U.S.Department
of Transportation
**Federal Railroad
Administration**

Environmental Externalities and Social Costs of Transportation Systems – Measurement, Mitigation and Costing: An Annotated Bibliography

Federal Railroad Administration
Office of Policy
August 1993

Moving America

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- Bibliographies

INTRODUCTION

The United States transportation system is a key component of the economic network of this country. This system provides ready access to jobs, recreation, health-care facilities, and social and cultural pursuits, and moves enormous amounts of freight. There are, however, significant environmental and social costs incurred in this process. Decision makers should consider these costs -- in addition to infrastructure, capital and operating costs -- when choosing among transportation alternatives. These effects, not usually accounted for in market transactions, are generally termed external costs, or externalities, borne by society as a whole or by specific segments of society.

There is increasing interest in how the full costs of environmental and social impacts can be weighed in the decision-making process. To allow planners, policy makers, legislators, and other interested parties to make better informed decisions about modal choices, more and better information is needed about measurement of environmental impacts, mitigation strategies and approaches to pricing transportation operations to take better account of environmental impacts. The purpose of this annotated bibliography is to help address this problem.

The bibliography is accompanied by two charts identifying environmental and social (including energy) effects of implementing various transportation systems, as well as potential mitigation measures, and costing/pricing strategies that could reduce these effects. These strategies, identified from the literature, have not been independently analyzed or evaluated, and some are mutually exclusive.

The bibliography is organized according to the framework of the charts and summarizes a number of recent publications/papers/articles that address measuring, mitigating, and costing transportation's environmental and social impacts. (The chapter numbers correspond to headings on the Charts, and the first and last chapters, covering General Overview Studies and Current Research Now Underway, are not numbered.) The bibliography does not address the other factors important in planning transportation systems, such as economic growth and development and user benefits, which also must be weighed and balanced in the evaluation process.

The first chapter covers reports/articles that provide an overview of these impacts. (Some of the citations are repeated in other chapters, with additional information relevant to the subject of a particular chapter.) Subsequent chapters address individual areas of impact, and the last chapter summarizes the scope of studies currently underway that address these topics. The areas most covered in the literature are air quality, noise, energy, safety, and congestion, and the bibliography, therefore, reflects this emphasis. Some of the reports cited have additional bibliographies that may be useful to the reader.

The bibliography has been prepared by an Environmental Task Force directed by Marilyn (Mickey) Klein in FRA's Office of Policy. The other task force members responsible for its preparation are Stephen Grimm, Brenda Moscoso, and John Paolella. For questions, comments, or suggested additions (for a future edition of this publication), please contact Ms. Klein at 202/366-0358 (Fax: 202/366-7688), Office of Economic Analysis, Office of Policy, Federal Railroad Administration.

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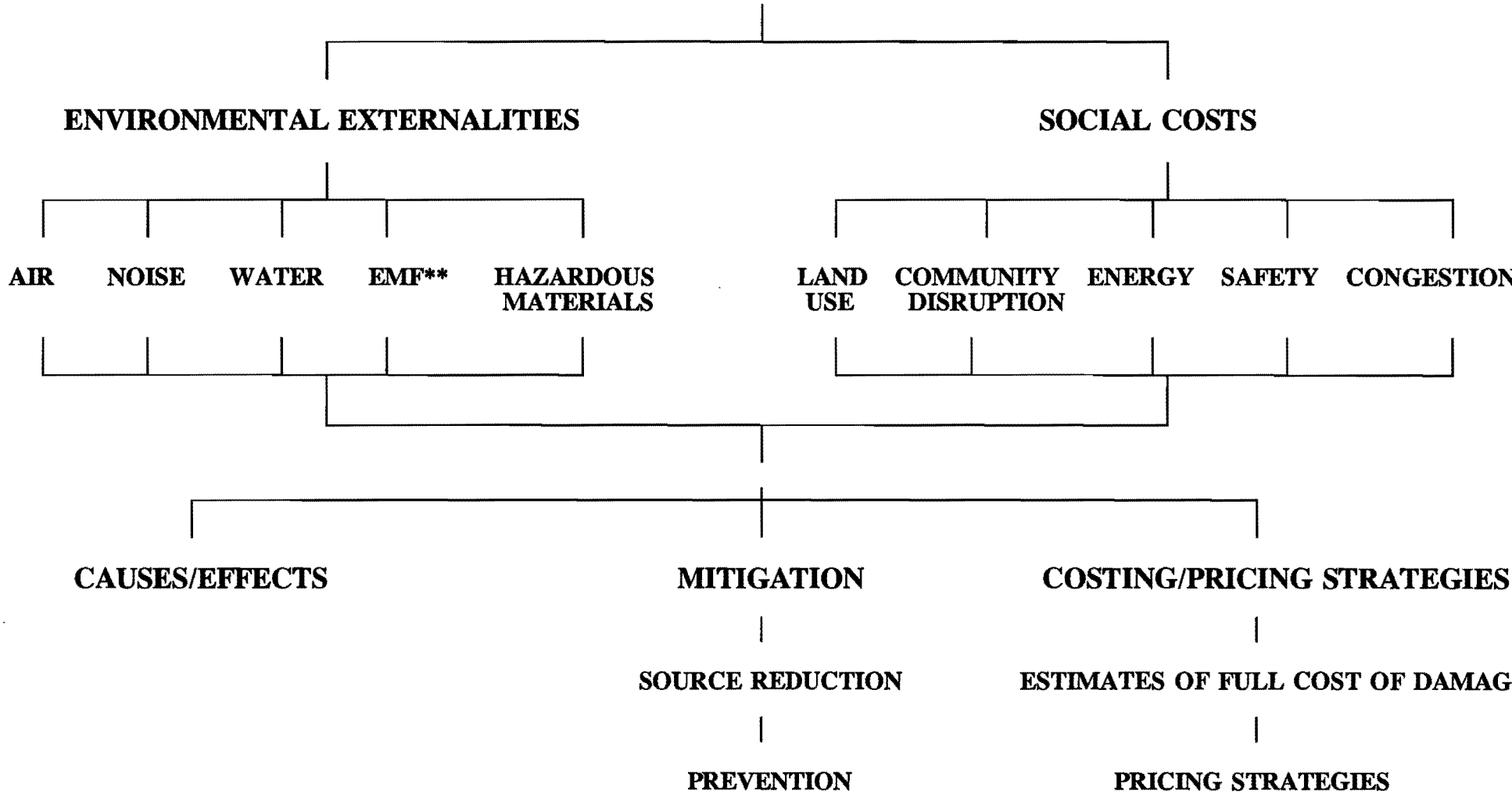
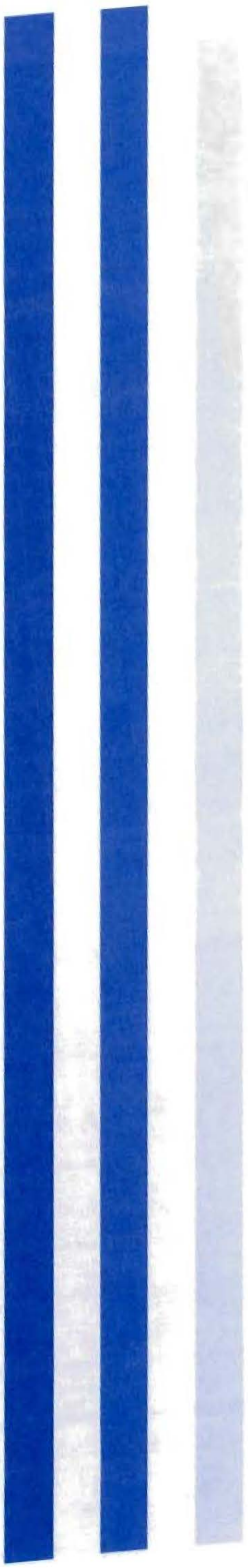


* For the detailed version of this chart, see the accompanying charts following this outline

** Electromagnetic Fields (EMF)



SOCIAL COSTS OF TRANSPORTATION SYSTEMS

VI. LAND USE

Although land use issues have environmental effects, transportation has important socio-economic land use implications. In urban areas, transportation facilities (ports, highways, parking lots repair and disposal facilities, rail a transit lines and airports) require substantial acreage, competing with other land uses.

A. CAUSES

- Direct land use for facility and ancillary requirements (parking, maintenance, disposal of vehicles and waste)

EFFECTS

- Removes housing/businesses
- Impacts pedestrians, bicycle or transit linkages
- Takes land from and impacts use of resources:
  - historic
  - wetlands
  - scenic
  - cultural
  - archaeological
  - parks
  - recreation areas
  - habitats of endangered or threatened species
- Provides incentive for development
  - housing
  - industry
  - commercial
- Alters land use patterns
  - commercial
  - location of transportation facility impacts development decisions
  - depending on mode, ca produce sprawl or concentrated development

B. MITIGATION STRATEGIES

1. SOURCE REDUCTION
   - Intensify development - use land adjacent to existing facilities more efficiently
     - encourage higher densities
     - encourage mixed use residential, commercial, appropriate industrial
   - Increase utilization of existing facilities - install park and ride lots at malls, open shops/services at transit stops
   - Restrict urban fringe development - deny infrastructure improvements that encourage sprawl development

2. PREVENTION
   - Site transportation facility to minimize community disruption
   - Select least intrusive mode
   - Reduce jurisdictional conflicts through cooperative land use agreements
   - Improve land use and transportation planning/design
     - design communities for efficient transportation movement
     - minimize walking distances to transit points and enhance pedestrian, bicycle access

3. ABATEMENT
   - Install buffers to reduce transportation impacts on adjacent receiving environment (see noise)

C. COSTING/PRICING STRATEGIES

1. ESTIMATION OF FULL COSTS OF DAMAGE
   - Direct cost of acreage required for facilities
   - Estimate tax loss as a result of land used for facilities

2. PRICING STRATEGIES
   - Tolls/surcharges on use of transportation facility to fund infrastructure required as a result of the sprawl generated by additional users
   - Assessments on single level parking facilities occupying large tracts
   - Tax increment financing
   - Value capture
   - Entrance fees to encourage more compact development

IX. SAFETY

Transportation takes a heavy toll in accidents and deaths, with 43,500 motor vehicle fatalities, and 1.6 million disabli injuries in 1991. The economic cost of these accidents was $96.1 billion (*Accident Facts,* 1992 Edition).

According to *Accident Facts,* 1992 Edition, passenger transportation accidents account for about one-fourth of all accidental deaths. However, the risk of death to the passenger, expressed on a per-mile-basis, varies greatly by transportation mode. Automobile travel presents the greatest risk; air, rail, and bus travel have much lower death rate The average death rates for 1988–1990 expressed in deaths per 100 million passengers miles by mode were: automobiles - 1.12; buses - 0.03; railroad passenger trains - 0.03; and scheduled airlines - 0.02.

A. CAUSES

- Human error
- Equipment failure
- Equipment design
- Right of way condition
- Insufficient policing/traffic control
- Routing
- Congestion
- Weather
- Natural disaster

EFFECTS

- Accidents
  - congestion
  - increased pollution
  - injuries
  - lost productivity
  - insurance costs
  - legal costs
  - deaths
- Health problems
  - emotional loss and psychological damage sustained by survivors and others affected by accidents
  - increased susceptibility to illness
  - reduced longevity, increased time in hospital

B. MITIGATION STRATEGIES

1. SOURCE REDUCTION
   - Design safer vehicles
     - improve technology: brakes, structural support, construction material, visibility
   - Improve emergency services
   - Reduce congestion
   - Improve the right-of-way
     - design improvements to improve visibility of junctions
     - improve effectiveness of hazard warning signs
     - improve condition of right-of-way
     - control hours that vehicles/drivers can be on rights-of-ways
     - lower speed limits
     - eliminate at-grade-crossing hazards
     - install absorbent asphalt to reduce highway water spray
   - Telecommuting
   - Promote shift to safer modes

2. PREVENTION
   - Develop Intelligent Vehicle Highway Systems (IVHS) and Automatic Train Control Systems (ATCS) to reduce congestion and improve safety
   - Educate those who operate vehicles
     - public awareness
     - periodic driving/operating test
   - Institute high insurance rates for repeat offenders

3. ABATEMENT
   - Mandate better policing and traffic control
   - Require safety devices, e.g. airbags/antilock brakes, etc.

C. COSTING/PRICING STRATEGIES

1. ESTIMATION OF FULL COSTS OF DAMAGE
   - Economic costs related to deaths and injuries
     - congestion costs caused by accidents
     - wage loss
     - medical expense
     - insurance administration
     - fire loss (structure/nonstructure fires)
     - motor vehicle damage
     - uninsured work loss
     - emergency services
     - lost productivity (morbidity cost)
     - legal and court costs
     - emotional loss (pain and suffering)
     - increased susceptibility to other illnesses/injuries

2. PRICING STRATEGIES
   - Safer right-of-way with concomitant user charges
   - Mandate safer vehicles, build cost into price
   - Higher insurance rate, e.g. "Pay at the Pump" program for insurance that can take driving record into account, to help reduce accidents

VII. COMMUNITY DISRUPTION

The presence of all types of transportation facilities, and particularity those that create a physical barrier, can have a significant, disruptive effect upon communities. Transportation facilities can divide communities and farms and disrupt wildlife habitats.

A. CAUSES

- Location of transportation and ancillary facilities
- Design of transportation/ancillary facilities

EFFECTS

Location and Design

- Dividing communities with effects on pedestrian/vehicular linkages to community services/commercial facilities
- Impacts on local government services/revenues
- Visual/pollution effect on adjacent important built and natural features
- Relocation impacts
  - housing
  - businesses
  - jobs
  - community facilities

Operational

- Noise and vibration
- Air quality
- Safety
- Declines in property value

B. MITIGATION STRATEGIES

1. SOURCE REDUCTION
   - Location of facility in an existing transportation corridor
   - Selection of least disruptive mode
2. PREVENTION
   - Design facilities to minimize impacts on residential and commercial development, cultural facilities, and community services
3. ABATEMENT
   - Providing physical connections between areas severed by the transportation facility, using crossovers, bridges, underpasses, or other linkages to maintain access for people/vehicles and for domesticated grazing, wildlife populations (to maintain genetic pools, migratory/grazing patterns)
   - Adequate relocation assistance procedures and suitable replacement facilities

X. CONGESTION

Transportation congestion creates high stress levels for users as well as adverse effects on surrounding areas. Currently, FAA reports congestion delays at airports cost $5 billion annually. Highway congestion is estimated to cost $41 billion each year and waste 3 billion gallons of fuel (about 5 percent of U.S. annual consumption) (General Accounting Office, 1989 Report). Congestion occurs in all transportation modes, at least during peak periods. Future transportation demand estimates reveal that surface transportation demand will continue to increase leading to additional congestion and a decline in average surface speeds. Air travel demands could double early in the next century and triple by 2040 (*Special Report 226, Airport System Capacity,* Transportation Research Board, 1990).

C. COSTING/PRICING STRATEGIES

1. ESTIMATION OF FULL COSTS OF DAMAGE

- Physical connection construction costs to maintain linkage
- Cost of duplicate public facilities when communities are split by a facility
- Relocation costs
  - housing
  - businesses
  - jobs
  - community facilities
- Negative effect of visual impact upon property values
- Damage to and loss of use of significant historical and cultural resources and parkland, recreation and wildlife areas

2. PRICING STRATEGIES

- Toll charges/surcharges to fund mitigation strategies such as noise, property value losses, impacts
- Restrict hours through charging entrance fees to provide funds for public transportation

X. CONGESTION

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A. CAUSES

- Development patterns
- Location of labor force
- Automobile reliance, particularly SOV
- Access to stations/airports
- Access to intermodal terminals
- Truck traffic
- At-grade crossings:
  - highway-highway
  - highway-rail
- Random interruptions in traffic flow
- Accidents
- Weather
- Construction/maintenance

EFFECTS

- Wasted time
- Wasted fuel
- Added pollution
- Slowed economic productivity
- Increased costs, including repair, insurance costs
- Higher stress levels
- Regional domino effect
- Adverse effects on adjacent land use

B. MITIGATION STRATEGIES

1. SOURCE REDUCTION
   - Shift from capacity stressed facilities to facilities with more capacity, where feasible
     - freight from truck to rail
     - freight from rail to barge (during periods of peak demand)
     - passengers from short-haul air to high-speed rail
     - commuters from SOV to HOV/transit/commuter rail, where available
   - Integrate transportation and land use planning
     - provide bypass routes, provide access for pedestrians, bicycles to transit/intercity rail, rail access to airports
     - reduce travel through proximity of residential/commercial/appropriate industrial properties
     - locate freight terminals outside congested areas; thus, decreasing the need for large vehicles to enter congested areas; use smaller vehicles for distribution of goods
   - Reduce need for trips through:
     - home based work
     - trip consolidation - both commercial and personal

2. PREVENTION
   - Eliminate at-grade crossing hazards
     - highway/rail crossings
     - highway/highway crossings
   - Increase capacity
   - Implement Intelligent Vehicle Highway systems (IVHS)/ Advanced Train Control System (ATCS)

3. ABATEMENT
   - Institute time of day limitations/tolls
     - ban large highway vehicles/small aircraft during peak periods
     - institute peak period tolls/landing fees, reduce these for off-peak periods
     - ration availability - use of odd/even system to ban vehicles on certain days
   - Internalize costs of using publicly provided facilities so as to remove/reduce artificial disincentives for modal shifts
   - Stagger working/delivery hours

C. COSTING/PRICING STRATEGIES

1. ESTIMATION OF FULL COSTS OF DAMAGE
   - Lost time - personal, business, government
   - Fuel consumed and other operating costs - insurance, maintenance, etc.
   - Lost productivity - facilities, materials, equipment
   - Decline in value of adjacent property
     - lost property tax revenues
     - loss in property values

2. PRICING STRATEGIES
   - Congestion pricing with revenues dedicated to public transportation, HOV, etc.
     - on highways to spread peaks, reduce demand
     - at airports to spread peaks
   - Parking charges and parking rights purchases (cash-outs) or provision of transportation vouchers
   - Rideshare and transit incentives

VIII. ENERGY

The transportation system is heavily dependent on petroleum sources. In 1991, virtually all (96.1%) of the transportation energy consumed consisted of petroleum products used to power automobiles, trucks, ships, airplanes and trains. The transportation sector's share of petroleum consumed increased to 65% of the petroleum used in the U.S. in 1991. While transportation's share of total petroleum use has increased since 1989, total petroleum consumption declined slightly between 1989 and 1991. Highway transportation consumed 72.4% of the transportation energy used in 1990 (excluding military consumption). Transportation petroleum use represents 137.1% of domestic production for 1991. Dependence on imported oil has trade deficit and national security implications (*Transportation Energy Data Book:* Edition 13).

A. CAUSES

- Heavy dependence on energy intensive auto and air transport
- Lack of incentives to limit consumption
- Lack of incentives to improve engine efficiency
  - CAFE standards resisted by industry
  - gasoline tax difficult to implement - no incentive for purchase of fuel efficient cars
  - underpriced/taxed petroleum compared to other countries

EFFECTS

- Oil spills from:
  - drilling
  - leaking storage tanks
  - affecting supply/cost
  - transport accidents/incidents
    - ground contamination
    - water pollution
- Air Pollution
- Political instability in oil producing areas
- Reliance on foreign oil sources
- Oil price fluctuation affecting world economy

B. MITIGATION STRATEGIES

1. SOURCE REDUCTION
   - Environmentally sound and cost effective alternative fuels
     - gasoline (reformulated/more refined), hybrid gasolines for new high-combustion engines
     - Compressed natural gas (CNG) - for autos and light trucks
     - Liquid natural gas (LNG)
     - methanol
     - natural gas (methane)
     - hydrogen
   - Electrification
     - hydroelectric
     - gas turbine
     - fuel cell, battery
     - nuclear
     - coal
     - geothermal
     - wind
     - solar
     - ocean energies
     - biomass

2. PREVENTION
   - Redesign equipment, for transport of fuels
   - More efficient engines
   - Hydraulic retarders/storage of braking energy for propulsion
   - Aerodynamic design for vehicles
   - Cryogenic cables (superconducting state)
   - Fuel economy awareness
   - Rolling resistance reduction design
   - System operating characteristics/increasing load factors
   - Subsidies/tax credits/depreciation/depletion for alternative fuel development
   - Fees to recover the full cost of transportation
   - Strategies to reduce VMT and SOV.

3. ABATEMENT
   - Pricing, vehicle tax on size, efficiency, weight-distance
   - Promote the most fuel efficient modes
   - Alternative paving products
   - Alternative lubricants
   - Promote renewable sources

C. COSTING/PRICING STRATEGIES

1. ESTIMATION OF FULL COSTS OF DAMAGE
   - Pollution caused by fossil fuels
     - health risk/physical damage
   - Cost of reliance on foreign unstable sources
     - military/policing
   - Economic costs
     - federal deficit increase
     - infrastructure costs associated with energy production
     - further research and development of alternative fuels

RICING STRATEGIES

Energy tax

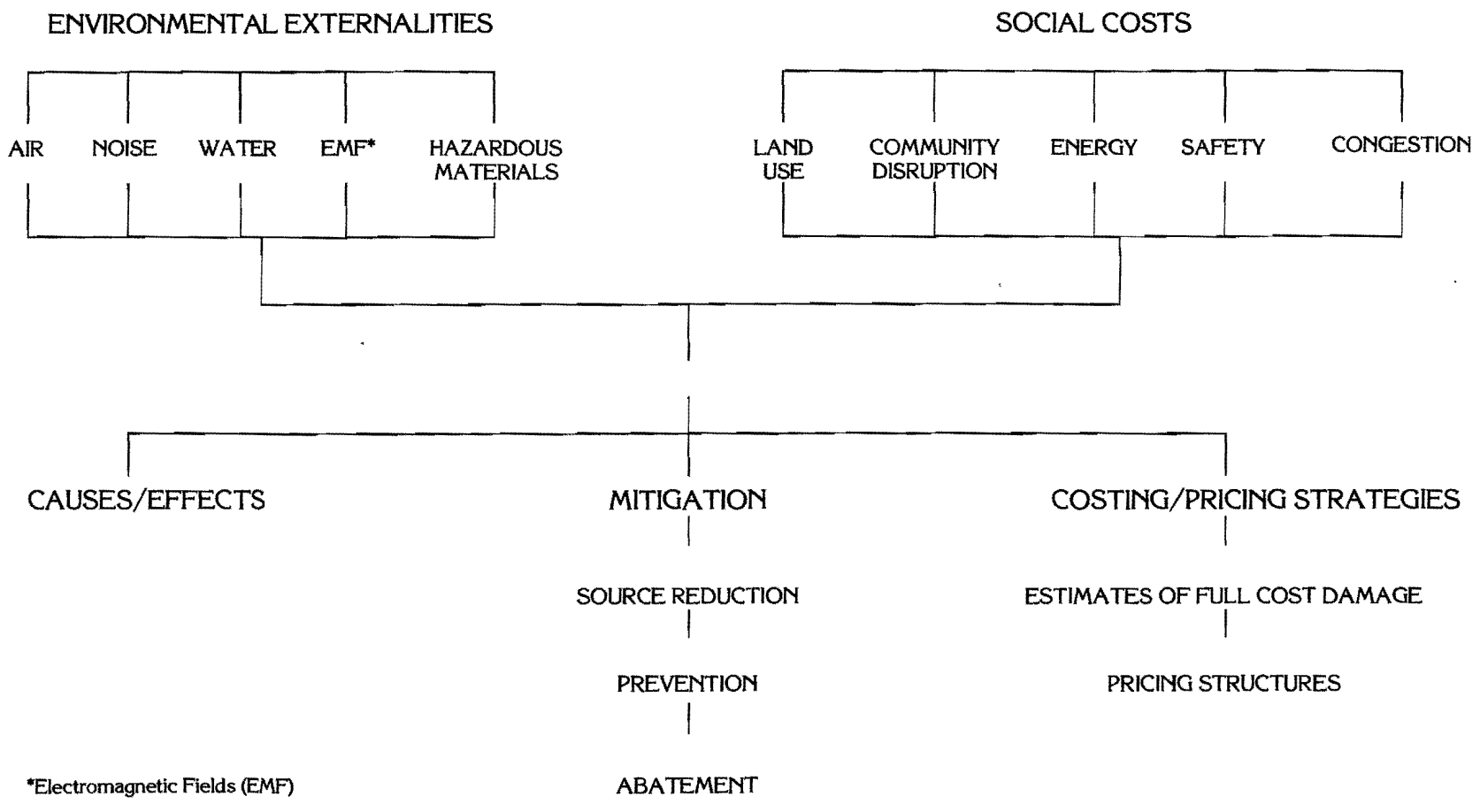
- Btu tax
- carbon tax
- gas tax
- fuel tax

Investment strategies, e.g. investment tax credits, fund for alternative fuels

Revenue neutral "feebates", based upon fuel economy

Remove depletion allowances for domestic oil production

TRANSPORTATION SYSTEM IMPACTS:



Effects, mitigation options and costing/pricing strategies have been identified from the literature and have not been independently analyzed or evaluated. Some are mutually exclusive.

