billion annually.[101]

3.4 SUMMARY

Over the past several decades, improvements in automobile-related infrastructure (highways, roads, parking lots), greater separation between jobs and housing, greater distances between destinations, and induced traffic (or additional travel prompted by road capacity expansions) have led to increases in vehicle travel.

The environmental consequences of vehicle travel and vehicle dependency pose a potential threat to long-term community and environmental health. Highway emissions cause chronic health problems, affect water quality, and impose economic costs stemming from crop damage, building and property damage, and damage to visibility. Transportation is also a generator of noise and a major contributor to global climate change.

Communities are also realizing that adding new road capacity no longer generates the same economic benefits it may have at one time. Studies have indicated that new highway development, which was often viewed as necessary to economic development in the past, offers increasingly fewer economic benefits at the state and national levels. As the national road network nears completion, the benefits of additional network construction decrease drastically. New roads may offer fewer benefits on the local level, too; although they may appear to spur growth, they often simply shift economic activity away from other areas.[102]

Communities across the country realize that adding new road capacity is not by itself a viable long-term solution to traffic congestion problems. As they also realize that adding new capacity offers fewer economic benefits than previously assumed, they are beginning to examine the relationship between development patterns, travel patterns, and their environmental consequences. Communities

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[98] U.S. Department of Transportation, Bureau of Transportation Statistics. *National Transportation Statistics 1998.* Table 4-42.

[99] Delucchi, M. et al. *The Annualized Social Cost of Motor-Vehicle Use in the U.S., based on 1990-1991 Data, June 1997.* Converted into 1999 dollars. (UCD-ITS-RR-96-3). Converted to 1999 dollars.

[100] Delucchi, M. et al. *The Annualized Social Cost of Motor-Vehicle Use in the U.S., based on 1990-1991 Data, June 1997.* Converted into 1999 dollars. (UCD-ITS-RR-96-3). Converted to 1999 dollars.

[101] Delucchi, M. et al. *The Annualized Social Cost of Motor-Vehicle Use in the U.S., based on 1990-1991 Data, June 1997.* Converted into 1999 dollars. (UCD-ITS-RR-96-3). Converted to 1999 dollars.

[102] Boarnet, Marlon G. “Highways and Economic Productivity: Interpreting Recent Evidence.” *Journal of Planning Literature.* Vol. 11, No. 4. May, 1997.

are recognizing that in order to meet federal air quality standards and protect other aspects of environment and community, they must turn toward more land use-based solutions to transportation challenges. We examine those solutions in Chapter 4.