GENERAL OVERVIEW STUDIES

There are some papers and reports that cover a wide range of social and environmental effects. These are included and summarized in this section. Several of these references are also discussed in other sections as relevant to a specific topic.

A. CAUSE/EFFECT - MEASUREMENT:

1. **Car Trouble, How New Technology, Clean Fuels, and Creative Thinking Can Revive the Auto Industry and Save Our Cities from Smog and Gridlock**, Steve Nadis and James J. MacKenzie, World Resources Institute, Beacon Press, Boston, MA, 1993.

   This book reviews the history of the development of the car culture and asks what are the social and environmental costs of all the cars we have today and all the ones we can expect in the future.

   According to the authors, "A broad look at our car-dominated transportation system reveals environmental, economic, and safety problems at every link of the chain - from the extraction of crude oil from the ground to the burning of carbon-based fuels in vehicles that jam our city streets, befoul the air, and not infrequently crash into each other. On top of this, we add the threat of altering the composition of our atmosphere and as a result resetting the Earth's thermostat. All for a vehicle that promised just an occasional jaunt in the country!"

   The authors suggest that long-term relief means going beyond road building and traffic controls. They maintain that the central issue is finding ways to entice people out of gasoline-powered cars. To do that, cleaner alternative vehicles, attractive modes of public transportation, and a new strategy for urban planning that makes most car trips unnecessary are needed.

2. **Freight Transport and the Environment**, European Conference of Ministers of Transport (ECMT), ECMT May 1991 International Seminar, prepared in cooperation with the Organization for Economic and Cooperative Development, Paris, France, 1991.

   In the past 20 years, growth in European freight transport has occurred primarily on highways, with 75 percent of the growth attributed to increased length of haul. At the seminar, three papers that presented the European perspective emphasized the importance and effect freight transport has on the environment, both today and in the future. Additional papers were presented detailing technical changes that may reduce future adverse emission and noise impacts from all modes. The inclusion of the appropriate environmental costs in transport pricing was a theme widely discussed.

3. **But the Replaced Refrigerator Was Landfilled: A Method for Including Environmental Benefits and Costs in Least-Cost Utility Planning (LCUP)**, M.J. Bernard, Argonne National Lab., IL, Department of Energy, Washington, DC, 1990.

   While considerable agreement exists that accounting for environmental externalities in LCUP is important, in actual practice environmental considerations are often given qualitative attention, at best. Each step - from energy extraction, through one or more conversions, transport and transmission, and to use - could impact the environment considerably. So might the extraction of materials for the production and the disposal of related hardware. This paper describes a process of including environmental planning and environmental costs and benefits in utility planning. It also discusses the types of environmental impacts that can be expected from various types of demand and supply-side utility programs and gives a detailed example of the environmental concerns associated with an electric utility's introduction of electric vehicles in an urban area.

B. MITIGATION STRATEGIES:

1. **"Environmental Quality and Transport Policy in Europe,"** Veli Himanen, Peter Nijkamp, and Juraj Padjen, Transportation Research, Part A, Policy and Practice, Vol. 26A, pp. 147-57, March 1992.

   The paper discusses the relationship of transport policy and environmental quality/sustainability and suggests that transport policy can improve environmental conditions if it decreases vehicle miles traveled, auto production and ownership, and increases the use of technological measures for cleaning exhaust gases. Four scenarios (status quo, traffic restraint, redistribution of demand, and reduction of demand) are analyzed and compared.

2. **Green Paper on the Impact of Transport on the Environment, A Community Strategy for Sustainable Mobility**, Commission of the European Communities, Brussels, Belgium, February 1992.

   This paper provides an assessment of the overall impact of transport on the environment and presents a common strategy for "sustainable mobility," which should enable transport to fulfill its economic and social role while containing its harmful effects on the environment. The report identifies critical issues relating to pollution and noise standards, truck size and weight, speed limits, energy consumption, land use, congestion, and the risks inherent in transporting dangerous goods. Measures that could take better account of the external costs of transportation are cited. The goals are to encourage and improve the more environmentally friendly modes (especially rail freight, intermodal, barge, and rail passenger systems) and to make efficient use of existing capacity.

3. **Special Report 233, In Pursuit of Speed: New Options for Intercity Passenger Transport**, Transportation Research Board, National Research Council, sponsored by the U.S. Department of Transportation, Washington, DC, 1991.

   This study of intercity passenger transport concludes that high-speed (200 mph) trains are feasible and could relieve airport and highway congestion. Environmental benefits of high-speed trains may include a reduction in air emissions. However, because of differences in the characteristics of high-speed rail, highway, and air transportation noise, it is unclear whether high-speed rail would reduce or increase ambient noise levels.

4. **Super-Trains, Solutions to America's Transportation Gridlock**, Joseph Vranich, St. Martin's Press, New York, NY, December 1991.

   This book describes high-speed rail developments in Europe, as well as efforts to introduce high-speed ground transportation in the U.S. It discusses how high-speed trains can reduce energy consumption and oil dependency, pollution, global warming, land use consumption, airport congestion, and noise.

5. **Transport in a Fast Changing Europe**, Group Transport 2000 Plus, Brussels, Belgium, 1990.

   This report was prepared by the working group, Transport 2000 Plus, formed in association with the Commission of European Communities, to examine the medium and long-term transportation and communication problems of the European Community. It highlights the crisis facing the European transportation system once the single market becomes a reality. Unless the pending crisis is addressed by the political sector, the transport system is likely to become paralyzed,

resulting in economic slowdown and increased damage to the environment. The report includes discussion of transportation's negative environmental effects, including land use, energy consumption, noise and vibration, visual intrusions, and air pollution.

The report recognizes that a balance must be struck between the environmental imperative and ramifications for economic growth. Any policy introducing environmental improvements more quickly than actually necessary, with a severely reduced GNP as a result, would be just as damaging as the too-little-too-late approach. Recommendations for action include a Euro bonus system that would tax petroleum products, a European infrastructure fund, as well as other alternatives.

6. **Transport Policy and the Environment**, European Conference of Ministers of Transport (ECMT), ECMT 1989 Ministerial Sessions, prepared in Cooperation with the Organization for Economic Cooperation and Development, Paris, France, 1990.

   This report includes the following chapters: The Interface Between Transport and the Environment; Transport Trends of Environmental Significance; Noise; Air Pollution; Regulations and Standards (exhaust emissions and noise emissions) in OECD countries; and Conclusions. The report considers how the comparative environmental advantages of alternative modes to private motorized transport can best be used and suggests that a combination of direct and indirect measures, including improvement of urban railways, along with charges or restrictions as disincentives to car use might be most effective. Any such actions will require political will and a major information campaign. For interurban traffic, the ECMT adopted a resolution that recommends making railway, inland waterway, and combined transport as efficient and commercially oriented as possible, with improved cooperation at the international level. It also recommends that any proposals to harmonize taxes and charges in international road freight transport should take into account the environmental damage caused by such traffic.

7. **Second Transport Structure Plan, Transport in a Sustainable Society**, Second Chamber of the States, General Session 1989-1990, the Netherlands.

   This paper, submitted to the Parliament as a Cabinet Document, sets out the relationship between transportation and the environment and the policy of the sustainable environment.

   According to this report, because of a dramatic increase in road traffic, the accessibility of economic centers in the Netherlands is being put at risk; the worsening problem of congestion is in danger of becoming insoluble; and the economic and social cost of congestion has risen to some 1 billion guilders per year. By the year 2010, if nothing is done, car use will have risen by 70 percent, and the cost of congestion will have quadrupled to 4 billion guilders per year, with gridlock expected in the principal urban areas. Unless rapid and effective steps are taken to encourage the transport of freight by rail and waterway, and to enhance the efficiency of road transport, the volume of lorry (truck) traffic in terms of ton-kilometers will grow by 100 percent.

   To achieve a sustainable society, there is an effort to limit external effects of transportation, such as air pollution, energy consumption, noise nuisance, the number of accident victims, the impact on wildlife and the countryside, the erosion of the quality of urban life, and the consumption of space. To preserve access in congested areas, special measures will be taken to enable lorries, shared cars, and buses to bypass the jams; other traffic will be allowed to use such facilities in return for payment. The Netherlands is working within the European Community to achieve a situation whereby a larger share of the real environmental cost is passed on to the user. They will continue developing effective transportation options and negative incentives, raising the variable cost of motoring through congestion pricing and higher gas taxes. Currently, road pricing has

received considerable political and public opposition. Consequently, it is not now an opportune time to implement this policy, but research will continue.

The strategy is to organize the country and its transport system in a way that minimizes the consumption of clean air, energy, and such little space as they have. The policy includes a carefully balanced location policy for housing, work, and recreation. Major new residential and industrial developments are to be easily accessible by public transportation. The cost of mobility will also have to be raised in the passenger and freight sectors. The need is to develop effective alternatives and negative incentives, so that the relative price of travel by public transportation and private car will be shifted in favor of public transportation. The Netherlands will be part of the European high-speed rail network, and the goal will be to promote a switch from air and road to rail travel. High-speed rail lines will allow extra capacity for freight, and goods transport by rail will be served by high quality links between the main seaport areas and their hinterlands.

C. COSTING/PRICING STRATEGIES:

1. **Results of Literature Survey and Summary of Findings: The Nature and Magnitude of Social Costs of Urban Roadway Use**, Mark E. Hanson, Resource Management Associates of Madison, Inc., Madison, WI, for the U.S. Department of Transportation, Federal Highway Administration, in the process of publication.

This report notes a growing interest in market-based approaches to transportation-related problems, correlated with interest in the broader issue of social costs of highway use. The paper also suggests that parallel developments in planning methods for electric utility planning are influencing the field of transportation planning. Hanson observes that when social costs are explicitly addressed in economic terms, they usually focus only on particular aspects of transportation issues. "There are very few studies which attempt to integrate all the different aspects of highway social costs into a comprehensive analysis of the social costs of highway use." In some areas, the literature is thin or totally absent (e.g., highway damage to surface and ground water resources).

Hanson finds that the three largest categories of social costs of highway use are air pollution, accidents, and congestion costs, and these areas should be emphasized when developing a cost accounting framework. The study reviews approaches taken in calculating social costs and suggests research to be undertaken, including:

o an updated study of the range of national and regional aggregate social costs (current estimates appear to be in the range of $60 to $660B per year, but with some costs deleted from the high estimate and added to the low estimate, costs could be narrowed to $150 to $300B per year); in conjunction with the estimate of national social costs, developing a set of urban and rural costs to better understand the diversity of costs across areas of the U.S. and within urban areas; these should take into account the highly variable travel patterns in different parts of urban areas, in order to estimate the costs that residential, and, possibly, industrial and commercial locations incur;

o developing and implementing highway social costs accounts, in order to develop consistent information on environmental burdens and provide a more complete picture of the direct consequences of transportation systems investments and use. From an economic perspective, the measured and perceived benefits of transportation choices of transportation system investment, management, and use could be better weighed against the private and social costs. The design of

the environmental accounts should be the subject of a research effort that would recommend the contents of such accounts, including specific measures, units, and means for collecting the data;

o a transportation demand management (TDM) research initiative, to measure responses to specific TDM measures; and

o an analysis of the application of utility least-cost planning to transportation planning.

2. **A Proposal for New York City: If Drivers Pay More, We'll All Drive Less**, Brian Ketcham and Charles Komanoff, Surface Transportation Policy Project, Vol. II, No. 10, December, 1992.

The authors look at car and truck traffic in New York and conclude that demand for more motor vehicle transportation is higher than it would be if all the costs of vehicle use were included in the price of the vehicle transport. They propose pricing transport use approximate to its full cost - including "hidden" costs. They advocate making driving as costly for drivers as it is for society by gradually internalizing external costs and eliminating subsidies.

3. **Benefit-Cost Evaluation in Transportation**, Douglass B. Lee, Draft Paper, U.S. Department of Transportation, John A. Volpe National Transportation Systems Center, Kendall, Square, Cambridge, MA, December 1992.

The paper describes the basic elements in, and the process of, benefit-cost analysis; an approach to decision making that shows the pros and cons of making a particular decision. The major components in the benefit-cost approach are defined and described in some detail: alternatives, impacts, and evaluation. These lead to a net benefit calculation.

In the first step, (Alternatives) base alternatives are described and investment and supporting actions are enumerated. In the second step (Impacts) the range of each alternative's consequences and their costs, benefits, and transfers are determined. According to Lee, the costs are normally limited to direct outlays for project purposes. Costs that are hard to define are merged with benefits. Benefits for building or improving transportation facilities are grouped into four categories: time savings (for people and goods); cost reductions (private and public, capital and operating); safety improvements; and quality improvements (comfort, security, convenience, reliability, etc.). Transfers are impacts that make someone better off at the expense of another and include noise and air pollution. The third step (Evaluation) answers the question, "Are we better or worse off if the investment is made?" This involves consideration of efficiency (the alternative that creates the highest net benefits for society as a whole) and equity (how the costs and benefits are distributed among different groups and locations). Effectiveness indicators can supplement both efficiency and equity analysis, as it measures how well an alternative works, satisfies the objectives proposed, and compares various indicators with other alternatives.

4. **Should Drivers Pay More? Win-Win Transportation: A No-Losers Approach to Financing Transport in NYC and the Region**, Charles Komanoff and Brian Ketcham, Auto-Free Press, Vol. 4, No. 2, November/December 1992.

The authors propose charging motorists for their "fair share of the fiscal and social costs of driving and to invest the revenues judiciously in transit and other non-motorized modes." Urban motorists would be charged for roadway use in proportion to the costs that they impose on society. These charges would range from $750 per year for cars driven in the suburbs to $14,000 per year for trucks used in the city. The authors estimate the hidden costs of roadway transport per year for NYC and non-NYC metro areas. Accidents and air pollution rank first, followed by land and noise. The rest goes to congestion, military to keep foreign oil flowing, climate change costs from

burning fossil fuels, and vibration. Air pollution costs were estimated using the number of excess deaths from all air pollution. Land costs were based on half of the space taken up by streets and highways, since the other half would have been used anyway to walk, bike, etc. Noise costs were based on Federal Highway Administration-sponsored studies correlating proximity to highways to property values and came to 50 cents per-day per-resident of NYC.

The authors propose a 2-tier phase-in of hidden costs into the price to drive and some general guidelines for implementation, such as using multiple tariffs and differentiating between trucks and cars and city vs. suburb. Finally, they discuss how to invest the funds collected.

5. **"The Environment-Mobility Dilemma,"** Rail International Proceedings, Session C, Workshop 17, Brussels, Belgium, June/July 1992.

This panel discussed the need to shift more traffic to environmentally benign modes and ways to measure the environmental and social impacts of transportation. Several papers are described below:

"A Solution Based on Market Principles," Lars Hansson (Sweden).

This paper points out that in the 1980s, there was increasing focus on the quality of mobility of different transport modes and the environmental impact of transportation. Externality charges, internalizing environmental effects, will allow appropriate tradeoffs to be considered.

When the Swedish Parliament adopted a new Transport Policy Act in 1988, costs for traffic emissions were explicitly reflected in the infrastructure charges for road, rail, and domestic air traffic. Explicit evaluations of external effects in Sweden imply road user charges that amount to 240 percent of the budgetary costs for highways and roads, while the social costs for rail traffic would only increase by 8%. Noise effects, which were considered, are not included as they are not part of the transport cost responsibility adopted.

"Environmental Problems in the Transport Sector and Concepts Proposed for Their Solution," Werner Rothengatter (Germany).

This paper observes that private cars, trucks, and aircraft are the biggest sources of pollution among the different forms of transport. However, under free market conditions, the modes that pose the greatest threat to the environment are those that will increase the most. Environmental problems caused by transport can be resolved by restrictive controlled economic measures or by application of market mechanisms, but market economy instruments should predominate to allow more sources to be reached. Market economy instruments consist of: i) introduction of a price mechanism, and ii) expansion of infrastructure on the basis of economic and ecological criteria.

Price policy should be based on the principle of recovery of social costs, including infrastructure costs, environment-related costs, and other external effects, such as the cost of congestion. Dr. Rothengatter suggests that such a pricing policy would result in the modes with the highest intrinsic environmental costs having to pay the highest extra charges - through road pricing, fuel taxes, or by paying for environmental certificates. Predicted actual demand for infrastructure would be based on the demand that remains after internalization of social costs by means of user charges.

"Mobility and the Environment," Antonio Tamburrino (Italy).

Dr. Tamburrino discusses the concept of "environmentally sustainable mobility." He points out the need to obtain exhaustive scientific data on environmental effects and to develop a sound

evaluation of economic, social, and environmental costs and benefits, activating a public decisional process to build consensus on these.

6. **The Going Rate: What It Really Costs to Drive**, James J. MacKenzie, Roger C. Dower, Donald D.T. Chen, World Resources Institute, Washington, DC, June 1992.

   This report explores the full cost of an auto-dependent transportation system, estimating what the implementation of the "polluter pays" principle and its logical extensions would mean for the country. The report suggests that gas taxes and other user fees covered only about 60 percent of the $33.3B governments spent on building, improving, and repairing roads in 1989; the rest of the money came from taxpayers and other sources. The cost of vehicular air pollution is estimated at $10B per year. The report quotes Transportation Research Board figures that annual delays in travel time will increase by 5.6 billion hours over the next two decades, wasting an additional 7.3 billion gallons of fuel per year, adding 73 million tons of carbon dioxide to U.S. emissions annually, and increasing travelers' costs by $41B.

7. **Transport and the Environment in Finland**, Statistics Finland, for the Ministry of Transport and Communications, Helsinki, Finland, June 1992. (English edition, which is an abridged version of the more comprehensive Finnish report.)

   This report, which discusses environmental issues in Finland, contains statistics, estimates and projections, research results, and information on aspects of transport policy and legislation. One development objective for the next few years concerns the pricing of environmental damage attributable to traffic. There is discussion in Finland about shifting taxes from vehicle acquisition to operation, making causing of damage the prime object of traffic taxation. For cars, this could be done by increasing the fuel tax. Although this rise in variable costs is expected to influence people's travel decisions, there is the risk - at least in the short term - that easing the acquisition cost of cars will increase traffic volumes and lead to the use of larger cars. There is already a surtax, or pollution tax, on transport fuels.

8. **Paying for Highways, Airways, and Waterways: How Can Users Be Charged?**, U.S. Congress, Congressional Budget Office, May 1992.

   This study considers alternative ways of setting prices for the use of highways, airways, and waterways, and the advantages and disadvantages of different approaches. Its focus is on using prices to create incentives for efficient use of the existing infrastructure in the short run and in making efficient investments in new infrastructure.

   To achieve economic efficiency, the price of a service should equal its marginal cost in the short run - that is, the value of resources used in producing the last unit of service. An efficient price should reflect private, public, and external marginal costs. The sum of these is referred to as the "social cost." The study suggests that the government can promote economic efficiency by charging users the difference between marginal social cost and marginal private cost. However, alternative pricing schemes can be difficult to administer, and new administrative mechanisms would be needed.

   In the case of congestion, the marginal cost of delay determines the efficient level of congestion charges. The amount users are willing to pay to alleviate congestion delays can suggest how expanding capacity would be beneficial. Analysts have made rough estimates of the marginal social costs of highway congestion, weight, distance, and pollution, although additional research to update and refine the estimates - especially of emission costs - would be desirable. Efficient pricing could raise enough revenue to reduce or eliminate existing taxes.

If aviation users were charged extra for peak hour use, some would shift to less busy times, thereby alleviating congestion at peak periods. The FAA has estimated that congestion and delays add about $5B annually to airline operations. It is unlikely that charging users for the congestion they cause would raise that much in revenues. The revenues that could be expected from congestion pricing are more likely to be between $1B and $2B, depending on how much congestion is considered optimal (acceptable), how much is due to weather, and how much time is worth to passengers. FAA has estimated that the average value of time for business trips, expressed in 1991 dollars, is $44.24 an hour, while the estimated value for nonbusiness trips is $38.03 an hour.

The report observes that pollution is another social cost that should be taken into account in aviation. Noise pollution is an important factor in an airport's decision to increase the number of runways and operations. Air pollution from jet fuel may need to be priced as traffic expands. At present, however, there is stronger agreement among analysts about the practicability of pricing for congestion than for other social costs.

Congestion at locks and dams is somewhat different from congestion on highways and at airports. Congestion on these modes occurs at peak travel times, whereas congestion at a lock can occur whenever several tows arrive at about the same time. Scheduling lockages, or providing traffic information to tow operators, could reduce congestion delays. Operators might be willing to pay a small fee to cover the cost of administering a reservation system. Operators may choose to pay for a reservation to avoid delay at peak times.

9. **Financing High Speed Rail and Maglev Systems in Europe, Japan and the U.S: Implications for Systems Financing in Florida**, Thomas Lynch, Center for Economic Forecasting and Analysis, Florida State University in cooperation with the Center for Urban Transportation Research, University of South Florida for the Florida Department of Transportation, January 12, 1992.

Among other things, this report discusses the need to treat environmental externalities in the development of transportation systems. The Swedish have costed several externalities by implicit and empirical evaluations of social benefit and/or environmental benefit from alternative modes. According to the report, the truck and the automobile have higher environmental and social costs than the rail option. For traffic safety, the social costs include: 1) loss in production; 2) medical treatment and hospital care; 3) administrative costs; and 4) property damage. Explicit valuations of human values include the value of life expressed as the risk or change in the risk of being involved in a traffic accident, not the valuation of life itself. The report refers to Lars Hansson who distinguishes between three different methods of evaluating environmental externalities: 1) financial costs such as loss in productivity in forestry or costs of corrosion; 2) costs of compensatory measures; and 3) quantifying environmental effects in monetary terms. Studies in France, Luxembourg, Belgium, and the Federal Republic of Germany show socio-economic costs amount to 2.5 percent of GNP for road accidents. An essential element in the evolution of dispersed land use patterns has been the emergence of the automobile. This article also delineates the nature and magnitude of automobile subsidies in the U.S. and considers their significance for transportation and land use policy.

10. **Directions, The Final Report of the Royal Commission on National Passenger Transportation, Summary**, Minister of Supply and Services, Ottawa, Canada, 1992.

Among other things the Commission looked at was the effect of transportation on the environment. They concluded that most travellers do not pay the full costs of the passenger transportation services they use; prices do not reflect a traveller's use of the system, and environmental and other social costs are rarely factored into the costs of the passenger transportation system. Total costs of

the different modes are broken down by type: infrastructure, environmental, accident, special transport tax/fee, and vehicle/carrier. They recommend that environmental charges also include the costs of clean-up and mitigation and the administration of environmental policies and regulations. Safety and accident costs will include the cost of government safety services and health care costs currently borne by the health insurance system. The Commission recognizes that travelers should pay only for what they use, and pricing should encourage neither overuse nor underuse. They recommend that governments apply emission charges on as close to a per-unit basis as possible. The Final Report itself goes into much greater detail on costing externalities.

11. **"Automobile Subsidies and Land Use: Estimates and Policy Responses,"** Mark Hanson, Journal of the American Planning Association, Vol. 58, No.1, Winter 1992.

The magnitude of indirect subsidies is highly uncertain and methodologies to estimate them controversial. Air pollution, water pollution related to road salt use, personal injury and lost earnings associated with accidents, and land use opportunity costs for land removed from other uses are studied for Madison, Wisconsin. Acid deposition from NOx emissions and greenhouse effect from CO2 emissions are excluded due to lack of previous research. Annual per capita indirect subsidies and several other subsidy measures are included. The review of studies yielded a mid-range estimate of air pollution damages at $7B (in 1983 dollars). In 1982, the average personal injury cost per accident in Wisconsin was $7,700.

As understanding of wet and dry deposition has improved in recent years, air emissions from mobile sources are increasingly recognized as sources of water pollution and acid rain. There is now a body of research on water pollution from salt for snow and ice removal. A study by Murray and Ernst (1976) identified $2.7B (1976 dollars) in annual water pollution damages in the U.S. Over 90 percent of the damage was attributed to vehicles and highway structures.

12. **CONEG High Speed Rail Regional Benefits Study, A Report on the Benefits to the Region of Improved Passenger Rail Service Between Boston and New York**, prepared for the Coalition of Northeast Governors High Speed Rail Task Force, by Parsons Brinckerhoff Quade & Douglas, Inc., Cambridge Systematics and Regional Science Research Institute, October 1990.

This study identifies the regional benefits, quantitative and non-quantitative, of improved passenger rail service between Boston and New York City. The study estimates that with 2.85 million annual passengers diverted from air and highway travel, the high-speed rail program can save 24.5 million gallons of gasoline and jet fuel consumed annually, and will have beneficial impacts on carbon monoxide, hydrocarbons, nitrogen oxides, and other emissions, with a net reduction of over 2,600 tons annually.

The study observes that in 1986, passengers at four of the region's major airports experienced 16.3 million hours of airside delays. By 1996, that number is expected to grow to 22.5 million hours. These four airports rank among the 10 most congested in the country. Average highway speed throughout the corridor is 46 miles-per-hour. Diversion of passengers from air and automobiles can reduce hours of delay on both modes.

Insurance companies could save an estimated $3.8M annually in accident claims by a diversion of travellers to high-speed rail. If the train, as predicted, can divert 114 million passenger miles and 190 million vehicle miles, there would be 2.3 lives saved annually. Increased train ridership could also result in an expected reduction of 950 accidents and 95 injuries annually. Given these statistics, using values commonly in use by some departments of transportation - fatality = $387,000; injury = $11,000; and accident = $2,000, annual safety benefits would be $3.8

million. The study does not distinguish between intercity and metropolitan area highway emissions, speed, accidents, injuries, and deaths when computing benefits.

13. **"The Transport Planner's View,"** A. Nilsson, Swedish State Railways, included in Sub-Theme 3: Transport and the Environment - A Balanced Policy, in Railways, Environment and Transport Quality, A Collection of Expert Papers Prepared in 1989 for the International Transport Workers Federation, London, U.K., February 1990.

In Sweden, the 1988 Transport Policy Decision established that transport charges were to cover total (variable and fixed) socio-economic costs and that these costs were to be the responsibility of the user. The variable transport charges are to meet the short-term socio-economic marginal costs - including the cost of maintaining infrastructure, the costs of traffic surveillance, and external costs. The fixed transport costs shall in principle cover the difference between the marginal costs and the total socio-economic costs of transport services. Taxes and charges not motivated by transport policy reasons are to be formulated on a uniform basis for different modes.

External effects liable to charges are road accidents, congestion, and environmental effects (emissions). Calculation of marginal effects of traffic noise is not considered possible. In order to put road and railway charges on the same basis, the State has taken over responsibility for railway infrastructure. The author states that the goals have not yet been fully attained. For example, heavy freight road transport has not been required to fully cover estimated socio-economic marginal costs.

As a base for the transport policy decision of 1988, extensive research and development work was carried out, especially into environmental effects. "Instead of making direct estimations of emission effects - in practice an impossible task always resulting in underestimations - calculations have been made of society's estimations of the emissions." A price per weight unit has been set for a particular emission, and application is similar for all sources, whether or not a transportation source. Under this system, railways are charged the same per emission unit from diesel-powered vehicles as road traffic.

To initiate the discussion about the costs of heavy goods road transport, the Swedish National Railways has developed an estimate of the total 1986 socio-economic costs of motor transport. Based on earlier surveys, it was found that heavy goods transport by road generates SEK 4.5 and 5.5 billion in costs while the charges and taxes paid by this transport segment total only SEK 2 billion. Once the public and decision-makers understand the railways' advantages, the author believes railways will be the transport mode of the future.

14. **Transport Policy and the Environment: Urban Traffic Management**, European Conference of Ministers of Transport Ministerial Session, Prepared in Cooperation with Organization for Economic Cooperation and Development (OECD), 1990.

This report recognizes that it is very difficult to isolate transportation's contribution to overall air and water pollution.

Three approaches to cost estimating are presented. The first, the resource approach, measures environmental effects in terms of the social product linking the disamenity to the cause. The second, the utility approach, measures the willingness to pay to pollute or stop polluting using carefully designed opinion polls or observing and evaluating behavior patterns such as the additional costs incurred in changing living areas - the lower limit of the valuation of an improved quality environment. The third, the risk approach, assigns specific probabilities to future losses and manages such losses with a strategy mix of diversification, insurance, and prevention. Diversification is accomplished through parallel development of alternative modes in order to

reduce total environmental risk; insurance through premiums that cover the costs of environmental damages; and prevention through determining the costs of preventing damage. If the prevention approach is used to evaluate impact by component, and two or more components share responsibility for one or more impacts, then there is the possibility of counting the same costs more than once.

Traffic noise and air pollution costs are measured as proportions of GNP for OECD countries, the average being 0.5 percent. The figures for the individual countries, however, are based on different methods and value judgements. The report points out that international and time related comparisons are not very meaningful if there are big differences between the preference settings. The costs they derive account for damages such as: productivity losses; expenditures for medical care; loss of asset values; costs for repair of buildings; as well as more difficult things to measure, such as willingness to pay for better air quality. However, these figures also account for mitigation costs such as: indirect expenditures on vehicles; road/rail and home construction for noise reduction; and expenditures for pollution reduction.

Cost contributions of the different modes in Germany are also studied.

15. **User Charges and Transportation Efficiency: The Railroad Viewpoint**, Frank N. Wilner, Information and Public Affairs Department, Association of American Railroads, Washington, DC, 1990.

This paper cites various reports showing the high cost of highway congestion, fuel dependence, air pollution, accidents and the costs of relieving congestion to satisfy demands on the highway and inland waterway systems. Mr. Wilner also observes that U.S. railroad facilities have substantial excess capacity, are in excellent condition, and, in terms of the environment and safety, are a preferred mode of transportation. He argues that heavy trucks and barges underpay significantly their direct cost responsibility. "Also, there are indirect costs such as congestion, noise, water and air pollution, and increased accident exposure. ... These underpayments have contributed to a siphoning of business from railroads to trucks and barges. ... Mechanisms for full cost recovery must be developed."

16. From Peter Passel's "Economic Scene" columns in The New York Times since 1990.

Passell reviews others' perspectives regarding transportation externalities. He points out that the environmentalists in the administration need the economists to design policies that generate the least possible drag on growth, and the economists need a solid front to push through market-based regulations bound to offend the old environmental guard. In his July 30 1992 column, he presents Clifford Winston's view that roads and airports are crowded because cost-based prices are not used to ration available capacity. Also, if heavy trucks were charged for the damage they cause to highways, more freight would move by rail. Passell asks whether the "best minds" (often influenced by lobbyists) can be relied on to make decisions when neither the costs nor the benefits can be quantified.

In his April 1 1992 column, he critiques different tax options. He views the V.A.T. (value added tax) - collected at each stage of the production process - as an easy ticket to bigger government because it is not as apparent to the taxpayers. The problem with this tax is that it is regressive, because the rich spend less in proportion to their income. Passel concludes that taxes on gasoline are easy to collect, progressive, and force consumers to reckon with the damage caused by traffic congestion, local air pollution and greenhouse warming. However, the gas tax is politically hard to sell. In his October 30 1991 column, he reviews Peter Gordon's proposal to phase out mass-transit construction subsidies and convert operating subsidies into transit vouchers for low-income

families who cannot afford to commute by car. He also proposes creating demand driven transit systems.

In his December 9 1990 column, Passel looks at tolls as a way to thin out midtown Manhattan traffic and proposes several strategies for doing this. The biggest hurdle is the politics of congestion pricing, but the idea can be made more appealing by reducing tolls at non-rush hour times.

In his July 25 1990 column, Passell discusses California's problem with traffic-related smog. "The quick and dirty way to get Californians to drive less would be to ration car use or parking or gasoline consumption - or all three." The Environmental Defense Fund (EDF) favors rationing road use by price, using congestion or emission taxes. The idea of tolls is rejected as it would aggravate congestion. Michael Cameron of the EDF proposes giving everyone limited rights and allowing low users to sell to high users. Extra allowances could also be sold through vending machines.

17. **Report of the Seventy-Ninth Roundtable on Transport Economics, Environment & Transport Infrastructures**, Organization for Economic Cooperation and Development (OECD) Publications Service, Paris, France, December 1988.

This work presents three OECD member countries' approaches for developing transport projects' environmental impact statements. The French classify environmental effects into three categories: 1) physical environment - air, water, and noise; 2) socio-economic environment - rehousing, safety, obstacles to travel, and equilibrium of the agricultural and rural economy; and 3) heritage - fauna and flora, ecosystems, archeological heritage and landscape, and architecture. In the areas of water pollution and vibration, more research is needed before these can be costed. In the area of water pollution, methods for conservation have received greater attention than methods for evaluation. The Swiss rank the severity of environmental impacts in matrix form - project activities (life cycle) v. environmental damages - with a 3 to 5 level rating system.

The overall report describes the stages in evaluating the impact of transport infrastructures on the quality of life: 1) determine what the indicators of exposure are to ascertain the scale of the disturbance caused; 2) determine degree-of-annoyance indicators; 3) study behavior patterns to cope with the disamenities; and 4) determine the impact on health. Although the price those exposed are willing to pay to avoid the disamenity is its monetary value, this raises methodological difficulties. Alternatively, the value attached to avoiding disamenities can be calculated on the basis of actual behavior. The price differential of two comparable properties can be studied, but the impact of any one factor cannot be singled out. Moreover, where the causal chain is complex, the assignment of a monetary value is based on assumptions which leave the process open to question.

Damage to health occurs from a combined effect of different factors and it is difficult to determine each one's particular contribution. Sometimes the cost of prevention can be a substitute. In the case of air pollution, not enough is known about diffusion and incubation to measure the impact. When measuring social costs, it is difficult to place a monetary value on change in human behavior such as stress or apprehension. The specialists consider that there are a whole series of more or less cogent indicators for the assignment of a monetary value to effects. The members present a multi-criterion approach where some effects are assigned a monetary value and others a category of impact by differentiating degrees of damage.

18. **"Cost Allocation By Uniform Traffic Removal - Theoretical Discussion and Example of Highway Cost Applications,"** Chris Hendrickson and Anthony Kane, Transportation Research, Vol. 17B, August 1983.

    The problem with allocating roadway costs is determining the appropriate division of cost among the various vehicle classes. The general properties a good procedure should have are discussed, along with the uniform traffic removal technique which possesses these properties.

19. **Transportation Cost Survey**, Todd Litman, 113 Decatur Street, Olympia, WA 98502, 206/943-9025, February 1992.

    This paper summarizes current thinking concerning the full costs of roadway transportation. Litman states that society's use of and dependency on automobiles has increased at an exponential rate, to the point that the costs of driving may outweigh benefits. He suggests that it now makes sense for society to modify the resource allocations, regulations and price structures to encourage less driving and increased use of other travel modes. Accomplishing this goal requires changing transportation planning practices. Until now, transport planners' primary goal has been how to meet drivers' needs for roads, parking, and services at the least cost. Other modes were only given token attention. Developing a balanced, multimodal transportation system requires more complex decision making. Planners must determine how to allocate resources among various modes to achieve a number of social, economic and environmental goals.

    Benefit/cost, rather than simple cost effectiveness analysis is needed. While transport economics has often attempted to quantify benefits and user costs, external costs have received little attention. Fortunately, a number of techniques are now available to quantify non-market goods, allowing impacts, such as air pollution and accident risks to be incorporated into decision making. The paper discusses the following costs of highway use, comparing estimates made by different researchers: user costs; external costs resulting from motor vehicle traffic congestion; accident risk; road construction and maintenance; municipal services; parking; roadway land value; reduced tax revenue; low density land use (urban sprawl); air pollution; noise; energy costs; water pollution and hydrologic impacts; waste disposal; and the value of having multiple travel options.

20. **Efficient Highway User Charges - Appendix E to the Final Report on the Federal Highway Cost Allocation Study**, Douglass Lee, U.S. Department of Transportation, Transportation Systems Center, Cambridge, MA, May 1982.

    To derive highway user charges, Lee first estimates unit costs in cents-per-mile for the cost components as functions of vehicle characteristics and operating conditions. Then, he estimates the actual operating conditions that the vehicle will encounter. Total user charges are estimated in cents-per-mile for typical vehicles and conditions in rural vs. urban areas. According to Lee, there are many gaps in basic knowledge, including the contributions of different vehicles to congestion and pollution under varying conditions and the valuation of noise, travel time, and air and water pollution. In order to arrive at an efficient price, individual consumers must pay the full social costs of their decisions. The costs of congestion occur in the form of excess travel time, increased expected damage and injury from accidents among vehicles, and additional vehicle operating costs for wear and fuel. All are measured relative to what the costs would be under uncongested conditions. The orientation of this report is to estimate what the correct prices should be. The author divides private user costs into vehicle interference - delay, accidents among vehicles, and increased vehicle operating costs - and negative externalities - air pollution, water pollution, noise, visual intrusion, and danger to non-users and property. Many of the data and engineering relationships upon which the price estimates are based are known to be inadequate, and steps are being taken to improve them, but better information is not yet available.

Lee presents three strategies for pricing externalities. 1) Where restoration is reasonable and market prices reflect social costs, actual expenditures are a good measure of damage. Some of the problems with this approach are the uncertainties about: the magnitude of the impacted population; whether the expenditures result in more than or less than true restorations; and the degree to which the expenditures can be attributed to the specific source of pollution. 2) Revealed preferences deal with surrogate markets for noise, air pollution, and danger which is sufficiently localized to allow buyers and renters to demonstrate the amount of money they are willing to pay to forego the annoyance. Because the choices are made in packages, deriving prices depends on multivariate statistical analysis. 3) Optimal control costs place a lower bound on the value of the damage. But, to derive the optimal level you must know the amount of damage.

21. **Methods for Allocating Highway Costs**, Douglass Lee, U.S. Department of Transportation, Research and Special Projects Administration - Transportation Systems Center for Federal Highway Administration, PL-81-017, Cambridge, MA, April 1981.

Pricing concepts are reviewed and applied to the problem of designing efficient highway user charges that include external costs. Truck/rail competition is unlikely to improve resource allocation if each mode is subject to different cost recovery constraints. Prices should be set so users pay the marginal costs of their usage and overuse and waste are avoided. Because some externalities are long-run costs, the popular pay as you go philosophy - each year's revenues should equal each year's expenses - cannot be applied. Highway user charges should include disincentives to the generation of external costs, even though their precise dollar value will probably never be known. Damage from air pollution, water pollution, noise, danger to non-users, and costs of cleanup and control are measured. The three costing methods used are: measuring damages, revealed preferences, and optimal control costs. Sometimes these can be used independently and reconciled. Finally, different implementation strategies for user charges are reviewed.

22. **Transportation Efficiency, An Economic Analysis**, Todd Litman, TESC Masters of Environmental Studies, 113 Decatur Street, Olympia, WA 98502, 206/943-9025, January 17, 1991.

This paper suggests that travel impacts vary significantly depending on the choice of mode and the conditions under which a trip takes place. It is in society's interest to promote transportation which provides the maximum benefit at the least cost, i.e., transportation which is most "efficient." This paper examines the meaning of this concept and how it can be accomplished.

Litman states that the analysis indicates that many transportation problems, including congestion, neighborhood impacts, energy demands, environmental impacts, and inequity, are not separate issues; rather, they reflect inappropriate pricing, especially the underpricing of automobile use, and a lack of viable alternatives to driving. This analysis is especially important because per capita motor vehicle use continues to grow, imposing increasing costs and increasing our dependency on cars. The paper maintains that three factors affecting transportation policy, transportation's user benefits, user costs, and society's benefits are well represented by user groups, business interests, and government agencies. If user costs become unreasonably high, or if an opportunity exists to expand a transport resource, there are many organizations, both public and private, that are ready to respond. The fourth perspective, society's costs, has fewer organized advocates.

This paper attempts to quantify the various social (or "external") costs of common transportation options and to develop practical tools for applying economic theories. Although the paper focuses on costs, the author makes it clear that transportation is an important and essential good that offers many benefits. It also assumes that mobility and access are so important that society cannot afford to squander transport resources.

ENVIRONMENTAL EXTERNALITIES

I. AIR POLLUTION

Most Americans would agree that air pollution is a serious problem, particularly in urban areas. However, the actual measurement of air pollution's effects and cost of damage remains an area of some controversy in the scientific and economic community. Global warming, acid rain and ozone are just three areas where there are conflicting data and conflicting scientific opinions. In part, these conflicts exist because air pollution occurs from both natural and anthropogenic activities. A further complication is that the impacts may occur a great distance away from the pollution source or may occur long after the emission release. Considerable research is being conducted at the present time, and additional research will be needed in the future before the impacts and damages can be fully determined.

A. CAUSE/EFFECT - MEASUREMENT:

1. **"Contrary to Popular Notion, Ozone Is a Renewable Resource,"** Johnstone Quinan and Dick Furno, The Washington Post, April 15, 1993.

   In this article, the authors discuss the dynamic nature of ozone (O_3) in the stratosphere (that area of the atmosphere between approximately 10 and 30 miles high). They explain the cycle that creates and destroys stratospheric ozone, the role stratospheric ozone plays in protecting living cells, and the difficulty scientists have had in assessing the negative effects from the presence of chlorofluorcarbons (CFCs) in the stratosphere.

   Stratospheric ozone is created when solar ultraviolet (UV) radiation strikes an ordinary oxygen molecule (O_2) and splits it apart. When the single oxygen atom hits another O_2 molecule, ozone is formed. The new ozone molecule has the special ability to absorb a specific band of UV radiation (UV-B), but when it does it breaks down into O_2 and a single oxygen atom. Then the cycle is ready to repeat itself. (This process is fundamentally different from the creation of ozone at or near ground level where hydrocarbon and nitrogen dioxide molecules - both emitted mostly from motor vehicles - in the presence of sunlight form ozone. Near the earth's surface, ozone is directly harmful to plant and animal life).

   The importance of stratospheric ozone lies with its special ability to absorb the UV-B ultraviolet radiation which is especially damaging to living cells. Therefore, stratospheric ozone has the important role of reducing the amount of harmful UV radiation reaching the Earth's surface. For this reason, the loss of stratospheric ozone caused by the presence of CFCs in the stratosphere has caused great concern among the public and environmental groups.

   When CFCs (commonly used in motor vehicle air conditioning systems, among other places) are accidentally or intentionally released, they migrate to the stratosphere. There, ultraviolet light begins a series of chemical reactions that can destroy significant amounts of ozone before it can absorb UV-B (the reactions are detailed in a diagram). This leads to concern that "ozone holes" found over the poles in recent years could harbinger significant declines in stratospheric ozone, increasing amounts of UV radiation reaching the Earth's surface, with subsequent increases in the occurrence of skin cancers and other disorders.

   However, it now appears that the stratospheric ozone cycle is much more dynamic than previously thought, with stratospheric ozone constantly being destroyed and recreated. This leads to the description of ozone as a renewable resource. In fact, it appears that the ozone holes which have occurred over the poles in winter months are rapidly closed long before the next winter season arrives.

The amounts of ozone present in the stratosphere at any one location are also highly variable and dependent on wind conditions. Hence, ozone concentrations can vary widely from hour-to-hour, making impact analysis and trend predictions of ozone loss as a result of CFCs difficult at best. Additionally, ozone concentrations have separate natural cycles that are influenced by such forces as the solar flare cycle, the periodic warming of the southern Pacific Ocean ("El Niño" effect), etc. For example, the amount of ozone present in the stratosphere above temperate latitudes is normally about 20 percent higher in April than it is in October. This is 4 to 5 times that drop attributable to human activities, including CFC effects.

Overall, while it appears clear that the overall depletion in the ozone layer is real, ozone is constantly being replenished. There are many other factors at work affecting the concentrations of stratospheric ozone at any one location.

2. **"In the Debate About Ozone, No Depletion in Rhetoric,"** The Washington Post, April 15, 1993.

This article discusses the difficulties in measuring the effects resultant from depletion of stratospheric ozone. One difficulty is the lack of data describing the amount of ultraviolet radiation reaching the Earth's surface. Without a baseline to measure against, no one can know just how much more UV radiation is reaching the surface as a result of stratospheric ozone losses. A second difficulty is the lag time between exposure to increased UV radiation and the onset of skin cancers and other maladies. Consequently, the impact from an increase in ozone depletion-caused UV radiation is difficult to predict at this time.

Additionally, while it is known that certain UV radiation is very harmful to living tissue, both plants and animals have developed mechanisms over the millennia to counteract the natural fluctuations in natural background UV levels. Studies are now underway to determine the impacts of increasing UV radiation, but these are not yet complete.

3. **"Smoke and Mirrors,"** Alan Green, Washington City Paper, Washington, DC, March 5, 1993.

Getting motorists into car pools or onto mass transit would go a long way toward helping Washington meet its air quality "attainment" goals. But even a metrorail system that cost $7.3B hasn't made many give up driving. Alternative strategies include imposing an annual tax on autos tied to miles operated and pollution emitted, more stringent pollution-control devices for cars already on the road, sale of cleaner - more expensive - new cars, and limiting each household to one gasoline-powered vehicle. However, these strategies will face strong opposition from powerful interest groups such as car makers and service station owners.

Scientists always assumed that the nitrogen responsible for the environmental damage caused to the Chesapeake Bay was coming from sewage treatment and runoff from farmland. But, it was recently discovered that airborne nitrogen, a substantial proportion of which comes from auto emissions, is responsible for as much as 25 percent of the nitrogen entering the Bay.

This article describes the effects of ozone on humans. Automobiles are the problem, and eliminating traffic is the best solution. However, the data shows that in terms of usage of mass transit, car pooling, and so on, when you compare 1980 data to 1990 data, fewer people are using mass transit and car pooling. Occupancy rates of vehicles are going down, not up. According to the author, this region's transportation infrastructure was built to accommodate automobiles, and public policy decisions have only encouraged more driving.

Transportation planners have devised scores of innovative programs to get people out of their cars. Local lawmakers point to several strategies that will help achieve the area's clean-air goals. Two of them - reformulated gasoline, which has lower concentrations of smog-producing pollutants; and Stage II vapor-recovery nozzles, the accordionlike collars that capture fumes which escape during refueling - would collectively add about a nickel to the price of a gallon. A third strategy is to follow the lead of California and institute a "low-emission vehicle" program - this is a long term strategy as it requires a significant number of these cars on the road.

According to Donald Stedman of the University of Denver, the U.S. Environmental Protection Agency has always known, but never publicized, that half the pollution comes from 10 percent of the cars, and the 50 percent cleanest cars are responsible for less than 10 percent of the pollution. Thus, control efforts should be aimed at the top 10 percent of the polluters.

4. **"Is There Air Conditioning After CFCs?,"** Rik Paul, Motor Trend, February 1993.

Auto air conditioning systems use a refrigerant called R-12 (freon is DuPonts's trademarked name), a chlorofluorocarbon (CFC) compound known to deplete stratospheric ozone. In 1989 prior to strict recycling regulations, CFC emissions from auto air conditioning systems totaled 48,000 metric tons annually (about 21 percent of all CFC emissions). As of December 31, 1995, the production of R-12 must cease, and only non-CFC refrigerants will be permitted in new auto air conditioning systems. While new non-CFC refrigerants are available, they cannot be readily used in older systems that were designed to use R-12. While some of these older systems may be converted to use the newer non-CFC refrigerant (no conversion packages are currently available), others will continue to require R-12 in order to operate. For non-converted systems, the only available source of R-12 will be from recycling older systems.

5. **Motor Vehicle-Related Air Toxics Study**, Technical Support Branch, Emission Planning and Strategies Division, Office of Mobile Sources, Office of Air and Radiation, U.S. Environmental Protection Agency, April 1993.

This EPA report provides details on the toxic air pollutants emitted from motor vehicles. These toxic pollutants include benzene, formaldehyde, 1,3-butadiene, acetaldehyde, diesel and gasoline particulates, and gasoline vapors as well as selected metals and other pollutants. Both road and non-road sources are discussed. The aggregate cancer risk generated by each pollutant was estimated under three scenarios: a base control scenario, which takes into account implementation of the motor vehicle-related Clean Air Act requirements; a scenario involving expanded use of reformulated gasoline; and a scenario involving expanded adoption of the California standards. The study describes the qualitative change in toxic pollutant levels with the use of alternative clean fuels, discusses the costs of various existing regulatory control programs and provides a qualitative discussion of the toxics benefits of these programs.

6. **National Air Quality and Emissions Trends Report, 1991**, U.S. Environmental Protection Agency, Office of Air Quality, Planning and Standards, Research Triangle Park, NC, 27711, October 1992.

This is the nineteenth annual report of air pollution trends for air pollutants for which the U.S. Environmental Protection Agency (EPA) has established National Ambient Air Quality Standards (NAAQS). EPA has established standards for six pollutants: carbon monoxide, lead, nitrogen dioxide, ozone, particulates, and sulfur dioxide. There are two types of NAAQS established: 1) to protect public health (the primary standard); and 2) welfare (the secondary standard). This report tracks two kinds of air pollution trends: air concentrations (direct measurements of pollutants at selected sites); and emissions (estimates based on the best available engineering

calculations). The report provides a detailed listing of selected 1991 air quality summary statistics for every metropolitan statistical area (MSA) in the nation. The 1982-91 trends for 15 cities throughout the U.S. are also presented, as are summaries of air pollution statistics from other countries.

EPA estimates that overall emissions from all sources (including mobile sources) declined between 1970 and 1991. Of the major pollutants, carbon monoxide decreased 50 percent, nitrogen oxides declined 1 percent, particulates declined 61 percent, volatile organic compounds (ozone precursors) declined 38 percent, and sulfur oxides declined 27 percent. In spite of the overall decline in emissions, air pollution remains a widespread problem adversely affecting millions of people.

Based on single year air quality readings only for counties that actually have air pollution monitoring equipment in place, some 86 million U.S. residents lived in counties which did not meet at least one air quality standard during 1991. 70 million of these resided in counties that exceeded ozone standards. However, only 500 counties (out of a total of 3,100 counties nationwide) have monitoring equipment, and, because of meteorological conditions or other factors, a single year's measurements may not be representative of air quality problems. For example, EPA indicates that a three year (1987-89) compilation of air quality data reveals an additional 70 million residents (for a total of 140 million people) actually live in ozone nonattainment areas.

7. **Report on Locomotive Emission Inventory: Locomotive Emissions by County,** Booz-Allen & Hamilton, Inc. for the California Air Resources Board, August, 1992.

This report presented as a supplement to the Locomotive Emission Study (Booz-Allen & Hamilton, Inc., 1991), uses the information on train operations contained in the Locomotive Emissions Study to provide the following additional details regarding the locomotive emission inventory: emission inventories by county for the original six air basins included in the study; locomotive emission inventories for all other counties that have rail activity; predictive estimates of rail emissions by county for the years 2000 and 2010; and information on seasonal and daily variations in rail activity. Emission estimates are based on rail activity in 1987.

The following general methodology was followed to calculate locomotive emission inventories for each county in the state: 1) determine the total emissions per-train; 2) evaluate the emissions per-mile for each train and for each basin; 3) determine the length of track in each county in each basin and the specific trains that operate over each track segment; and 4) multiply emissions per-mile for each train by miles of track in each county and then add together all train emissions operating over the same tracks.

8. **Rethinking the Ozone Problem in Urban and Regional Air Pollution,** Committee on Tropospheric Ozone Formation and Measurement, National Research Council, National Academy of Sciences, Washington, DC, 1992.

Of the six major air pollutants for which National Ambient Air Quality Standards have been designated under the Clean Air Act, the most pervasive problem continues to be ozone. Despite considerable regulatory and pollution control efforts over the past twenty years, high ozone concentrations in many areas of the U.S. continue to be a major environmental and health concern. In this report, the committee examines trends in tropospheric ozone concentrations in the U.S.; reviews current approaches to control ozone precursors; and assesses current understanding of the chemical, physical, and meteorological influences on tropospheric ozone. The committee also provides a critique of the scientific basis for current regulatory strategies and offers recommendations for improving the scientific basis for future regulatory strategies.

One of the committee's findings is that current emissions inventories significantly underestimate anthropogenic emissions of VOCs (volatile organic compounds). Measurements of specific VOCs in urban areas indicate that VOC emissions from mobile sources have been underestimated in these inventories by a factor of two to four.

Another finding is that the use of alternative fuels has the potential to improve air quality, especially in urban areas. Alternative fuel use, however, will not necessarily alleviate the most critical problem associated with motor vehicle emissions - increased emissions as in-use vehicles age.

9. **Procedures for Emission Inventory Preparation: Modifications to Guidance Document**, Ch. 5-Emissions from Aircraft, Ch. 6-Emissions from Locomotives, Volume 4, U.S. Department of Transportation, Federal Aviation Administration, Washington, DC, November 1, 1991.

   Chapter 5 describes the procedure for calculating emissions from aircraft within a given area. The basic methodology determines aircraft fleet make-up and level of activity and then calculates air pollutant emissions on an annual basis. The focus is on emission characteristics of the source relative to the mixing zone - the vertical column of air that ultimately affects ground level pollutant concentrations. Aircraft operations of interest within this layer are: approach, taxi/idle-in, taxi/idle-out, takeoff, and climbout. Different factors affecting emissions are covered. Emission rates for civil, commercial, and military aircraft engines are included. Variations of the methodology, which account for seasonal changes or specific operational considerations, are covered. Finally, changes expected in the fleet in the future and the effect on emissions are briefly described.

   Chapter 6 illustrates how a state or local agency can calculate emissions from locomotives in a given area. The recommended methods for calculating the emissions from various types of rail service based on generic or national operating characteristics are described. Procedures for tailoring the recommended methods to more closely reflect local operating conditions are also presented. Line-haul and yard locomotive emission factors are presented for HC, CO, NOx, SO2, and PM.

10. **Locomotive Emission Study**, California Air Resources Board (CARB), prepared by Booz-Allen & Hamilton (BAH), Inc., August, 1991.

    This extensive report provides substantial detailed information on railroad locomotive emissions and suggests various strategies for reducing them, including: changes in operating practices and maintenance; use of "lighter" diesel fuels; modification of locomotive engines; alternative fuels; and electrification.

    Estimates of the emission characteristics of locomotives and the relative contribution of locomotives to air pollution are presented. BAH compares its calculations with those of the CARB for 1987 and some substantial differences exist. For example, CARB estimated that rail operations would produce 20.07 tons/day of hydrocarbon (HC) emissions while BAH estimated that only 4.2 tons/day would be produced. However, for nitrogen dioxide, BAH estimated that rail operations would produce 99.1 tons/day while CARB estimated that only 73.3 tons/day would be released. BAH indicated that sufficient evidence existed to conclude that their methodology produces a considerably more accurate estimate. The increased accuracy results from the recognition of many factors that influence emissions, including differences in locomotives and locomotive fleet consists, geography, direction of operation, and type of traffic moved. The CARB is now using factors generated in the BAH report.

11. **"Health Effects of Tropospheric Ozone,"** Morton Lippmann, Environmental Science and Technology, Vol. 25, No. 12, 1991.

Ozone (0_3), as an air pollutant, is found in the troposphere, the lowest region of the atmosphere located between the earth's surface and about 6 to 10 miles high. Ozone is almost entirely a secondary air pollutant, formed by a photochemical reaction involving reactive hydrocarbons (HC) and nitrogen dioxide ($N0_2$) in the presence of sunlight. Therefore, ozone's negative impacts may occur well away from the source of the HC and NO_2 emissions.

Ozone concentrations vary greatly from indoors to outdoors. Oddly enough, outdoor local concentrations of ozone are actually lower in the vicinity of heavy motor vehicle traffic. This occurs because ozone in the presence of nitric oxide (NO) (contained in motor vehicle exhaust) is converted into an ordinary oxygen molecule (O_2). However, in areas away from the traffic, ozone concentrations increase because active photochemistry is producing additional ozone. Indoor concentrations of 0_3 almost always are substantially less than outdoors, because many indoor surfaces cause ozone to become O_2 and ozone sources are lacking.

Exposure and dose are important in determining impacts. Ozone accumulates over multiple hours, and the impacts persist for many hours or days after exposure, at levels commonly encountered in ambient air. However, chronic effects of ozone exposure appear to dissipate after exposure is ended. Unfortunately, there is a lack of a definitive data base on chronic effects of human exposure to ozone.

The author suggests that the control of ambient ozone to levels within the current national ambient air quality standards (NAAQS) present little, if any, margin of safety against adverse effects from ozone (the 1979 NAAQS for ozone is 0.12 ppm). Overall, about 50 percent of the U.S. population resides in communities where the ozone NAAQS is exceeded, and it appears that ozone formation can be controlled only by reducing ambient air concentrations of hydrocarbons or $N0_x$.

12. **"Greenhouse Gases and Global Change: International Collaboration,"** Thomas Rosswall, Environmental Science and Technology, Vol. 25, No. 4, 1991.

The article primarily discusses the anthropogenic (human caused) sources of greenhouse gases and the effect of their increasing concentrations. Levels of carbon dioxide, the principal greenhouse gas in terms of total impact, have increased 25% since the industrial revolution. In the next 50 years, the increase in emissions of greenhouse gases are estimated to result in global warming of 0.3° per decade and the effect will not be uniform. The northern latitudes are likely to have the greatest increase, primarily during the winter months, affecting rainfall and human activities such as forestry and agriculture.

The increasing temperatures will also result in increasing sea levels, the effects of which are difficult to project since accurate topographic maps do not exist for many areas. The problem is very serious, and emissions of greenhouse gases must be reduced; however, this is likely to be very difficult to achieve, as per capita emission levels from fossil fuel burning are unevenly distributed among the nations of the world, and they are likely to increase in developing nations.

If it is assumed that CO_2 atmospheric levels must not exceed 400 parts per million (ppm) and the present level is 350 ppm, then annual anthropogenic emissions must not be greater than 2.5 Pg carbon. Currently, however, fossil-fuel burning emissions are 5.5 Pg and deforestation is 1.7 Pg. To achieve annual 2.5 Pg goal on a per capita basis worldwide, the emission rate would be limited to 330 Kg of carbon; however, 1982 U.S. emissions per capita were 4900 Kg and in Sweden they were 2200 Kg.

13. **"Changing Ozone, Evidence for a Perturbed Atmosphere,"** Stuart A. Penkett, Environmental Science and Technology, Vol. 25, No. 4, 1991.

There is much legitimate concern about the dramatic loss of ozone in the stratosphere over Antarctica, and there should be even more concern about the increasing loss of ozone observed in the polar and mid-latitude regions of the stratosphere in the northern hemisphere. Additionally, there is compelling evidence that the ozone concentration in large parts of the northern hemisphere troposphere is steadily increasing, principally as a result of transport emissions and biomass burning. To some extent, this increase offsets the upper atmospheric loss; however, the increase in ground level ozone also causes vegetation damage. Shifts in atmospheric ozone concentrations at different altitudes will also influence the vertical temperature profile.

The realization that ozone was involved in long-range transport first occurred in Europe. European studies have focused on ozone as a regional rather than an urban problem, and the regional nature of ozone is now receiving attention in the U.S. New extensive studies are underway that may allow the development of a clear quantitative link between the emission of pollutants and their effects.

14. **"Stratospheric Ozone in the 21st Century, the Chlorofluorocarbon Problem,"** F. Sherwood Rowland, Environmental Science and Technology, Vol. 25, No. 4, 1991.

Concentrations of chlorofluorocarbons (CFCs) together with other trace gases (carbon dioxide, methane, etc.) are increasing in the atmosphere. CFC concentrations in the troposphere (the lowest region of the atmosphere located between the earth's surface and the tropopause) are expected to increase until 2010, (10 years after completion of the CFC phaseout process, scheduled for 2000). CFCs will have a maximum stratospheric effect on ozone 5 to 10 years after that date, a consequence of the time delay between surface release and CFCs reaching the upper atmosphere. Given the long lifetime of CFCs, stratospheric ozone depletion and the effects of this ozone loss will be felt on a global scale throughout the 21st century.

15. **"Controlling Urban Air Pollution: A Benefit-Cost Assessment,"** Alan J. Krupnick and Paul R. Portney, Science, Vol. 252, 1991.

The authors present a benefit-cost analysis for the control of ozone. Their analysis indicates that, subject to a number of uncertainties, the costs of the new controls, including transportation control strategies, exceed the benefits by a considerable degree.

For example, the cost of mandatory introduction of alternative motor vehicle fuels (methanol, ethanol, or reformulated gasolines) would increase annual costs nationally by $3 billion. In calculating the benefits, the authors used epidemiological data indicating that an average asthmatic will experience asthma attacks about 0.2 fewer days per year, and the average non-asthmatic will experience about 0.1 fewer restricted activity day per year and other minor health benefits as a result of reduced volatile organic compound (VOC) emissions and subsequent reduction in ozone levels. This epidemiological data was then applied to average health impact values of $25 for an asthma attack, $20 for one restricted activity day and, $5 for one coughing spell. Their calculations predict national aggregate health improvements from ozone reduction total $250 million per year.

However, if these same health impact values are used with clinical, rather than epidemiological, data, the authors calculate the annual benefit would rise to $800 million annually. Consequently, the choice between epidemiological or clinical approaches has a significant impact on the benefits calculation.

Complicating the benefit calculation further, the authors indicate that had they used a different epidemiological study, the benefits would have been less than half of those calculated. The average health values used are also variable. The authors indicate, for example, that other researchers have calculated average health values ranging from $10 to $40 for an asthma attack. Had the upper bound estimates been used in the analysis, the authors calculate that the benefits would be $2.0 billion, for a 35% nationwide reduction in VOC, and $2.4 billion in the South Coast (Los Angeles, CA) area alone of meeting the ozone standard. Conversely, using the lower bound estimates, benefits would be only 3% of the upper bound estimates.

In their benefit calculation, the authors also did not include benefits for which it was impossible to predict physical effects or make reasonable dollar attributions. For example, the authors did not include any benefit for reduction in vegetation damage either to agriculture or forests.

16. Steering a New Course: Transportation, Energy and the Environment, Deborah Gordon, Union of Concerned Scientists, Island Press, Washington, DC, 1991.

In this book, the author describes how the U.S. can avoid a deteriorating transportation system characterized by increased energy use, air pollution, and congestion. Included is an examination of the relationship between the various transportation modes and the environment, such as the contributions of the transportation sector to air pollution, use of alternative fuels, and the development of high efficiency vehicles.

The U.S. transportation sector contributes significantly to virtually all air pollutants including carbon monoxide (67%), carbon dioxide (30%), nitrogen dioxide (41%), hydrocarbons (38%), particulates (23%), and sulfur dioxide (5%). Carbon dioxide is the major greenhouse gas and total annual transportation emissions of carbon dioxide are estimated to increase from the 1.7 billion tons produced in 1988, to between 1.9 and 2.2 billion tons by 2000. Of the approximately 1.7 billion tons of CO_2 emitted in 1988, about 1.1 billion (66%) was produced by the consumption of motor gasoline, .3 billion was produced from diesel fuel (16%), and .2 billion was generated from jet fuel consumption (13%).

The substitution of alternative fuels for gasoline and diesel fuel used in transportation could have a substantial impact on the emissions released. While overall emissions would increase if alternative fuels were derived from coal sources, the use of electric and hydrogen fueled vehicles (with the fuel produced from nonfossil fuel sources) could reduce emissions by as much as 100 percent. A detailed comparison of the range of alternative fuels, their impacts and their advantages and disadvantages is presented.

17. **"Sensitivity Analysis for Land Use, Transportation, and Air Quality,"** Jeff May and George Scheuernstuhl, Transportation Research Record No. 1312, Energy and Environment, Transportation Research Board, National Research Council, Washington, DC, 1991.

The air quality effects of a higher-density land use scenario, where a high percentage of the employment growth expected between 1989 and 2010 was concentrated along transit corridors, was compared with that for the expected lower-density suburban growth development typical in the Denver region. Although transit patronage increased significantly in the higher-density scenario, vehicle miles of travel remained relatively unchanged. Carbon monoxide levels increased under the higher-density land use case, but remained well below the federal standard. Other pollutant levels did not vary significantly between the two scenarios. Concentrating much of the 1989 to 2010 regional employment growth along transit corridors did not improve air quality. It appears

both population and employment need to be concentrated in the transit corridors to alleviate the problem. In the high-density scenario, because substantial employment growth was allocated along the transit corridors without equivalent redistributed population, a greater spatial separation between population and employment resulted. This separation led to increased miles of travel for non-peak, nonwork trips, which eliminated much of the benefit of transferring peak-period drive-alone work trips to transit and carpooling.

18. **Transport Policy and the Environment**, European Conference of Ministers of Transport (ECMT), ECMT 1989 Ministerial Sessions, prepared in Cooperation with the Organization for Economic Cooperation and Development (OECD), Paris, France, 1990.

This report includes a chapter on air pollution, primarily focusing on mobile sources. The chapter describes the differences in the exhaust characteristics of gasoline and diesel engines, details the share that emissions contribute to overall man-made air pollutants, and provides an estimate of emission trends both in terms of total emissions and in emissions per-vehicle-kilometer. Also included are descriptions of the adverse impacts: direct, indirect, short- and long-term. Statistics are provided on air quality concentrations in selected European cities.

The report considers how the comparative environmental advantages of alternative modes to private motorized transport can best be used and suggests that a combination of direct and indirect measures, including improvement of urban railways, along with charges or restrictions as disincentives to car use, might be most effective. Any such actions will require political will and a major information campaign. For interurban traffic, the ECMT adopted a resolution that recommends making railway, inland waterway, and combined transport as efficient and commercially oriented as possible, with improved cooperation at the international level. It also recommends that any proposals to harmonize taxes and charges in international road freight transport should take into account the environmental damage caused by such traffic.

19. **The Challenge of Global Warming**, Edited by Dean E. Abrahamson, Natural Resources Defense Council, Island Press, Washington DC, 1989.

The major premise set forth in this book is that the burning of fossil fuels, deforestation and the release of industrial chemicals will result in global warming - the "greenhouse effect." The greenhouse effect results from the atmospheric buildup of gases that absorb heat (long-wave, infrared radiation). The physical impacts of global warming include a rise in sea levels and global climatic changes which will result in the disruption of human activities. CO_2 is the principal greenhouse gas, accounting for one-half of the current and projected scope of global warming; others include methane, nitrous oxide, freon and tropospheric ozone.

The book summarizes the scientific aspects of the greenhouse effect, including discussions of the types of greenhouse gases and their sources. Descriptions of the specific greenhouse gases are included as are their sources, longevity, and estimated future impact upon global temperatures. Suggested strategies for reduction in greenhouse gases are detailed, including: a 50% reduction in the burning of fossil fuels; increasing energy efficiency (thereby lessening greenhouse gas emissions); increasing biomass by reforestation, etc. (to lock-up currently airborne CO_2); installing CO_2 stack scrubbers; use of alternative fuels (including nuclear); and controlling industrial emissions.

20. **Urban Ozone and the Clean Air Act: Problems and Proposals for Change**, Staff Paper, Oceans and Environment Program, Office of Technology Assessment, U.S. Congress, Washington, DC, April 1988.

Human exposure to ozone causes immediate, short-term changes in lung function and may have a role in long-term development of chronic lung diseases, especially if the exposure is repeated over a lifetime. However, ozone's contribution to the development of chronic lung disease is limited, and the damage to humans is difficult to estimate. Rural ozone concentrations in the rural southern and eastern U.S. is high enough to reduce crop yields by 1 to 20 percent. The crops most susceptible to damage include soybeans, wheat, cotton, and certain produce. If rural ozone concentrations were reduced 25 percent, it is estimated that agricultural benefits would total some $2 billion.

B. MITIGATION STRATEGIES:

1. **Meeting Mobility and Air Quality Goals: Strategies that Work**, Jon Kessler and William Schroeer (draft paper), U.S. Environmental Protection Agency, Office of Policy Analysis, February 10, 1993.

This paper suggests that it may be necessary to go beyond traditional measures to meet air quality goals. "Strategies that address the inefficiencies of the transportation market and use tangible incentives to reduce pollution can help urban areas achieve mobility and air quality goals without untenable costs." The paper posits that "Given the current funding and construction bias in favor of the auto, demand for auto travel is so strong that simply providing travel alternatives will not lessen the growth in auto travel. On the other hand, demand management alone will not be a sufficient response; road pricing will have little success managing demand for auto travel if drivers have no new alternatives."

The authors suggest that combined, integrated strategies are needed. The paper's discussion of strategies that work includes: revenue neutral "feebates" (directly targeting the vehicle purchase decision, with new car buyers either given a rebate or charged a fee based on the vehicle's emissions, fuel economy, or other individual or combination of desired characteristics); accelerated scrappage - to speed fleet turnover by offering economic incentives to retire older, high-emitting vehicles; financing roads by targeted user charges instead of general taxes, through vehicle miles traveled (VMT)/emissions pricing, collected according to odometer readings taken at annual registration or during mandated inspection and maintenance checks; congestion pricing, using advanced collection technology on tolled facilities; reshaping parking subsidies into employee benefits, by cashing-out tax subsidies for employer-paid parking, and reevaluating the need for parking requirements; unlocking the potential of innovative travel alternatives, such as removing restrictions on paratransit; expanding use of telecommuting; and employing zoning to stimulate use of travel alternatives to driving.

2. **"Oxygenated Gasolines,"** Dennis Simanatis, Road and Track, 1993.

This article discusses the benefits and limitations of oxygenated gasolines being used to reduce emissions of hydrocarbons, carbon monoxide and nitrogen dioxide. Oxygenated fuel provides the greatest emission reduction benefit in pre-catalyst motor vehicles (vehicles without a catalytic converter). In these vehicles, the oxygenated fuel causes the engine to run "leaner," that is, it increases the air (oxygen)/fuel combustion ratio, resulting in reduced emissions. In catalyst equipped vehicles (vehicles with a catalytic converter), the beneficial impact of oxygenated fuels is less pronounced, since these vehicles also have an oxygen sensor present. This sensor operates in conjunction with the on-board computer to adjust the air (oxygen)/fuel mixture to a "leaner" ratio

automatically, except during cold starts and during heavy acceleration. Thus, when operating, the computer "senses" the presence of the additional oxygen molecules in the oxygenated fuel and lowers the air/fuel ratio to compensate for the additional oxygen. Consequently, the primary benefit derived from the use of oxygenated fuels in catalyst equipped vehicles occurs only under during cold starts and acceleration.

3. **Green Fees: How a Tax Shift Can Work for the Environment and the Economy**, Robert Repetto, Roger Dower, Robin Jenkins, Jacqueline Geoghegan, World Resources Institute, Washington, DC, November 1992.

   (Also see the annotation for this reference under the Congestion Chapter) Attempts to control mobile emissions through strict and increasingly expensive new vehicle standards is relatively inefficient for two reasons. First, emission control effectiveness deteriorates with vehicle use and improper maintenance; and, second, as new vehicles become more expensive, older, less expensive vehicles (that produce substantially more emissions) become more attractive to purchasers. This prolongs the service life of older vehicles and raises the average age of the vehicle fleet.

   One solution to this problem is to charge vehicle fees in nonattainment areas. The fees charged would be based on estimated annual emissions and set at a level roughly based on estimated marginal damages. The authors cite a 1988 EPA sponsored study, for the Northeastern U.S., where the marginal damage from volatile organic compounds was estimated to be $.70 per kilogram. Therefore, a car emitting 1.5 grams of hydrocarbons per-mile and being driven 10,000 miles annually, would pay an emission fee of about $10 per year. Based on a 1990 estimate, an emission charge averaging $10 per-vehicle would produce approximately $0.5 billion in annual revenues from vehicles driven in ozone nonattainment areas.

4. **Searching for Solutions, A Policy Discussion Series, Transportation and Air Quality**, U.S. Department of Transportation, Federal Highway Administration (FHWA), Office of Policy Development, No. 5, Washington, DC, August 1992.

   This report summarizes a 1991 FHWA seminar on key issues in air quality and transportation planning, supplemented by a paper by Greig Harvey and Elizabeth Deakin, adding the perspective introduced by the 1991 Intermodal Surface Transportation Efficiency Act, which was in legislative proposal at conference time. The paper concludes that significant reductions in mobile source emissions through reductions in travel would be hard to achieve without a fundamental change in U.S. policy towards transportation pricing and land use.

5. **The Challenges of Transportation and Clean Air Goals**, Dr. Arnold M. Howitt and Dr. Alan Altshuler, John F. Kennedy School of Government, Harvard University, June 1992.

   This paper discusses the Clean Air Act Amendments of 1990 and the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 and evaluates policies likely to be most cost effective and politically feasible in achieving air quality goals as well as the Department of Transportation's (DOT's) other missions. The paper points out that in developing general transportation/air quality policies and regional plans, differences in the cost-effectiveness of various transportation control measures must be considered - i.e., comparing what different policies cost to achieve a standard unit of pollution reduction (usually expressed as $/ton of carbon monoxide or reactive organic emissions, which are sources of ozone). However, good estimates of the cost-effectiveness of many control measures are not available. Federal implementing regulations may be too prescriptive, making it difficult for state and local officials to apply cost-effectiveness criteria to their choices. Distributional cost effects and political factors may also inhibit policy choices.

The authors suggest that clean air goals should be pursued to the greatest extent possible by measures that do not compromise mobility. On the one hand, the new legislation elevates air quality to top priority in a major change in DOT's mission. From another perspective, the new laws can be considered an incremental step in an evolutionary process that has been incorporating additional goals, including greater concern for environmental impacts, into the Department's mission.

6. **Southern California Accelerated Rail Electrification Program Report**, Executive Summary and Five Volumes, Los Angeles County Transportation Commission, South Coast Air Quality Management District, and Southern California Regional Rail Authority, prepared for the Southern California Regional Rail Authority, Los Angeles, May 1992.

   This report was prepared in response to the South Coast Air Quality Management Plan which dictates a 17% reduction in rail-related NOx emissions by the year 2000, and a 90% reduction by the year 2010. The report provides cost estimates, a projected schedule, and a financial plan for reducing rail-related emissions in Southern California through electrification. It also addresses technical, policy, and institutional issues that require resolution.

   The report indicates that the proposed electrification would be a relatively cost-effective way to reduce NO_x emissions. The cost effectiveness, measured by the per-ton cost of NO_x emission reduction, ranged from $2,180 to $2,520 (cost per-ton-per-day), for the most cost-effective route, to $143,900 to $223,120, for the least cost-effective route. This compares favorably with other required NO_x emission reductions. For example, the rule governing large industrial boilers had a cost effectiveness of between $2,200 and $52,800 per-ton, while the cost effectiveness of the rule applying to electric power generation was between $6,500 and $46,400.

7. **The Mass Transit - Air Quality Link: Assessing the Effectiveness of Mass Transit-Based Strategies for Reducing Ozone Precursors in the Boston Metropolitan Area**, David L. Antonioli, for Conservation Law Foundation, Boston, MA, April 17, 1992.

   The strong emphasis placed on market-based strategies in the Clean Air Act Amendments of 1990 has strongly reinforced an important aspect of environmental policy-making - the calculation of cost-effectiveness estimates for different pollution control strategies. The Conservation Law Foundation would like to explore the applicability of cost-effectiveness criteria to the transportation sector in terms of air-quality impacts. Because the transportation sector is a main contributor to the ozone problem, it is likely that Transportation Control Measures designed to reduce ozone precursor emissions from the transportation sector will play a large role in the Commonwealth's efforts to reach attainment with the National Ambient Air Quality Standards for ozone. It is widely believed that providing mass transit will encourage people to leave their cars at home or in a parking lot close to home.

   This analysis looks at the following mass transit policies to reduce ozone: 1) keeping fares low to attract new riders, 2) building park-and-ride lots at outlying mass transit stations, 3) renovating or extending mass transit services to new areas, and 4) establishing a dedicated revenue source for the Massachusetts Bay Transportation Authority that includes one or more auto disincentives. Cost-effectiveness values for the first three policies are estimated. Other important policy criteria are also applied. The author concludes that the first three alternatives would be extremely expensive and that the last option's prospects do not look promising at this time.

8. **Transportation Control Measure Information Documents**, U.S. Environmental Protection Agency, Office of Air and Radiation, Washington DC, March 1992.

   This extensive, loose-leaf formatted publication contains information on sixteen transportation control measure (TCM) categories. A TCM encompasses elements of both transportation system management (TSM) and transportation demand management (TDM) and the three terms are often used interchangeably. A TSM strategy refers to the use of low capital intensive transportation improvements that increase efficiency of facilities and services. This includes car or van pools, high occupancy vehicle (HOV) lanes, and bicycling. A TDM strategy generally refers to policies, programs and actions directed towards increasing HOV use (including transit, car or van pools), bicycling and walking. TDM can also include encouragement of driving outside congested peak hours or telecommuting.

   Each TCM is defined and covered separately in an individual chapter. Each chapter includes a discussion of the objectives, application variations, actual use examples, and implementation guidelines for state, regional and local agencies. The sixteen categories of TCM included are: trip reduction ordinances; employer-based transportation management programs; work schedule changes; area-wide ride-share incentives; tax incentives and subsidy programs; improved public transit; high occupancy vehicle lanes; traffic flow improvements; parking management; park-and-ride/fringe parking; bicycle and pedestrian programs; special events (managing parking and transit use; capacity improvements; etc.); vehicle use limitations/restrictions; accelerated retirement of vehicles; activity centers (relationship between land use activities and travel); extended vehicle idling; and extreme low-temperature cold starts (technological or other measures to reduce cold start emissions).

   The report describes the interrelationships between transportation and air quality, providing basic background data important to understanding how transportation activities affect emissions. Each air pollutant is described as are the variables affecting the vehicle emission rates. Discussions of the Clean Air Act, the Clean Air Act Amendments of 1990, and the Intermodal Surface Transportation Efficiency Act are also included.

9. **Cleaner Fuels, Cleaner Vehicles and Altered Driving Habits**, Heidi Snow, Natural Resources Policy Studies Center for Policy Research, National Governors' Association, Washington DC, 1992

   In this publication, the author describes the various measures established or strengthened by the Clean Air Act Amendments of 1990 to curb air pollution from mobile sources. Included are chapters on clean fuels, new vehicle standards, inspection and maintenance programs, and transportation conformity and control measures. Each chapter contains a detailed discussion of each issue, discusses the cost of many control measures, and describes how the control measures will reduce emissions. Also included is a glossary of terms, a listing of the nonattainment areas that must at least consider transportation control measures, and a matrix indicating the emission reduction measures that each area must consider.

10. **"The Roads Go On Forever?"** Joseph Mendelson, UTNE Reader, September/October 1992.

    The interstate highway system has dramatically reshaped our cities, our economy, our natural environment, our families, and our psyches. Highways have displaced communities, poisoned our air, contributed to the dangerous warming of our planet, and have been the site of more American deaths than all our wars combined. The average family spends nearly 20 percent of its household

income on transportation. The 1990 census shows that over the past decade 73.2 percent of us drove to work alone and only 5.3 percent of us now use public transportation.

The author discusses the potential of the Intermodal Surface Transportation Efficiency Act (ISTEA), but questions whether the institutional mechanisms and dominance of highway lobbyists will preclude fulfillment of the expectations ISTEA raises.

11. **Changing by Degrees: Steps to Reduce Greenhouse Gases**, Office of Technology Assessment, Washington, DC, 1991.

This Office of Technology Assessment (OTA) report responds to a Congressional request "Can the U.S. reduce CO_2 emissions in the near term?" OTA reports that it cannot yet predict the magnitude of climatic effects from greenhouse gases, yet it is clear that the decision to limit emissions cannot wait until the time when the full impacts are evident. The lag between emission release and their full impact may take decades or centuries. During the 1980s, the U.S. carbon dioxide emissions accounted for 20% of the world's total annual emissions. Based on 1987 estimates of U.S. CO_2 emissions, 32% comes from the transportation sector with the following modal breakdown: automobiles, 43%; light trucks, 20%; heavy trucks, 14%; aircraft, 14%; rail and marine combined 7%; and non-oil based, 2%.

The transportation segment also makes significant use of three types of ozone depleting chlorofluorocarbons (CFCs): CFC-12, CFC-11, and CFC-113. CFCs are of concern in global warming since CFCs have a proportional impact far greater than the actual amount released. In fact, a ton of CFC-12 has a greenhouse potential that is approximately 2,000 times greater than the release of a ton of CO_2 (measured in tons of carbon). All CFC emissions (including those from transportation sources) are estimated to account for about 25 percent of the effects from all greenhouse gases.

12. **The Air Pollution - Transportation Linkage**, A report from the State of California Air Resources Board, Office of Strategic Planning, Sacramento, CA, 1989.

California has sought to clean air by regulating many sources of air pollution. As a result of the motor-vehicle emission standards set, new vehicles are 80% cleaner than those manufactured in the 1970s. However, despite these efforts, California still faces the worst air pollution problem in the nation. A major issue is California's continued and growing reliance on the private car. Another dimension of the problem is conservation of energy resources. The purpose of this report is to explain how and to what extent air pollution is being generated on urban roadways and to provide a basis for designing transportation control measures that will be effective in reducing both air pollution and traffic congestion.

13. **"Transportation Fuels and the Greenhouse Effect,"** Mark A. Deluchi, Robert A. Johnston and Daniel Sperling, Transportation Research Record No. 1175, Fuels, Transportation Research Board, National Research Council, Washington DC, 1988.

This paper evaluates carbon dioxide, methane, nitrogen dioxide and other greenhouse gas emissions from gasoline, diesel fuel, methanol, natural gas, and hydrogen in highway vehicles. The emission estimates include those occurring from initial resource extraction to end use. Based on 1985 data, the U.S. contributed nearly 25 percent of the total world production of carbon dioxide from fossil fuels, and fuel burned on the highways contributed almost 25 percent of the U.S. production of carbon dioxide from fossil fuels. When production and distribution emissions are included, the total use of highway fuels accounts for about 27 percent of the U.S. caused fossil fuel carbon dioxide emissions.

The authors provide a detailed analysis of the carbon dioxide that would be produced by use of petroleum fuel alternatives. They conclude that the use of coal to produce highway fuels would substantially increase carbon dioxide emissions when compared to petroleum use. According to their calculations, use of a coal-based hydrogen fuel in transportation vehicles could increase carbon dioxide emissions by as much as 143 percent. They estimate that use of natural gas to produce highway fuels could reduce greenhouse gas emissions by as much as 19 percent. In contrast, a doubling of efficiency (from the average 14.5 miles per gallon in 1985) to 29 miles per gallon for petroleum fueled vehicles could reduce carbon dioxide emissions by as much as 50 percent.

Overall, their analysis shows that substantial long-term reductions in transportation-generated carbon dioxide equivalent emissions can only be accomplished through the use of high-efficiency vehicles, biofuels for natural gas vehicles, and methanol vehicles or nonfossil fuels for hydrogen and electric vehicles. In order for this to occur, the authors urge that fuels and technologies should be priced at their social or full economic, rather than their private, costs and that research and development should be directed at those fuel/vehicle combinations with low external costs, especially those that would reduce or eliminate carbon dioxide emissions. These efforts should include research on and development of solar energy and renewable technologies. In their view, the proper pricing of petroleum fuels will encourage efficiency improvements and reduce carbon dioxide emissions and increase national efficiency of resource use. Proper pricing, combined with increased research and development on solar energy production and hydrogen and electric vehicles, will hasten the efficient adoption of sustainable, environmentally sound, non-carbon dioxide producing transportation options.

C. COSTING/PRICING STRATEGIES:

1. **Region-Wide Toll Pricing: Impacts on Urban Mobility, Environment and Transportation Financing**, Anthony R. Kane, Patrick DeCorla-Souza, Congestion Pricing Symposium, US Department of Transportation, Washington, DC, June 1992.

   This paper uses a hypothetical case study to suggest that highway tolls can be used to reduce both congestion and air pollution and appear to be a more politically acceptable method of paying for public and private transportation investments than other pricing mechanisms. New electronic collection systems reduce collection costs and delays commonly found with manual collection systems, and the Intermodal Surface Transportation Efficiency Act provides new inducements for toll financing and congestion pricing strategies.

2. **Evaluating Energy, Environmental and Economic Externalities of Alternative Modes of Intercity Travel, Session 9: Intercity and Air Transport**, Prepared for Transportation and Global Climate Change: Long-Run Options: Asilomar Conference Center, Pacific Grove, CA, by the Center for Economic Forecasting and Analysis, Florida State University, August 1991.

   Among other items, this study refers to California 2000: Exhausting Clean Air, Major Issues in Managing Air Quality, prepared by the Assembly Office of Research (AOR), October 1989, which provides a 1987 estimate of the economic damages from air pollution for the South Coast Air Quality Management District. Their itemization of the estimated bills for air pollution damages includes: mortality, hospital care, sick days, minor restricted activity days, asthma symptom aggravated days, respiratory restricted activity days, costs for materials damage, forest damage, agricultural damage, and visibility reduction. The cost estimates suggest total costs between $600 to $730 per-person per-year for air pollution damages alone in the South Coast region. Reference

is also made to "A Policy Analysis Model Incorporating Acid Rain and Sulfur Dioxide Damages Associated with Power Plant Conversions from Oil to Coal in the State of Florida," by T.D. Crocker who established that acid rain related materials damage alone exceeded $154 per capita in the U.S. per year. Crocker also estimated that a shift in property values alone due to air pollution in many areas in Florida could exceed $2,774 per housing unit. Due to lack of quantitative information or evidence that effects are small, some categories were not included -- impact on flora, fauna, and habitat; soil erosion and reduced water conservation; recreational and commercial fishery losses; global climate effects; and many suspected health effects.

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

   In southern California, use of demand management combined with improvements in high-occupancy transportation alternatives appears to provide sufficient capacity for carrying the region's current and future population in an efficient manner consistent with air quality goals. However, current smog and congestion problems will continue until the true cost of auto travel is reflected in the price.

   Several changes in transportation pricing policies are recommended, including: peak-period pricing on congested corridors; buy-outs of employer subsidized parking; non-employee parking pricing; annual mileage and emission based smog fees; and deregulated private transit. The fee changes are estimated to cost $5 to $6 per-day, including $.30 per-day for non-employee parking, $2.25 per-day for employee parking and $3.00 per-day in regionwide congestion fees. Each of these policy changes is discussed in detail in the report.

   If the recommended pricing policies were implemented, total vehicle miles traveled would be reduced by 12 percent, and emissions of reactive organic gases (ROG: smog precursors - nitrogen oxides and hydrocarbons) would decline by 19 percent (a total of 53 tons of ROG per-day). The reductions are from the estimated 2010 baseline case and were obtained through use of a newly designed computer model that was designed to estimate drivers' responses to congestion and emission fees.

4. **Energy and Environmental Issues 1991, Transportation Research Record No. 1312**, Transportation Research Board, National Research Council, Washington, DC, 1991.

   Includes several articles. The most relevant are:

   "Transportation and Urban Air Pollution Policies for Developed and Developing Countries," Alan J. Krupnick.

   Improvements in urban air quality remain elusive in large cities throughout the world, including those in the U.S., where efforts have continued over 20 years to reduce emissions from vehicles and other sources. Germany, the Netherlands, Norway, and Sweden have until recently taxed clean cars (those using catalytic converters) less than others, or reduced their annual vehicle fees. European Community (EC)-wide vehicle emission standards, which will be somewhat less strict than those in the U.S., will make such differentiation unnecessary.

   "Pricing of Air Pollution in the Swedish Transport Policy," Lars Hansson.

   Swedish transportation policy has radically changed during the last decade. In 1979, the principle of a social marginal cost responsibility for road and rail traffic was introduced, taking into account

social costs for traffic accidents. In 1988, an essential part of the new Transport Policy Act was the principle of internalizing some of the traffic emissions. These were then explicitly considered in infrastructure charges for road and rail traffic and for domestic aviation. Negative external effects taken into account are traffic accidents, air pollution, noise disturbance, and congestion, through gas taxes, kilometer taxes, rail charges, and landing charges. Some of these charges have already been adopted by Parliament.

5. **Efficient Highway User Charges -- Appendix E to the Final Report of the Federal Highway Cost Allocation Study**, Douglass Lee, U.S. DOT Transportation Systems Center, Cambridge, MA, May 1982.

   Lee presents a model of air pollution costing with four steps: 1) determine emissions as a function of vehicle characteristics, road type, traffic volume and mix, and climate; 2) analyze the transmission, diffusion, and transformation of pollutants after they are emitted until they impact receptors; 3) document the impacts of these; and 4) value the impacts on receptors and attribute the costs to the units of output. Environmental scientists have constructed numerous mathematical models of the first three steps, and environmental economists have directed attention to step four. However, there are significant gaps between the steps. Haugaard, 1981, does an empirical analysis and comes up with dollar cost ranges for emissions.

   The kinds of damages included in pricing air pollution are: 1) human health -- epidemiological data, medical bills and loss of earnings; 2) materials - deterioration of properties and aggregate damage estimates for 32 kinds of materials; and 3) vegetation - regression analysis and plant surveys to estimate damage to vegetation for 77 crops plus shade trees and other ornamental trees. Aggregate air pollution damage costs for carbon monoxide, hydrocarbons, nitrogen oxides, sulfur oxides, and particulates from all sources is presented in 1981 dollars. The strategy used to assign pollution costs to vehicles was to convert the costs into per-gram units and multiply by the applicable emission rates to get the cents-per-mile charge for a particular vehicle.

II. NOISE

Despite improvements in noise emission controls for individual vehicles, ambient noise levels are expected to increase over time. The Federal Aviation and Highway Trust Funds cover air and road traffic related noise mitigation. However, there is no such fund to cover rail noise mitigation. Furthermore, more people are affected by highway and air noise. Consequently, most transportation noise research concentrates on air and road. Most studies attempting to cost transportation noise damage concentrate on the decrease in property values. Whether or not neighborhood development predates the transportation facility development is an important consideration.

A. CAUSE/EFFECT - MEASUREMENT:

1. **"The Battle for Barriers Intensifies,"** Stephen C. Fehr, The Washington Post, April 12, 1993.

   Traffic noise in many areas is high enough to qualify for barrier protection; yet, when the houses are too far apart the cost of the barriers becomes unjustifiable on a per house basis. Traffic volume and speed also affect traffic noise level. For example, according to the Federal Highway Administration, the loudness of 2,000 vehicles in an hour is twice as much as that of 200 vehicles in the same time; traffic moving at 65 mph is twice as loud as traffic moving at 30 mph; and one truck moving at 55 mph is as loud as 28 cars moving at the same speed.

2. **Noise Criteria for High Speed Maglev Trains**, Carl Hanson, Harris Miller Miller & Hanson Inc., prepared for U.S. Department of Transportation, Federal Railroad Administration, Washington, DC, Final Report: Task 2, September 1992.

   This report presents information on the criteria recommended for use in evaluating the noise impact from high-speed maglev systems. These criteria describe the noise environment considered acceptable for specific land uses, depending on the ambient noise. These recommendations are based on the best available data related to transportation systems with noise characteristics similar to high speed maglev. The conclusions are considered based on circumstantial evidence until more definitive methods can be verified.

3. **Noise Sources of High Speed Maglev Trains**, Report No. 291550-1, Harris Miller Miller & Hanson Inc., for U.S. Department of Transportation, Federal Railroad Administration, Washington, DC, May, 1992.

   According to the authors, airflow-generated, or aeroacoustic, sources result in increases in noise ranging from 50 - 80 times the logarithm of train speed and generally dominate noise levels from high speed trains at speeds of 250 km/hr (150 mph) or greater. Many of the acoustic sources associated with moving vehicles are known to be speed dependent, with speed raised to some power. Noise levels from high-speed rail systems normalized to a single 25 meter vehicle at different speeds are presented - these range between 75 dBA and 95 dBA. Noise impact is assessed for two stretches of the Northeast Corridor. Finally, the various mechanisms that may be involved in the generation of sound are discussed.

4. **General Accounting Office Report on Transportation Noise: Federal Control and Abatement Responsibilities May Need to Be Revised**, U.S. General Accounting Office/RCED-90-11, Washington, DC, October, 1989.

   In 1985, the Federal Aviation Administration estimated that about 5 million people lived in areas impacted by aircraft noise (Ldn 65 or above). There is a lack of recent data on rail noise. However, according to a 1979 EPA estimate, about 6.5 million were exposed to noise levels greater than 55 Ldn from railroad operations. Despite the growth in population, it is expected that less people will be affected as quieter aircraft and trains are used, operations are consolidated, and other advances are made. EPA estimated that in 1979 over 81 million people were subjected to highway traffic noise levels above Ldn 55, 16 million to noise levels above Ldn 65 and 1 million above Ldn 75. According to FAA's March 1985 report Aviation Noise Effects, studies have shown that a one decibel increase in Ldn usually results in a 0.5 to 2.0 percent decrease in property values. At a minimum, however, the cost of noise is the cost of moving to a new residence.

5. **"Aircraft Noise Generation and Control: Noise around Airports,"** Ch.13, John O. Powers, Noise Pollution: Effects and Control - Scope 24, published on behalf of the Scientific Committee on Problems of the Environment of the International Council of Scientific Unions, West Sussex, Great Britain, 1986.

   Different types of aircraft have noise sources which are uniquely characteristic of the type of propulsion system used by the aircraft. Many of the sources are common to all aircraft types, but their contribution is of a different magnitude. Noise control operating measures are also discussed.

6. **"Road Traffic Noise: Generation, Propagation and Control,"** Ch.12, C. Lamure, Noise Pollution: Effects and Control - Scope 24, published on behalf of the Scientific Committee on Problems of the Environment of the International Council of Scientific Unions, West Sussex, Great Britain, 1986.

   Lamure presents percentage contributions from the different basic sources to the total noise of the vehicle. The contribution from each source depends on the engine speed, except for the rolling noise which depends on the road speed. Measurement of noise due to road traffic is also discussed. Finally, the author presents different methods for reducing noise levels in the vicinity of a main road.

B. MITIGATION STRATEGIES:

1. **Determination of Traffic Noise Barrier Effectiveness, An Evaluation of Noise Abatement Measures Used on I-440**, L. Herman, W. Bowlby, and R. Brisson, presented at Transportation Research Board, 72nd Annual Meeting, Washington, DC, January 1993.

   The noise abatement efforts used on I-440 were studied to evaluate their effectiveness. Noise level reductions as high as 9.5 dB at the receiver locations were attributed to depressing the roadway with the average reduction being 2.8 dB. Of the forty sites tested, 75 percent realized at least a 5 dB reduction due to barriers alone. The results of 24-hour measurement periods show the variation in traffic noise levels, as well as background influences on levels and insertion loss determination. Comparison tests of absorptive and reflective barriers at two sites indicated that benefits were realized by the use of absorptive barriers on fill sections where barriers were installed close to shoulders.

2. **Pilot Noise Barrier Program: Final Report**, Report No. 291090, prepared by Harris Miller Miller & Hanson Inc. for Massachusetts Turnpike Authority, December 1992.

   Detailed actual cost estimates that were developed for the construction of different types of noise barriers along the Massachusetts turnpike are presented. They include a table containing the costs incorporated in the estimates.

3. **"Antinoise Creates the Sounds of Silence,"** Joe Alper, Science, Vol. 252, American Association for the Advancement of Science, April, 26, 1991.

   The author believes several luxury cars will be equipped with Active Noise Control (ANC) mufflers. According to a representative from Noise Cancelation Technologies (NCT), "Electronic mufflers is a billion dollar market." Unlike conventional mufflers, the devices quiet exhaust noise without generating back pressure, thereby improving power and performance while cutting fuel consumption by 2 to 5 percent. An NCT electronic muffler cut noise levels of grain loading equipment for CSX in Baltimore by 80 percent.

4. **Fighting Noise in the 1990s**, Organization for Economic Cooperation and Development, Paris, France, 1991.

   This report assesses the relative effectiveness of the various elements of noise abatement policies with reference to road traffic, air traffic, rail traffic, and neighborhood noise. Population levels exposed to road, aircraft, and railway noise are presented for six countries. Management of road traffic and urban transport in general is a key instrument in reducing motor vehicle noise. The level of success achieved depends on the approach adopted. Effective traffic plans distribute traffic throughout the existing or newly created road network so as to protect quiet districts while concentrating nuisance on a few main routes. Policies which rely solely on measures affecting vehicle speeds and traffic fluidity to reduce noise levels are not as effective. The most promising solutions are traffic restrictions affecting noisy vehicles. Non-economic incentives are essential if noise abatement is to be successful. Despite policies to control noise emissions from individual vehicles, ambient noise levels are expected to increase over time. Short-term and medium-and long-term measures to encourage low-noise commercial vehicles towards the year 2000 are presented. Subsidies and charges to encourage use of low-noise vehicles in the Netherlands are discussed. Different traffic management systems schemes are also discussed.

5. **"Energy and Environment 1990: Transportation-Induced Noise and Air Pollution,"** Transportation Research Record No. 1255, Transportation Research Board, Washington, DC, 1990.

   Some of the papers in this Record deal with airplane noise and its mitigation, the rating system for assessing sound insulation, research on traffic-induced noise - mainly mitigation, and high-speed rail systems. For airport related noise, sound insulation modifications for buildings are probably the best way to mitigate the impact. Sound insulation resulted in a 9-17 dB improvement near Denver's Stapleton International Airport, and a 4-10 dB improvement near the Baltimore Washington International Airport. One author presents five basic concepts on which criteria may be established for assessing intrusiveness of low noise levels generated by aircraft in remote, quiet locations.

6. **Inter-noise 90: Science for Silence - Proceedings**, Vol. I and II, Edited by H.G. Jonasson, Gothenburg, Sweden, August 13-15, 1990.

   Three hundred twenty one papers dealing with issues such as noise control, measurement techniques, effects of noise, and vibration control are included in this book. Transportation vehicle noise control is analyzed in many of the papers.

7. **Guide on Evaluation and Attenuation of Traffic Noise**, prepared by Task Force for Environmental Design, Operating Subcommittee on Roadway Design, American Association of State Highway and Transportation Officials, March 1985.

   A systems approach which involves shared responsibility is presented. To use any single method for noise reduction might be prohibitive in cost, but through a joint effort of those involved, an appropriate balance of responsibilities can be obtained.

   Attenuation measures, such as modification of highway horizontal and vertical alignment, modification of right-of-way width, noise shielding, and soundproofing buildings, are discussed in detail. Special attention is given to noise barrier design considerations.

C. COSTING/PRICING STRATEGIES:

1. **"Density of Residential Land Use and The Impact of Airport Noise,"** Dean Uyeno, Stanley W. Hamilton, and Andrew J.G. Biggs, Journal of Transport Economics and Policy, January 1993.

   The study estimates the impact of airport noise on property values for detached houses, for multiple-unit residential condominiums and for vacant land. J.P. Nelson (1980) reviewed twelve studies. For nine of these the range was about 0.40 to 1.10 percent per decibel, based on 1967 to 1976 data. Research by G. Pennington, N. Topham, and R. Ward (1990) suggests that most noise-affected houses would lose approximately 6 percent of their value. The results of the study show property value decreases of 0.65, 0.90, and 16 percent, for detached houses, condominiums, and vacant land, respectively.

2. **Highway Traffic Noise in the United States: Problem and Response**, Federal Highway Administration, Office of Environmental Policy, Noise and Air Analysis Division, Washington, DC, August 1990.

   This report presents noise barrier construction costs, which range from $630,000 to $1,488,000 (1981 dollars) each, and length (in miles) for ten states. Barriers are the most common form of abatement for highway noise.

3. **"Aircraft Noise and Residential Property Values Adjacent to Manchester International Airport,"** G. Pennington, N. Topham and R. Ward, Journal of Transport Economics and Policy, January 1990.

   Lower market values of properties affected by aircraft noise are found to be wholly attributable to the neighborhood and other characteristics of the properties - noise becomes a relatively insignificant factor. The authors use house mortgage data and noise contour maps to reveal a low negative, but weak and non-robust, relationship between aircraft noise and property values. Their initial estimates - that market value is reduced by on-average 6 percent - are within the range of those derived in previous studies. But, the effects of noise on property values become statistically insignificant when neighborhood characteristic effects are allowed for. Any negative effect of

higher noise levels may, to some extent, be offset by the greater accessibility of noisy properties and the possible effect on the prices of these properties.

4. **"Highway Noise and Property Values. A Survey of Recent Evidence,"** Jon P. Nelson, Journal of Transport Economics and Policy, May 1982.

   A survey of nine studies of areas in Canada and the U.S. suggests that traffic noise on a main highway decreases the price of a house by between 8 and 10 per cent. Nelson develops a noise depreciation sensitivity index, which is the ratio of the price of quiet to the price of an average house and lot. He examines some of the most controversial assumptions that underlie the hedonic price model of property values.

5. **Efficient Highway User Charges - Appendix E to the Final Report of the Federal Highway Cost Allocation Study**, Douglass Lee, U.S. Department of Transportation, Transportation Systems Center, Cambridge, MA, May 1982.

   Medical costs and control costs can both be considered in evaluating noise effects, but revealed preference studies using property value data have provided the best information to date. Sound level = vehicle vol. x emissions per vehicle/distance. With this you can develop noise contour maps. The willingness to pay for a noise-free environment is estimated by extracting the noise component of the price of a housing unit by comparing sales values. The best estimate is -0.4 percent of market value per dBA(Leq) in excess of 55 dBA. Lee comes up with noise costs per-vehicle mile for urban highways (1981 dollars) for auto, medium truck, and heavy truck. He assumes the middle sensitivity group is the one affected, and the relationship is approximately linear over the relevant range. He makes no allowance for commercial activities impacted by noise impacts and suggests that there is no linearity in the relationships.

6. **"The Practical Determination of a Charge for Noise Pollution,"** A. Alexandre, J. Ph. Barde, and D.W. Pearce, Journal of Transport Economics and Policy, May 1980.

   After reviewing various proposals for taxing traffic and aircraft noise, the authors suggest a formula aimed at reducing noise at the source and at raising revenue to be used for mitigating noise in the environment. Following work by Alexandre and Barde, they calculate a noise impact indicator that serves as an assessment basis for noise from road traffic and aircraft. Although they are unable to calculate an incentive rate for traffic noise, they do calculate dollar charges per-landing for two, three, and four engine aircraft. These range from $79 to $100 per-landing.

III. WATER

Although it is very difficult to isolate transportation's contribution to overall water pollution, it is recognized that transportation related activities contribute substantially. Most of the research in this area has concentrated on methods for conservation and very little has been done in the area of valuation. However, some of the methodologies used for costing transportation related air pollution can be applied to costing water pollution.

A. CAUSE/EFFECT - MEASUREMENT:

1. **"Twenty Years of the Clean Water Act,"** Debra S. Knopman and Richard A. Smith, Environment, January/February 1993.

   According to the authors, scientists still cannot reliably answer the most basic questions about national water quality. How much of specific pollutants do different sources contribute? What fraction of the surface water and groundwater fails to meet water quality standards for toxic substances and conventional pollutants?

   When looking at data provided by the different states, EPA cautions that the numbers should not be compared or aggregated to a national level due to inconsistencies in how these data are generated. Furthermore, the existing U.S. databases present a fragmented picture of national water quality, and almost no information on potential toxic organic compounds and trace metals is available.

B. MITIGATION STRATEGIES:

1. **The Water Quality Impacts of Commuting** (DRAFT), Kevin Weiss, U.S. Environmental Protection Agency (EPA), Office of Water, Washington, DC, 1993.

   This memorandum describes water quality impacts due to vehicular traffic and proposes implementing a flexible workplace policy that includes telecommuting, teleworking and work-at-home. The author presents a summary of road and highway storm water pollutant concentrations and comparisons of typical runoff from residential and commercial areas. Vehicular traffic is a major source of metals in urban runoff. EPA has recognized that given the problems associated with end-of-pipe controls from urban runoff, programs directed at pollutant sources are often the most practical way of reducing pollutant discharges to water. Transportation control measures in particular have been shown to be effective where properly implemented. Although there is a significant link between vehicle traffic and water pollution, it is generally less publicized than links to other sources.

2. **Analysis of Pollution Controls for Bridge Painting**, L. Smith, U.S. Department of Transportation, Federal Highway Administration and the Pennsylvania Department of Transportation, 1991.

   In this paper, pollution control measures for bridge painting are evaluated. Technical feasibility, productivity, and cost are analyzed for the different techniques.

C. COSTING/PRICING STRATEGIES:

1. **Results of Literature Survey and Summary of Findings: The Nature and Magnitude of Social Costs of Urban Roadway Use**, Mark E. Hanson, Resource Management Associates of Madison, Inc., Madison, Wisconsin, for Federal Highway Administration, U.S. Department of Transportation, in the process of publication.

   According to the author, there are "very few economic cost estimates of the highway damage to surface and ground water resources despite widely acknowledged impacts. If indirect costs are considered, the damage to these water resources from leaking storage tanks containing fuels will add significantly to the total costs." He further states that there are quantitative estimates of the social cost of smell and odor.

2. **U.S. Environmental Protection Agency Research Program on the Environmental Impacts and Control of Highway Deicing Salt Pollution**, R. Field and M. O'Shea, U.S. Environmental Protection Agency (EPA), Risk Reduction Engineering Lab, Cincinnati, OH, 1992.

   The authors report that the total annual cost of salt-related damage is estimated at $5.4B. The paper also outlines the results of several studies on highway-deicing impacts characterization and control conducted under EPA's research program on urban stormwater and combined sewer overflow pollution control in the 1970s.

3. **Distribution of Common Construction Materials**, F.W. Lipfert and M.L. Daum, Brookhaven National Lab., Upton, NY, U.S. Department of Energy, Washington, DC, April 1990.

   Degradation of construction materials due to acid deposition is largely an economic issue; its importance is measured in dollars. To estimate these costs requires information on the distribution of various types of construction materials, i.e., the "stock at risk" in the built environment, in addition to appropriate dose-response functions and many other data inputs. Assessment calculations for only a single city will inevitably be of questionable validity for the regional problem. Such an assessment may be regarded as a problem in mapping. Using economic dose-response functions and the geographic distributions of the materials at risk, the ultimate goal is to map the distribution of rates of acidic deposition into the distribution of economic damages.

4. **Water Pollution Control - Assessing the Impacts and Costs of Environmental Standards**, Ralph A. Luken and Edward H. Pechan, Praeger Special Studies - Design/Environmental Planning Series, 1977, p18.

   According to this paper, water pollution damages cannot be estimated due to uncertainty regarding certain relationships between effluent limits and water quality changes in those residuals.

IV. ELECTROMAGNETIC FIELDS

There is increasing public awareness of possible health implications due to exposure to electromagnetic fields (EMF). It has been suggested that a correlation exists between EMF and increased risk of childhood leukemia. This concern makes it imperative that such exposure be quantified and evaluated, in order to determine what level, if any, could cause health problems. Most of the studies are concerned with quantifying the output of EMFs and measuring the effects.

A. CAUSE/EFFECT - MEASUREMENT:

1. **Final Report on Magnetic and Electric Field Testing of the Amtrak and Metro North Northeast Corridor and New Jersey Transit North Jersey Coast Rail Systems, Volume I - Analysis**, prepared by Electric Research and Management for U.S. Department of Transportation, Federal Railroad Administration, Washington, DC, March 1993.

   This report documents the low frequency electric and magnetic fields associated with the operation of Metro North in New York and the Amtrak Northeast Corridor (NEC) rail system. The study and data analysis were complicated by the existence of three different rail technologies along the existing route. The magnetic field and electric field measurements associated with the study were grouped into four areas. They were on-board the trains, in the passenger stations, along the track rights-of-way, and near the substations, which supply power to the rail system.

   Comparison of measured fields to existing standards indicate: the highest electric field levels were found on station platforms of the NEC and were at the extreme low end of the World Health Organization (WHO) limit; the magnetic field measurements were 20 times less than WHO criterion; the magnetic field levels are in compliance with the International Radiation Protection Association's recommended limit; and the highest electric field levels found in or around the existing electrified railroad facilities were less than 5% of the threshold limit value established by the American Conference of Governmental Industrial Hygienists.

2. **"Executive Summary: Health Effects of Low-Frequency Electric and Magnetic Fields,"** Special Report by an Oak Ridge Associated Universities (ORAU) Panel, Environmental Science & Technology, Vol. 27, No. 1, pp. 42-51, January 1993.

   The Department of Labor (DOL) was concerned about reports of cancer resulting from electric and magnetic fields and requested the Committee on Interagency Radiation Research and Policy Coordination (CIRRPC) to evaluate current data concerning possible health effects relating to these fields. In response to the DOL request, CIRRPC asked ORAU to establish a panel for scientific review and evaluation of the reported health hazards of exposure to extremely low-frequency electric and magnetic fields (ELF-EMF).

   This review indicates that there is no convincing evidence in the published literature to support the contention that exposure to ELF-EMF generated by sources such as household appliances, video display terminals, and local power lines presents demonstrable health hazards.

3. **"Health Effects of Low-Frequency Electric and Magnetic Fields,"** David A. Savitz Environmental Science & Technology, Vol. 27, No. 1, pp. 52-54, January 1993.

   This article indicates that, as in many evolving research areas, the only consensus among scientists regarding potential health effects from power-frequency electric and magnetic fields seems to be that the evidence is insufficient to draw firm conclusions. The author believes that the burden should be placed upon the critics to postulate errors in the positive reports and to suggest studies

that would either demonstrate that such errors occurred or enhance the previous report by demonstrating that it was free from such errors.

4. **"Health Effects of Low-Frequency Electric and Magnetic Fields,"** Thomas S. Tenforde, Environmental Science & Technology, Vol. 27, No. 1, pp. 56-58, January 1993.

   The author concluded that the Special Report by the Oak Ridge Associated Universities panel is seriously deficient in both content and logic and should not be regarded as a definitive statement on the possible relationship between exposure to ELF fields and cancer risk.

5. **Final Report on Magnetic and Electric Field Testing of the Massachusetts Bay Transportation authority (MBTA) Urban Transit System Volume I - Analysis, Draft,** prepared by Electric Research and Management, Inc., for U.S. Department of Transportation, Federal Railroad Administration, Washington, DC, January 1993.

   This report documents the low frequency electric and magnetic fields associated with the operation of the MBTA system in the Boston area. Comprehensive measurements were made on and along the MBTA transit lines and facilities.

   The magnetic field and electric field measurements made on or near the Boston MBTA facilities were grouped into six areas: within on-board passenger compartments; within the operator's position; in the passenger stations; along the track rights-of-way (wayside); inside and outside the traction power supply stations; and in a dispatcher's control room.

   Comparison of MBTA fields to existing standards indicate: the highest electric field levels encountered were 200 times less than the lower end of the World Health Organization (WHO) limit; the magnetic field measurements were two orders of magnitude below the WHO criterion in each band; the highest measurement of the total ELF magnetic field was below the International Radiation Protection Association's recommended limit; and the highest electric field levels found in or around the existing MBTA electric transit facilities were well within the threshold limit value established by the American Conference of Governmental Industrial Hygienists.

6. **Final Report on Magnetic and Electric Field Testing of the Washington Metropolitan Area Transit Authority Metrorail System Volume I - Analysis, Draft**, prepared by Electric Research and Management, Inc., for U.S. Department of Transportation, Federal Railroad Administration, Washington, DC, January 1993.

   This report documents the low frequency electric and magnetic fields associated with the operations of the Washington, DC Metropolitan Area Transit Authority Metrorail Urban Transit System.

   Comparison of Washington Metropolitan Transit Authority fields to existing standards indicate: the highest electric field levels encountered in these measurements were found outside the traction power supply and were at the lower end of the World Health Organization (WHO) limit; the magnetic field measurements were at least an order of magnitude below the WHO criterion in each band; the average measurement of the total ELF magnetic field was 10 cm above the floor at the center of the 3000 series cars (18% of the International Radiation Protection Association's recommended limit), and the levels in other parts of the train were less; and the highest electric field levels found in or around the existing Metrorail electrified urban transit facilities were well within the threshold limit value established by the American Conference of Governmental Industrial Hygienists.

7. **Final Report on Magnetic and Electric Field Testing of the French Train A Grande Vitesse (TGV) Rail System Volume I - Analysis**, prepared by Electric Research and Management, Inc., for U.S. Department of Transportation, Federal Railroad Administration, Washington, DC, December 1992.

   This report documents the low frequency electric and magnetic fields associated with the French Train a Grande Vitesse (TGV). Measurements were made on and along the route between Paris and Tours, France. This report presents the results of the analysis of extensive measurements of magnetic and electric fields within the coaches and locomotives, along the wayside, at passenger stations, near electric power supply stations, and inside control facilities of the TGV rail system in France.

   Comparison of TGV fields to existing standards indicate: the highest electric field levels encountered in these measurements found in the coaches were four orders of magnitude below the lower end of the World Health Organization (WHO) limit; the magnetic field measurements in the coaches or on the station platforms were less than 4% of the WHO criterion in each band; The average time for varying magnetic field levels in the passenger coaches is approximately 3% of International Radiation Protection Association's recommended limit; and the highest electric field levels found around the existing TGV electrified railroad facilities were less than 4% of the threshold limit value established by the American Conference of Governmental Industrial Hygienists.

8. **"Electric and Magnetic Fields: Managing An Uncertain Risk,"** Gordon L. Hester, Environment, Vol. 34, No. 1, pp. 7-32, January/February 1992.

   A growing body of evidence indicates that exposure to the electric and magnetic fields (EMF) created by electrical devices and transmission lines may pose a risk to human health. However, scientists are not certain which aspects of EMF are associated with risk. Better understanding of EMF effects is needed before society can make investments to reduce the potential health risks.

   While this article does not specifically treat transportation, it is a good study on electric and magnetic fields (EMF). Despite the current uncertainty, several actions are justified. First, EMF research is needed on health effects, exposure assessment, and field reduction. Second, there is a need for a high-quality, coordinated long-term effort that will yield the answers society needs.

   Continued ambiguity about health is by no means desirable, and, in fact, will probably lead to greater problems as the need for new electrical facilities grows.

9. **Safety of High Speed Magnetic Levitation Transportation Systems: Final Report on Magnetic Field Testing of TR-07 Magnetic Vehicle Volume I - Analysis**, Fred Dietrich and William E. Feero, Electric Research and Management, Inc., funded by U. S. Department of Transportation, Federal Railroad Administration (FRA), Washington, DC, April 1992.

   The safety of various magnetically levitated (maglev) and high-speed rail trains proposed for use in the U.S. is a responsibility of FRA. The characterization of electric and magnetic fields emissions and associated public and worker exposures to these fields, are a growing health and safety concern worldwide. As part of a comprehensive safety assessment of the German Transrapid (TR-07) maglev system undertaken by FRA, magnetic field measurements were performed at the Transrapid Test Facility. This volume summarizes the experimental findings and compares results to common home, work, and power lines emissions for selected bands.

The magnetic field measurements were conducted on board the Transrapid Maglev Vehicle and in the vicinity of the vehicle, guideway, passenger station, control center, and power supply facility at the Transrapid Test Facility.

Comparison of Transrapid fields to existing standards indicate: the on-board field levels are at least two orders of magnitude less than the World Health Organization limit, with an even greater margin of compliance at other locations; the magnetic field measurements in the coaches or on the station platforms were 10 times less than the International Radiation Protection Association's recommended limit; and the field levels associated with the TR-07 System comply with the threshold limit value established by the American Conference of Governmental Industrial Hygienists by a 1,000 to 1 margin.

10. **"Electromagnetic Fields Are Being Scrutinized For Linkage to Cancer,"** Sandra Blakeslee, New York Times Medical Science, April 2, 1991.

    If the risks exist, scientists say they probably are very small. Nevertheless, the question is gaining new urgency as studies conducted in the U.S. and abroad corroborate earlier findings that exposure to weak electromagnetic fields, like those produced by power lines, and some home appliances, are correlated with slightly higher risk of leukemia and cancers of the breast, prostate, and brain.

    Scientists are not looking at a conventional model of cancer in which exposure to chemicals alters cell DNA directly by breaking chemical bonds or mutating cancer genes. Instead the search explores cell membranes, receptors, channels into cells, junctions between neighboring cells, communication networks among cells, and hormonal systems.

B. MITIGATION STRATEGIES:

1. **Compendium of Executive Summaries from the Maglev System Concept Definition Final Reports**, U.S. Department of Transportation, Federal Railroad Administration, U.S. Army Corps of Engineers, U.S. Department of Energy, National Maglev Initiative, Washington, DC, March 1993.

    This multiple volume report on maglev system concept definition studies for the National Maglev Initiative references strategies designed to eliminate any negative impacts arising from magnetic fields. The strategies are specifically suggested for magnetically levitated trains but analysis may have application to steel-wheel-on-rail systems as well. Strategies include: magnetic shielding, passive/active field cancellation, and designing fields to diminish rapidly with distance from source.

V. HAZARDOUS MATERIALS

While the transportation of hazardous materials and hazardous waste is an emotional issue because of the potential for a major disaster, it can best be addressed by research concerning the safety afforded by specific routings, modes, and equipment used in the transportation of these materials. In most cases such movements must be dealt with on a case-by-case basis.

A. CAUSE/EFFECT - MEASUREMENT:

1. **Freight Transportation: Truck, Rail, Water, and Hazardous Materials, Transportation Research Record No. 1313**, Transportation Research Board, National Research Council, Washington, DC, 1991.

   "State and Local Issues in Transportation of Hazardous Materials: Toward a National Strategy," M. Abkowitz, P. Alford, A. Boghani, J. Cashwell, E. Radwan and P. Rothberg, pp. 49-54.

   This paper presents findings of a recent conference whose objective was to identify effective methods for managing hazardous materials transportation within the evolving national system. The conference was organized into five major themes: community preparedness and response; evaluating and communicating risk; routing and citing considerations; data collection and information management; and inspection and enforcement.

B. MITIGATION STRATEGIES:

1. **Freight Transportation: Truck, Rail, Water, and Hazardous Materials, Transportation Research Record No. 1313**, Transportation Research Board, National Research Council, Washington, DC, 1991.

   "Benefit-Cost Evaluation of Using Different Specification Tank Cars to Reduce the Risk of Transporting Environmentally Sensitive Chemicals," C.P.L. Barkan, T.S. Glickman and A.E. Harvey, pp. 33-43.

   This paper presents an analytical approach to quantifying the benefits and costs of transporting specific chemicals in tank cars. The results indicate that reduced liability, which more than offsets the increased capital and operating costs required, would result from using a specific type of tank car.

2. **"Modeling Equity of Risk in the Transportation of Hazardous Materials,"** R. Gopalan, K.S. Kolluri, R. Batta and M.H. Karwan, Operations Research, Vol. 38, No. 6, November-December 1990.

   This paper develops and analyzes a model to generate an equitable set of routes for hazardous material shipments. Its objective is to determine a set of routes that will minimize the total risk of travel and spread the risk equitably among the zones of the geographical region in which the transportation network is embedded.

3. **Guideline for Applying Criteria to Designate Routes for Transporting Hazardous Materials**, U.S. Department of Transportation, Research and Special Programs Administration, Final Report, Washington, DC, July 1989.

   These guidelines were prepared to assist state and local officials in analysis of alternate routes to be used by highway vehicles transporting hazmat.

C. COSTING/PRICING STRATEGIES:

1. **Assessing the Release and Costs Associated With Truck Transport of Hazardous Wastes**, Environmental Protection Agency, Office of Solid Waste, Washington, DC, 1984.

   This study estimates the release from and the costs of the truck transport of hazardous waste carried in bulk and container shipments. Perhaps the most important result of this study is that the release rates associated with transporting hazardous wastes by truck appear to be as large as the potential releases at treatment and disposal sites.

SOCIAL COSTS

VI. LAND USE

The relationship between transportation and land use has been receiving renewed attention in recent years, particularly in air pollution nonattainment areas. It is widely recognized that a relationship exists between the availability of transportation and land use development patterns. Often, this relationship has been manifested by highway construction, suburban sprawl, and increased air pollution. However, defining the precise interaction has proven to be more difficult. Land use patterns influence transportation choices and strategies and, in turn, are influenced by the availability of transportation alternatives.

A. CAUSE/EFFECT - MEASUREMENT:

1. **"Automobile Subsidies and Land Use: Estimates and Policy Responses,"** Mark Hanson, Journal of the American Planning Association, Vol. 58, No. 1, Winter 1992.

   This article presents an estimate of automobile subsidies and considers their significance for transportation and land use policy. Urban land theory is used to link subsidies to land use. Registration fees, gasoline taxes, and funding alternative modes are considered as potential policy responses.

   Douglass Lee reports that user fees and earmarked taxes at all government levels provided only 69% of highway expenditures in 1985. This paper shows that these data appear to underestimate the subsidies. In theory, long-term auto subsidies have resulted in overuse and over-provision of highways. This in turn has resulted in sprawl. If transportation costs become low enough, there is little advantage to being near an urban center. Cervero (1989) notes that local streets have considerable unused capacity in that nationally they provide 80% of the lane miles of roadway while carrying only 15% of the vehicle mileage.

   Determining the optimal amount of highways and congestion is beyond the scope of this research. It has been reported that, worldwide, at least one-third of a city's land is devoted to roads, parking lots, and other motor vehicle infrastructure. In U.S. cities, close to half of all urban area goes to accommodating the automobile, while in Los Angeles the figure reaches two-thirds. Foregone property tax revenue is used as a conservative estimate of the opportunity cost of land. Newman and Kenworthy identify a set of policies for physical factors that planners can control to reduce automobile dependence and reduce sprawl: 1) increase urban density, 2) strengthen the city center, 3) extend the proportion of the city that has inner-area land use, 4) provide a good transit option, and 5) restrain the provision of automobile infrastructure.

2. **Public Transportation and Land Use Policy**, Boris S. Pushkarev and Jeffrey M. Zupan, Indiana University Press, 1977.

   The low density of urban development in the U.S. is both the consequence and cause of the nation's dependence of the automobile. This has three drawbacks: 1) it restricts the mobility of those who cannot use an auto for whatever reason, 2) it causes inordinate energy consumption and is environmentally destructive, and 3) the larger cities lack the space to accommodate all travel by auto at an acceptable cost. To reduce auto use, direct restraints on the auto will be necessary. The effect of higher density urban development is both to restrain auto use and to encourage the use of public transportation. Data suggest that neighborhoods with 15-dwellings per-acre produce about 30% fewer auto trips per-person than those with 5 dwellings per-acre. Simultaneously, public transit use is more than 100% greater. The long-term viability of an auto-dominated urban

pattern is uncertain, and higher densities save resources not only by reducing transportation, but also by reducing household consumption of energy and materials and preserving land. As urban density increases, each person makes fewer trips by car. During peak periods, an auto occupant on the street needs 20 times, and on a freeway, 10 times more space than a transit rider at comparable speed and reasonable comfort level.

3. **The Growth Shapers: The Land Use Impacts of Infrastructure Investments**, prepared for the Council on Environmental Quality by Urban Systems Research & Engineering, Inc., Washington, DC, May 1976.

   This handbook examines the major role played by many publicly funded infrastructure projects (including roads, airports, and mass transit) in the local development process. Public infrastructure investments affect local growth by influencing the location, cost, density, timing, and quantity of new development. While the link between infrastructure improvements and land use has long been recognized, little has been done to control the design and location of new infrastructure. Rather, the focus has been on ameliorating the negative impacts arising from development generated by the infrastructure improvements. By changing the design of the infrastructure itself, an effective control measure is added to other land use controls.

   The handbook discusses the interactions of infrastructure and land use and investments and land use, provides a practical framework for forecasting these interactions, and describes methods for controlling secondary effects. This framework is applied to the analysis of highways and mass transit facilities.

B. MITIGATION STRATEGIES:

1. **Searching for Solutions, A Policy Discussion Series, Edge City and ISTEA - Examining the Transportation Implications of Suburban Development Patterns**, U.S. Department of Transportation, Federal Highway Administration (FHWA), Office of Policy Development, No. 7, Washington, DC, December 1992.

   This publication presents the views of a variety of transportation, social science, and land use experts as expressed at a seminar conducted by FHWA in August 1992. The seminar focused on the challenges created by edge city development patterns and the opportunity for flexibility created by the ISTEA provisions to meet those challenges.

   The movement of jobs and residences from the traditional center city to the suburbs has resulted in new "edge cities." These edge cities have developed on the outskirts of the old urban centers resulting in greatly expanded metropolitan boundaries. In fact, since 1970 an estimated 80 percent of the new office construction has occurred in these edge cities.

   The growth of "edge cities" has established the context for much of future transportation planning, as it is estimated that the suburbs of the 60 largest metropolitan statistical areas (MSAs) now contain some 67 percent of the jobs in those areas. With the enactment of ISTEA and its new planning requirements, programs, and decision-making flexibility, it appears appropriate to reconsider the importance of the relationship of land use development and transportation in decision-making.

2. **Searching for Solutions, A Policy Discussion Series, Transportation and Air Quality**, U.S. Department of Transportation, Federal Highway Administration (FHWA), Office of Policy Development, No. 5, Washington, DC, August 1992.

Land use approaches have been part of the dialogue about emissions control since the 1970 Federal Clean Air Act Amendments. Recent debates have made much of the linkage between low density land uses and high rates of per-capita travel. Data from large cities worldwide show that low residential density consistently corresponds with high measures of metropolitan average per-capita vehicular travel consumption (VMT, trips, fuel consumption, emissions). Evidence indicates that income accounts for only a portion of travel variability with land use.

Environmental groups claim that infrastructure investments will worsen per-capita emissions when they support development at the urban fringe - where the lowest density, highest travel consumption occurs - and will improve per-capita emissions when they create arrangements of land uses that require less vehicular travel - by placing compatible uses in close proximity, or by linking activity centers and residential areas through mass transit. Land use and transportation planning should be more closely coordinated. It is suggested that EPA may be able to - although with some difficulty - assign emissions reduction credit to land use control measures. There is uncertainty in this area regarding which land use patterns correlate with reduce per capita vehicular trend consumption; which relationships (residential, retail/service density are causal; and what is the magnitude of improvement to be expected from various measures or combination of measures, and over what time frame? It was agreed that some Federal guidance to help clarify the options would smooth and speed the policy making process.

C. COSTING/PRICING STRATEGIES:

1. **The Costs of Sprawl, Executive Summary**, Council on Environmental Quality, Washington DC, April 1974.

This study attempts to integrate various economic, environmental, natural resource, and social costs of the different types of development in order to help local decisionmakers. It indicates whether the costs incurred are public or private. Three types of costs are analyzed: 1) economic costs - residential, open space/recreational, schools, streets and roads, utilities, public facilities and services, and land; 2) environmental effects - air and water pollution, noise, vegetation, wildlife, visual effects, and water and energy consumption; and 3) personal effects - use of discretionary time, psychic costs, travel time, traffic accidents, and crime. The approach was to assume typical site conditions and an absence of any existing infrastructure at the site and then, using standard unit cost figures, to estimate the costs of building alternative types of development.

According to the study, "for communities covering the same area, over 50 percent of the land in the high density planned community remains completely undeveloped, whereas all the land is at least partially developed in the low density sprawl community. On the other hand, the low density sprawl community has more land that is improved but vacant, an indication of the amount of leapfrogging that occurs there." Planning and higher densities result in significant savings in economic costs, environmental costs, natural resource consumption, and some personal costs for a given number of dwelling units.

VII. COMMUNITY DISRUPTION

Both the infrastructure required to support transportation systems and the system operation often result in large scale community disruptions. With ground transportation systems, this frequently takes the form of a linear corridor that can sever and isolate otherwise contiguous communities, both human and natural. While some efforts have been expended on measurement and mitigation, it appears that this area has not received the same level of attention as other transportation externalities. Adverse effects are best addressed on a case-by-case basis.

A. CAUSE/EFFECT - MEASUREMENT:

1. **"Effects of Elevated Heavy-Rail Transit Stations on House Prices with Respect to Neighborhood Income,"** Arthur C. Nelson, Transportation Research Record No. 1359, Economics, Finance, and Administration, Transportation Research Board, National Research Council, Washington DC, 1992.

   This paper investigates the economic impact that the presence of elevated heavy-rail transit stations has had on residential neighborhoods. Based on a study in Atlanta, GA, elevated transit stations have a positive price impact on homes in lower income neighborhoods and a negative price effect on homes in higher income neighborhoods.

B. MITIGATION STRATEGIES:

1. **"Environmental Auditing: An Introduction to Issues of Habitat Fragmentation Relative to Transportation Corridors with Special Reference to High-Speed Rail (HSR)"** Robert S. De Santo, Dwight G. Smith, Environmental Management, Vol. 17, No. 1, pp. 111-114, 1993.

   The siting and construction, in the short term, and habitat removal and fragmentation, in the long term, are environmental consequences of transportation corridor construction efforts. These consequences may be beneficial although they are often adverse. A beneficial effect of a long corridor is that it can serve as a wildlife passageway, if the corridor incorporates elements that enable wildlife to pass along habitats adjacent to the right-of-way. However, particularly in rural areas, wildlife migration corridors and dispersal orientation can be altered or destroyed by the linear transportation corridor. Transportation corridors also sever natural populations and result in gene pools isolation, significantly weakening the community. Avoidance of fragmentation is the first rule of impact reduction; however, the careful selection of the corridor can reduce the fragmentation impacts by maximizing the size of the created fragments. The width of the corridor determines the degree of wildlife movement restriction. Adverse impact can be lessened using culverts, under and overpasses, and one-way gates. These measures also reduce the mortality otherwise experienced by individuals moving across the corridor.

   When compared with highway corridors, rail corridors have four characteristics that minimize adverse environmental impacts: dry roadbeds that discourage unwanted vegetation; runoff is filtered by stone ballast; a service road limits shift of materials to the width of the slope; and drainage ditches control runoff flow and erosion. Rail corridors also have the advantage of occupying a smaller land area because they are significantly narrower than highway footprints, a substantial advantage that improves the feasibility of underpasses. In addition, rail beds can be elevated on pilings, allowing passage underneath so that there is virtually no physical barrier to species movement.

VIII. ENERGY

Virtually all of the transportation energy consumed in 1991 was generated from petroleum. In addition, to pollution caused by the use of this fossil fuel, use of imported oil can have both economic and political repercussions.

A. CAUSE/EFFECT - MEASUREMENT:

1. **Transportation Energy Data Book: Edition 13**, Oak Ridge National Laboratory, Stacy C. Davis and Sonja G. Strang, prepared for U.S. Department of Energy, Office of Transportation Technologies, Washington, DC, March 1993.

   This publication is a statistical compendium prepared and published by Oak Ridge National Laboratory under contract with the Office of Transportation Technologies in the Department of Energy. Designed for use as a desk-top reference, the data book includes statistics and information that characterize transportation energy use and presents data on other factors that influence transportation energy use.

2. **"Transit Station Energy Impacts,"** Patrick Coleman, Mark Euritt, and C. Michael Walton; Research Report SWUTC/92/60033-1, Southwest Region University Transportation Center, Center for Transportation Research, University of Texas, Austin, TX, December 1992.

   Transit trips - when compared with automobile travel - not only relieve traffic congestion, but also offer energy savings per person. Transit trips also affect land use and development patterns that surround a transit station. This report addresses the energy effects of development that occurs within a certain radius of a transit station which would encourage trip ends to and from land uses in the area served by transit. Since infrastructure serving high-density development is more efficient than infrastructure serving low density, typically suburban, land uses, the potential exists to conserve energy that is used in everyday trips. In this report, a methodology is developed to estimate the energy savings associated with land use changes in the station areas.

3. **Methodology for Freight Transportation Energy and Emission Studies**, A.M. Khan, for the Canadian Society for Mechanical Engineering Forum, June 1-4, 1992, Montreal, Canada, June 1992.

   This paper describes methodological advances in the estimation of freight transportation energy and emissions. The overall methodological framework is covered and a comparative examination of a number of recent studies is presented.

4. **"Evaluating Energy, Environmental And Economic Externalities of Alternative Modes of Intercity Travel,"** Dr. Thomas Lynch, Prepared for Transportation and Global Climate Change: Long-Run Options: Asilomar Conference Center, Pacific Grove, CA, August 25-28, 1991.

   The author points out that almost 50 percent of all global warming activities originate from energy consumption. A large component of this energy consumption, particularly in the U.S., comes from motor vehicle consumption of fossil fuels for transportation. The low relative price of fuel has resulted in: increasing reliance on foreign sources of fuel; increasing federal deficit; wasteful consumption and no search for an alternative source; wasteful infrastructure investments; a

disadvantaged competitive transportation infrastructure; and enormous amounts of emissions and associated economic damage caused by the emissions.

Transportation emissions carry not only substantial costs in terms of energy efficiency but also substantial disruption of economic productivity, due to illness, material damage and a range of other externality costs that must begin to be factored into the cost of the transportation system itself.

5. **Energy and Environmental Factors in Freight Transportation**, A.M. Khan, A.K. Socio-Technical Consultants, Ottawa, Canada, for Transport Canada, Economic Research Branch, Ottawa, Ontario, July 1991.

   This study produces energy efficiency and environmental estimates for the freight transportation system in Canada, with emphasis on intercity transportation. The effects of likely future traffic growth and selected scenarios are also assessed.

   The study found that at the aggregate national level, rail freight is the most efficient user of energy (in tonne-km terms) and air freight is the most inefficient. On a per tonne-km basis, truck service by Class I and Class II for-hire carriers uses more than three times the fuel required by railway freight and domestic marine. In the year 2010, if 10% of tonne-kilometers were to be shifted to rail, a total of 864 million litres of diesel fuel would be saved (6.0% of petroleum-based fuels required for 2010 in freight transportation). Reduction in emissions would parallel fuel savings.

6. **Rail Vs. Truck Fuel Efficiency: The Relative Fuel Efficiency of Truck Competitive Rail Freight and Truck Operations Compared in A Range of Corridors**, Abacus Technology Corp., Chevy Chase, Maryland, for the U.S. Department of Transportation, Federal Railroad Administration, Office of Policy, Washington, DC, April 1991.

   The report evaluates the fuel efficiency of rail freight operations relative to competing truckload service. The findings are based on computer simulations of rail and truck freight movements between the same origins and destinations, based on actual rail and truck operations. Data was provided by U.S. Class I and regional railroads and by large truck fleet operators. Rail achieved from 1.4 to 9 times more ton-miles per gallon than competing truckload service. The study included consideration of rail circuity, fuel used in rail switching, terminal operations, and truck drayage (for rail).

7. **"External Social Costs as a Factor in Least-Cost Planning- An Emerging Concept,"** Lori A. Burkhart, Public Utilities Fortnightly, Vol. 124, August 31, 1989.

   The consideration of external social costs in conservation planning is only beginning. Much debate on the issue remains, including whether ratepayers should be responsible for costs to society as a whole. Difficulties abound in quantification, as well as in deciding the types of costs to be considered external to a resource option. But there is increasing interest in the concept of social responsibility, and more states will likely embrace consideration of externalities in conservation planning.

8. **Transportation Energy, Transportation Research Record No. 1155**, Transportation Research Board, National Research Council, Washington, DC, 1987.

This publication includes several articles concerning energy and transportation including the following:

"Converting Transit to Methanol: Costs and Benefits for California's South Coast Air Basin," Stephanie J. Frederick, Jane C. Morrison, and Kenneth A. Small, pp. 12-17.

Methanol offers much promise as an alternative fuel whose combustion produces no sulfates and fewer nitrogen oxides and particulates than diesel fuel. Another advantage is that large quantities could be manufactured from domestic coal supplies. On the basis of the assumption that an extensive methanol program might well begin with public transit, the costs and benefits of converting the bus fleets of California's South Coast Air Basin to methanol are estimated. Benefits are based on the reduced mortality attributable to lower sulfates and particulates; costs encompass both bus conversion and replacement. When these benefits are compared with costs over a wide range of methanol prices, conversion to methanol is found to merit further consideration as an antipollution strategy. It is proposed that the analysis be extended to additional potential benefits and costs to other locales and types of vehicles.

B. MITIGATION STRATEGIES:

1. **"Transportation Fuels Tax Would Hit Individuals,"** David S. Hilzenrath, The Washington Post, June 9, 1993.

A transportation fuels tax proposed to replace the Clinton Administration's Btu tax would apply to most forms of transportation and, like the Btu tax, fall more heavily on rural areas where people drive greater distances and lack access to public transportation. Such a tax would be easy to implement as the bureaucracy to collect taxes on gasoline already exists. The proposed tax would increase the current 14.1 cent tax by 7.5 cents. The Btu tax would have raised the tax by 7.6 cents when fully implemented.

Whether the tax would lead to significant energy conservation is unclear Economists generally agree that Americans are slow to alter their driving habits in response to higher fuel costs. Nevertheless, consumers could adapt to a tax concentrated at the gas pump more easily than adjust to a tax spread out in many places, from utility bills to food prices. With a gas tax, motorists could respond by switching to mass transit or more fuel-efficient cars.

A tariff on oil imports could reduce U.S. reliance on foreign petroleum but could create windfall profits for domestic oil producers at the expense of consumers, by enabling the producers to raise their prices to match the increased cost of imported oil.

2. **"The New Energy Tax and Its Impacts,"** Joyce Yanchar, DRI/McGraw-Hill, Spring Energy Conference, Washington, DC, May 27, 1993.

Ms. Yanchar reported that an energy tax was chosen by the Clinton Administration because of its potential to: reduce the deficit, promote energy conservation, reduce environmental damages, and reduce dependence on foreign sources of energy. When measured against carbon reductions, oil import reductions, domestic production, energy prices and the tax base, the Administration's Btu tax scored overall better than other energy taxes - a level Btu tax, a carbon tax, a motor fuels tax, and an oil import fee.

3. **"Energy Tax: A Good Idea? Probably,"** Robert J. Samuelson, Washington Post, March 24, 1993.

   The White House indicates that an energy tax would raise about $22 billion in revenues, prod Americans to use energy more efficiently, reduce our dependence on imported oil, and cut pollution. After phase-in: the Btu tax would increase the price of oil by $3.50 a barrel, or about 18 percent of today's price; the price of a ton of coal would increase $5.60, a 26 percent increase; and the price for a thousand cubic feet of natural gas would rise about 13 percent. The author believes that since the proposed tax is so mild, both the claims for it and objections to it are exaggerated.

4. **"The Pros and Cons of Alternative Energy Taxes,"** Joyce Yanchar and Susan Haltmaier, Special Study, DRI/McGraw-Hill, U.S. Review, March 1993.

   This study compares six energy tax alternatives and their potential impacts on the energy markets, the national economy, and the federal budget. The six tax alternatives are: the Administration's proposed Btu tax on all fuels; a level Btu tax on all fuels; a carbon tax on all fossil fuels; a retail ad valorem tax on all fuels; a retail motor fuels tax; and an oil import fee.

   This analysis phases each tax in over three years, beginning in 1994, and is designed to collect $30 billion in gross revenues in 1997. This analysis indicates that oil and natural gas markets would be hit the hardest by an oil import fee, while the motor fuels tax would affect only oil imports. The burden of the remaining taxes would be felt in all energy markets.

   The level Btu tax and carbon tax would raise coal and natural gas prices proportionately more than oil prices. The Administration's proposed Btu tax would correct for this heavier burden on domestic versus imported energy sources with an oil supplement, and thus moderate the domestic energy production losses induced by other taxes.

   Carbon emissions and oil imports would decline in response to an oil import fee; however, this would be costly to the economy. All of the other taxes except the oil import fee have similar impacts on the national economy, with the motor fuels tax slightly preferable to the other taxes. The oil import fee imposes twice the burden in terms of inflation and growth.

   The burden of the full price and income shifts is slightly progressive as a percent of spending and slightly regressive as a percent of reported income. For all income groups, the total burden of the oil fee is almost twice as heavy as that of the other options.

   The Administration's proposed Btu tax is a tax on the heat content of each energy source, with oil being taxed 2.3 times the tax rate on the other fuels. Non-fossil fuels, solar and wind power, would be exempt from the tax. The main disadvantage of this Btu tax proposal is that it is not optimal in reducing carbon emissions and hence global warming. It includes noncarbon-emitting energy in its tax base and does not align tax rates with relative carbon content. The advantage of this tax is that it is a broad-based tax, affecting all fossil fuels, nuclear, and hydropower. Its burden is distributed more equitably across fuels and regions than that of the narrow-based taxes.

5. **"Clean Fuels: An Overview,"** Fact Sheet OMS-6, U.S. Environmental Protection Agency, Office of Mobil Sources, January 1993.

   This paper discusses vehicle fuels that create less pollution than today's gasolines because of their physical or chemical properties. These fuels are called "clean fuels." The paper reviews the advantages and disadvantages of the following "clean fuels": electricity; ethanol; methanol; natural gas; propane; and reformulated gasoline.

Clean-fueled vehicles are here today and widespread use in the near future is feasible. It will take a concerted effort by all sectors of society, but a switch to clean fuels is the most viable way for many cities to attain clean and healthy air. Clean fuels in the marketplace will give consumers new choices and could decrease our dependence on imported oil.

6. **Choices: Finding the Motor Fuel of the Future**, ARCO Public Affairs, Los Angeles, CA, March, 1993.

   Motivated by environmental and security concerns, federal and state programs are seeking wider use of alternative fuels. This report examines six alternatives to conventional gasoline: electric vehicles - the least polluting of all, compressed natural gas, ethanol, methanol, liquefied petroleum gas, and a cleaner-burning form of gasoline developed by ARCO in 1989. For each alternative, this booklet looks at where it would come from, how much it would cost, its technical difficulties, its effects on the environment, and the impact its large scale use would have on national security.

   According to ARCO, at present electric vehicles show the most potential for the long-run, once problems with driveability, range, and cost are resolved. In the transition, we should avoid costly overhauls of a system that works in pursuit of temporary or marginally effective measures. In the interim, reduced-emissions reformulated gasoline will be a dominant motor fuel, because it offers a fast, cost-effective, and non-disruptive way to realize the nation's environmental objectives, in addition to making a contribution toward energy security, until a vastly superior alternative is feasible for everyday use. We must also aggressively seek better ways to conserve energy including car pooling and sound auto maintenance. Using fuel wisely can make a huge dent in both pollution and oil imports, at minimal cost.

7. **"High-Speed Passenger Ground Transportation: An Analysis,"** Marc D. Latman, Northeast Midwest Congressional Coalition, Northeast-Midwest Report, September 1992.

   This study discusses among other things the enhanced environment and increased energy and fuel efficiency aspects of high-speed ground transportation (HSGT). The report indicates that the amount of energy saved over conventional systems will differ depending upon which form of HSGT is chosen. Florida sponsors of maglev believe that HSGT options they are considering could use one-third to one-half as much energy per-passenger-mile as automobile travel and one-fifth to one-fourth as much as air travel. Another Florida study is cited that claims a diversion of auto and air travelers to HSR in Florida will reduce emissions by 61,015 tons in 1995, and perhaps 83,092 tons by 2006.

   The study states that fewer cars and airplanes could produce many environmental benefits, such as less congestion on the highways, in the skies, and at airports. It is estimated that with more efficient trains, 18,250 air shuttle flights annually (50) per day) might be cut from the New York to Boston route alone. This reduction in air travel could save 20 million gallons of jet fuel (at 1,100 gallons per flight for Boeing 727 aircraft).

8. **Environmental Impacts of a Modal Shift,"** M. William Newstrand, Marine and Intermodal Transportation: Freight Movement and Environmental Issues, Transportation Research Record No. 1333, Washington, DC, 1992, pp. 9-12.

   This study was performed to compare the results of a shift from water to either rail or truck. However, it allows a rail-truck comparison which indicates that rail vis-a-vis truck is mort fuel efficient and a safer mode.

9. Steering a New Course, Transportation, Energy, and the Environment, Deborah Gordon, Union of Concerned Scientists, Washington, DC, 1991.

   Ms. Gordon's book has a good chapter on alternative transportation fuels. She points out that our nation relies upon oil to provide almost all of our transportation energy. However, there are alternatives that would not only relieve this reliance but would also improve the environment. After some discussion concerning the evaluation measurements for alternative fuels, she discusses and evaluates the following alternative fuels: compressed natural gas, liquefied petroleum gas, propane, methanol, ethanol, reformulated gasoline, oxygenated additives, electricity (for electric vehicles), solar power, fuel cells, and hydrogen.

   No conclusive answer exists as to which fuel is the most environmentally benign and some may have as yet unknown harmful effects. Also, certain fuels may be advantageous in one region of the country but not in another. First, it must be determined what the trade-offs are for different alternative fuels before we commit to an alternative which could potentially have worse side effects than gasoline. Ms. Gordon indicates that because most alternative fuels have a relatively lower energy content than gasoline, increasing vehicle fuel efficiency is essential. Enhanced fuel efficiency will promote the feasibility and marketability of alternative fuels.

10. The Feasibility of a National Weight-Distance Tax, Report of the Secretary of Transportation to the United States Congress, pursuant to Section 933 of the Deficit Reduction Act of 1984, U.S. Department of Transportation (DOT), Washington, DC, December 1988.

    The current Federal highway user-tax structure may be inequitable, and a replacement based on vehicle weight and mileage might be more equitable. The DOT did not conclude whether or not a weight-distance tax (WDT) should be implemented, but did conclude that a WDT should be considered as a feasible alternative to the existing nonfuel taxes. A per-mile rate would provide significant improvement in equity for vehicles having different operating characteristics within the same weight group, and would possibly improve equity between weight groups as well. In addition, a weight-distance tax would serve to help protect highways from excessively heavy vehicles by providing a financial incentive to keep axle loads within design limits.

11. **"Does Free-flowing Traffic save Energy and Lower Emissions in Cities?,"** P.W.G. Newman, J.R. Kenworthy, and T.J. Lyons, Search, Vol. 19 No. 5/6, September/November 1988.

    Traffic and corridor studies from Perth are analyzed together with an international comparison of 32 cities to seek an answer to this question. This study concludes that free-flowing traffic does not lead to savings in fuel or time, or lowering of emissions in a city overall. The means of achieving these savings appear to lie in more fundamental transport and land-use planning, especially the role of urban density and how it relates to travel distances and use of other modes. This understanding can enable congestion to be used as a positive force in improving cities for many purposes, including energy and emissions considerations.

12. Special Report 220 A Look Ahead - Year 2020, Transportation Research Board, National Research Council, sponsored by U.S. DOT, Federal Highway Administration, American Association of State Highway Transportation Officials, National Association of Regional Councils, and Transportation Alternatives Group, Washington, DC, 1988.

    The section concerning energy projects that there will be a tightening of the petroleum market during this period, with the attendant rise in market power of a few producers. This will result in

higher prices and economic vulnerability, which will heighten the need for improved efficiencies and begin to generate viable markets for alternative energy sources. It is believed that concerns about environmental quality and national security are likely to be the driving forces that could begin the transition to alternative fuels.

C. COSTING/PRICING STRATEGIES:

1. **"Pondering an Energy Tax That Can't Please All the People,"** Matthew L. Wald, New York Times, January 31, 1993, p. 10.

The energy tax being considered by the Administration could reduce the budget deficit, cut oil imports and meet environmental goals. Measured in Btus, about 40 percent of the energy consumed in the U.S. comes from oil, 24 percent comes from natural gas, 23 percent from coal, 8 percent from nuclear, and 4 percent from hydroelectricity. If the tax were levied by energy content, those fuels would bear it in those proportions. Most environmentalists favor something more targeted: a tax on fuels in proportion to the amount of carbon dioxide created by their use. Among fossil fuels, natural gas produces the least carbon dioxide, oil is in the middle and coal produces the most. Hydroelectricity and nuclear power produce none; windmills and solar electric are also carbon free. Both a carbon tax and a Btu tax would dampen demand for oil, but neither would do anything for domestic oil producers. The independent oil producers have called for a fee of some kind on oil imports. Alternatively, a tax could be placed on gasoline.

2. **Methodologies For Quantifying the Emission Reduction of Transportation Control Measures**, prepared by Sierra Research, Inc. with support from JHK & Associates, prepared for San Diego Association of Governments, October 8, 1992.

This report indicates that transportation control measures are needed to help comply with environmental law. These include a variety of user taxes. Fuel taxes increase the price of fuel and directly affect vehicle operation. Tolls could alter route selection if they are applied on specific routes. Travel taxes are somewhat more flexible and could be levied on a vehicle mile traveled (VMT) basis or designed to alter peak demand, i.e., congestion pricing.

The fuel tax would have the broadest impact on travel behavior, as measured by VMT, but is dependent upon the tax assessed. Recent analyses for the Bay Area's Metropolitan Transportation Commission indicates that a $1.00/gallon tax would reduce travel roughly 4.55 percent.

3. **"Counting the Cost of Electric Vehicles,"** David Rudd, Engineering (London, England), Vol. 227, November 1987, pp. 656-7.

This article is a review of a study to quantify the advantages and disadvantages of electric vehicles (EVs). The study was organized by the European Cooperation on Scientific and Technical Research Organization, whose members are the European Economic Community (EEC) countries plus several non-EEC countries in Western Europe.

EVs offer several advantages over equivalent vehicles with internal combustion engines (ICVs). They conserve petroleum, are much quieter and do not pollute the air. In addition, they probably last longer and need less maintenance. The researchers indicated that use of about six million small EVs and one million ½-ton and 1-ton delivery vans would save 3.5% of the total petroleum consumption of the transportation sector in western Europe. The study shows that the annual resource-cost advantage of one small EV and two EV vans in the numbers stated above in each country would be as follows: a total cost advantage of £810 million/year which include environmental advantages of £1000 million/year and outweigh the disadvantages, notably those of battery cost.

IX. SAFETY

Transportation accidents claim tens of thousands of lives and injure millions of individuals per-year. It is important to quantify not only the "hard costs" but also the "soft costs," e.g. pain and suffering, lost productivity, etc., that are associated with these accidents, in order to take account of the full cost of accident exposure. By doing so, we may be able to ameliorate as much of the carnage as possible while still providing adequate transportation.

A. CAUSE/EFFECT - MEASUREMENT:

1. **Accident/Incident Bulletin, No. 160 Calendar Year 1991**, U.S. Department of Transportation, Federal Railroad Administration, Washington, DC, July 1992.

   This document is prepared from reports submitted by railroads to the Federal Railroad Administration and summarizes accidents/incidents that occurred in the United States during 1991.

   In 1991 there was a total of 25,911 accidents/incidents resulting in 1,194 deaths, of which 608 resulted from highway-rail grade-crossing accidents. Reportable accidents totaled 2,814, which resulted in damage of $222.9 million. There were 156 highway-rail incidents with total damage of $13.3 million.

2. **"Tractor-Trailers," Fatality Facts 1992**, Published by the Insurance Institute for Highway Safety, Arlington, VA, July 1992.

   The Insurance Institute for Highway Safety is an independent, nonprofit public service organization that develops ways to reduce motor vehicle losses. The data in this fact sheet is based largely on analysis of data from the U.S. Department of Transportation fatal accident reporting system. This fact sheet indicates that: 3,198 people died in tractor-trailer crashes in 1991; thirteen percent were truck occupants; the majority were in passenger vehicles; tractor-trailers accounted for less than 1 percent of registered vehicles, 5 per cent of vehicle miles traveled, and 6 percent of vehicles involved in fatal crashes in 1989; tractor-trailers have higher rates of involvement in fatal crashes (4.1 per 100 million miles traveled) than passenger vehicles (2.6). But tractor-trailers have a lower rate of involvement in crashes involving non-fatal injuries and property damage. The lower rate of non-fatal crashes associated with tractor-trailers reflects their high proportion of miles traveled on well-designed interstate highways. Only 22 percent of all passenger vehicle mileage is on interstates, while tractor-trailers put in 49 percent of their miles on interstates.

3. **"What Do Motor-Vehicle Collisions Really Cost Your Company?,"** John Castelli, Traffic Safety, May/June 1992, pp. 18-21.

   This article concerns how a major corporation, Johnson & Johnson, took steps to identify collision costs and to reduce accidents. The program attempted to get people to buy into the "soft costs," which are five times the "hard costs." The hidden costs to the company are identified as: property damage, replacement transportation, lost time on the job, worker's compensation and employee benefits, replacement labor, third-party property damage, and third-party bodily injury. Using these inputs with the cost-per-occurrence and the percent of the time that full cost is paid, an average cost-per-crash is estimated at $8,273.

4. **Accident Facts**, 1992 Edition, National Safety Council, Chicago, Illinois.

   This publication contains a wealth of data concerning all types of accidents. The 1991 estimate of 43,500 motor vehicle deaths is the lowest since 1962, and the death rate per 100,000,000 vehicle miles of travel is the lowest on record. The cost of motor vehicle accidents is estimated at $96.1 billion or 54 percent of the total cost of all types of accidents. These accidents include insured property damage from moving motor vehicle accidents. Not included are the costs for public agencies such as police and fire departments and courts, uninsured losses to employers of off-the-job accidents to employees, the value of cargo losses in commercial vehicles, and court-awarded damages in excess of direct losses.

   The cost of motor vehicle accidents of $96.1 billion is broken down as follows: wage loss - $24.5 billion, medical expense - $6.7 billion, insurance administration - $27.7 billion, motor vehicle damage - $29.0 billion, and uninsured work loss - $8.2 billion. For non-fatal injuries, estimates of actual wage losses are used; for deaths and permanent disabilities, it is the present value of all future earnings lost. An estimate of replacement cost value of household services of employed persons and homemakers is also included.

   In 1991, trucks comprised 23 percent of the registered vehicles and were involved in 31 percent of the fatal accidents. Medium/heavy trucks made up 3.7 percent of all registrations and were involved in 8 percent of fatal accidents and 3.8 percent of all accidents.

   The data concerning the types of motor vehicles involved in accidents in 1991 is not in conformity with the 1990 data, since in prior years trucks were classified by structure of vehicle. From 1991 on, they will be classified by weight.

5. **Accident Facts**, 1991 Edition, National Safety Council, Chicago, Illinois.

   In 1990, there were 46,300 motor vehicle related deaths, or 18.6 deaths per 100,000 persons. Motor vehicles are responsible for about 50 percent of all accidental deaths. The total cost associated with motor vehicle deaths for 1990 is estimated at $89.0 billion, or 51 percent of the total cost of accidental deaths ($173.8 billion).

   For 1990, truck tractors with semi or trucks with other combinations were involved in 6.6% of fatal accidents, yet they comprised only 0.8% of total vehicle registrations.

6. "**Accident Costs-Are We Using Them Correctly?**," Attachment to Motor Vehicle Accident Costs, Technical Advisory T-7570.1, A. Graham Bailey, U.S. Department of Transportation, Federal Highway Administration (FHWA), Washington, DC, June 30, 1988.

   The author starts from the premise that the selection of appropriate accident costs and proper use of these costs can have a profound influence upon the economic analysis in the prioritization and subsequent analysis of highway safety projects. The author states that the FHWA's recommended evaluation procedure for calculation of a Benefit/Cost ratio reaches unreasonable conclusions in some circumstances because of the costs assigned to fatalities.

   Mr. Bailey states that for many years there have been different accident costs developed by different governmental agencies and the National Safety Council. Recent estimates of the value of a life range from $220,000 to $3,500,000. He expresses concern that with the development and general acceptance of a significantly higher value for each fatality, it has become increasingly important to be sure that our economic analyses use these costs in such a way as not to ignore a significant number of injuries where no fatalities are evident.

7. **The Safety Effects of Mode Shifting Following Deregulation**, Kenneth D. Boyer, Professor of Economics, Michigan State University, Conference Draft, May 1987.

   This paper evaluates the effects on freight transportation safety that resulted from intermodal traffic shifts that followed the simultaneous deregulation of motor carriers and railroads in 1980.

   Professor Boyer indicates that since deregulation, traffic has shifted from the rails to trucks. He indicates that railroads are much safer than motor carriers and have experienced a dramatically declining accident rate since deregulation. This shift from the safer mode to the less safe mode is estimated to have increased freight transportation deaths by more than 29 per year, injuries by more than 349 per year, and accidents by more than 337 per year.

B. MITIGATION STRATEGIES:

1. **Benefit/Cost Analysis of Lane Marking**, Ted R. Miller, Urban Institute, Washington, DC, December 1991.

   The author analyzed the costs and benefits of "long-line" pavement markings-edgelines, centerlines, and skiplines between lanes. He examined the link between pavement markings and both reduction in crashes and increases in safety benefits; travel time saved; and cost-effectiveness of the two most common marking mediums. Miller estimates that each dollar spent on pavement markings produces a $56 savings in lives and reduced congestion. The cost-benefit ratio generally rises with traffic volume, and the urban ratio is almost triple the rural ratio.

2. **"Characteristics of Accidents and Incidents in Highway Transportation of Hazardous Materials,"** Douglas W. Harwood, Eugene R. Russell, and John G. Viner, Transportation Research Record No. 1245, Transportation of Hazardous Materials, Washington, DC, 1989, pp. 23-33.

   Existing accident and incident data bases provide insight into the nature of the safety risks involved in hazardous materials transportation by highways. This study analyzes data from the U.S. Department of Transportation Research and Special Programs Administration, Hazardous Materials Incident Reporting System, the Federal Highway Administration Motor Carrier Accident Reports and the Missouri Statewide Accident Reporting System. This paper focuses on the predominant role of traffic accidents as a cause of severe hazardous material incidents. Existing traffic accident data is used to determine the probability of a hazardous materials release, given an accident involving a hazardous materials-carrying vehicle.

   This study focuses on highway hazardous materials (hazmat) transport, since the highways account for 85 percent of the hazmat releases reported to federal agencies. This analysis shows the preponderant role of traffic accidents as a cause of severe hazmat incidents. Between 35 and 68 percent of severe hazmat incidents are caused by traffic accidents, depending on the definition chosen for a severe incident. Also, about 99 percent of all fatalities and injuries in accidents involving trucks carrying hazardous materials result from physical condition of the equipment, rather than the hazardous materials being transported.

C. COSTING/PRICING STRATEGIES:

1. **"This California Dream Is All About Auto Insurance,"** New York Times, Peter Passell, March 1993.

   Some Democratic politicians in California are pressing for radical changes in how motorists pay for auto insurance and collect for injuries - changes they believe would slash consumer costs and improve the quality of insurance. Their plan, called "pay at the pump," would use a surcharge on gasoline to cover the cost of auto accidents by charging a price based upon the driver's safety record. There is opposition from various groups over a number of concerns. Consumer groups are divided over the right to sue; trial lawyers have historically had problems with no-fault plans, and insurance agents could be adversely affected by such a plan. On the other hand, environmentalists are attracted to the idea as a way to cut pollution and congestion. Because driving more would raise insurance costs, consumers would be encouraged to drive less.

2. **The Going Rate: What it Really Costs To Drive**, James J. MacKenzie, Roger C. Dower, and Donald D.T. Chen, World Resources Institute, Washington, DC, June 1992.

   This report explores the full costs of a transportation system dominated by private motor vehicles. The authors calculate that the full costs of driving, if added up at the gas pump, could raise the price of gasoline by several dollars a gallon. All told, the costs of driving that motorists and truckers do not shoulder come to some $300 billion a year, say the authors. This estimate does not include other incalculable losses such as 47,000 people killed in motor vehicle accidents - about one in five while walking or riding a bicycle - in the most recent year for which statistics are available. There are also security costs of importing oil.

   Also cited is a June 1991 study by the Urban Institute for FHWA, which indicates that the total social costs resulting from motor vehicle accidents amounted to $358 billion. By far, the largest cost category was pain, suffering, and lost quality of life - a total of $228 billion, estimated on the basis of the willingness of accident victims to pay to reduce the risks of such effects.

   It is only fair that those who enjoy the benefits of motor vehicle use should pay the costs of that direct use. But no single mechanism appears best for charging for now-hidden costs of driving. It would be ideal if a price could be applied at the actual time and place that the cost is incurred, a pay-as-you-go approach. Some costs could be included in the existing gasoline tax structure, or incorporated into a user fee or insurance premiums. While the report does not evaluate in detail alternative methods for allocating the costs of driving, it does discuss the following alternatives: increased fuel taxes; charging for car insurance at the pump, increased taxes on trucks; parking and tax reform, tolls and time-of-day pricing of roadways.

3. **"Financing High Speed Rail and Maglev Systems in Europe Japan and the United States: Implications for Systems Financing in Florida,"** prepared by Dr. Thomas A. Lynch, Director, Center for Economic Forecasting and Analysis, Florida State University, Tallahassee, Florida in cooperation with the Center For Urban Transportation Research (CUTR), University of South Florida, for the Florida Department of Transportation, January 12, 1992.

   The Swedish National Road Administration has been developing and refining a benefit-cost road planning model similar to that in place in the U.S. This report discusses the Swedish approach and the need to include environmental externalities in the development of transportation systems. The Swedish model values several externality effects in monetary terms. The area of traffic safety includes the following social benefit measurements: loss in production, medical treatment and hospital care, administrative costs, and property damage. Explicit valuation of non-material effects

or human values include the value of life expressed as the risk (or change in risk) of being involved in a traffic accident, not the valuation of life itself. Also, factored into all transportation decision making in Sweden are the externalities of environmental effects.

As an example, the cost value or risk of road accidents in 1990 equivalent dollars is as follows: total social costs for road accidents are now valued at $4.2 billion, where $2.25 billion are evaluated as external costs. The report refers to Hansson who distinguishes between three different methods of evaluating environmental external economic effects: financial costs, such as loss in productivity; costs of compensatory measures; and quantifying environmental effects in monetary terms. Studies in France, Luxembourg, Belgium, and Germany show socioeconomic costs amount to 2.5 percent of GNP for road accidents.

4. **The Costs of Highway Crashes**, Final Report. August 1985-May 1991, McLean, VA, T. Miller, J. Viner, S. Rossman, N. Pindus, and W. Gallert, performed by The Urban Institute, funded by U.S. Department of Transportation, Federal Highway Administration, Washington, DC, October 1991.

This report summarizes the results of a research study on the comprehensive costs of highway crashes. The primary data bases used in this study come from the Fatal Accident Reporting System and the National Accident Sampling System of the National Highway Traffic Safety Administration, and the National Council on Compensation Insurance. The report is intended for highway engineers who are responsible for economic analyses of alternative highway safety improvements and/or new highway design.

In 1988, an estimated 14.8 million motor vehicle crashes involved 47,000 deaths and almost 5 million injuries. More than 4.8 million years of life and functioning were lost. Crash costs totaled $334 billion. They included $71 billion in out-of-pocket costs, $46 billion in wages and household production, and $217 billion in pain, suffering, and lost quality of life. Half of the out-of-pocket costs were property damage costs, the rest were medical, emergency services, work place, travel delay, legal, and administrative costs. Employers paid 21 percent of the out-of-pocket and productivity costs, the general public paid 48 percent, and the people involved in crashes and their families paid the remaining 31 percent, plus they suffered the pain.

There are three measures of crash costs: years lost, plus out-of-pocket or direct costs; comprehensive or willingness to pay; and human capital. Only the first two methods yield conceptually sound values for use in resource allocation. The comprehensive method yields a comprehensive value that includes the dollar cost, the lost income, and the costs of pain, suffering and lost quality of life. The comprehensive method values life by estimating risk reduction values, the amount people are willing to pay for small decreases in safety and health risk. The authors state that the comprehensive life and injury values are the preferred valuation method for benefit-cost and regulatory analysis. The weakness of the comprehensive method is that it assumes that people make rational decisions about health and safety. This report pioneers a method to overcome another weakness, the difficulty of measuring consistent values for different injuries. The method relies on the estimates of functional years lost from the years lost approach.

Comprehensive costs are presented by the authors for use in benefit-cost analyses. The report includes costs by type of injury and crash. Following are crash costs: per fatal crash - $2.7 million, per incapacitating crash - $229,000, per non-incapacitating crash - $48,000, per possible injury crash - $25,000, per property damage only (these crashes include injuries missed by police) - $4,500, and per unreported crash - $4,100.

This report discusses costs by nature and number of vehicles and non-occupants involved. This analysis revealed the following. The most costly kinds of crashes include motorcycle, pedestrian, pedalcycle, alcohol-involved, and heavy truck. Minor rural collectors, local rural streets, and

urban arterials are the most dangerous/vehicle-miles of travel (VMT). Motorcycles have safety costs of $2.14/VMT, buses $0.24/VMT, heavy trucks $0.19/VMT, light trucks $0.16/VMT, and cars $0.12/VMT. In nonfatal collisions involving only occupants, the most harmful events with the highest cost/injury involve, in order: trees, overturns, other fixed objects, and utility poles.

5. **Injury Control, Position Papers from The Third National Injury Control Conference, "Setting the National Agenda for Injury Control in the 1990s," April 22-25, 1991, Denver, CO.**, U.S. Department of Health & Human Services, in conjunction with the National Institute for Occupational Safety and Health and U.S. Department of Transportation, National Highway Traffic Safety Administration, National Academy Press, Washington, DC, 1985.

   Many injuries associated with motor vehicle crashes are preventable. In 1985, motor vehicle crashes cost our nation more than $75 billion. By 1991, this sum had increased considerably because of increases in the number of crash injuries and fatalities, increases in medical treatment and vehicle repair, and a rise in the general price levels.

   While there is a significant effect on our economy as a result of these crashes, the authors' desire to reduce the mortality and morbidity associated with these crashes because of the human tragedy that they represent - 45,000 persons killed each year on our roads with more than 60% of the victims under 35 years of age. In addition, crashes are responsible for 500,000 hospitalizations and 4.8 million non-hospitalized injuries annually.

   Worldwide, there are about 500 million cars and commercial vehicles in use, and more than half a million people die each year in motor vehicle crashes. In the U.S., motor vehicles crashes have killed 2.8 million people since 1900, more than twice the number of Americans killed in all wars since 1775.

   The economic impact of crash-related injuries is often overlooked. The economic cost to our nation of $75 billion breaks down as follows: injury-related costs were $48 billion, of which $12 billion were for direct medical and rehabilitation costs, $19 billion for indirect productivity cost associated with morbidity, and $17 billion for indirect productivity costs associated with mortality. This publication touches on the many aspects that are responsible for motor vehicle crashes, e.g. vehicle standards, road conditions, human behavior and risk factors, age, size, lack of awareness, etc. In addition, to identifying many possible causes, the authors provide many suggestions which could help to reduce crashes.

6. **"Crash Costs and Safety Policy,"** Accident Analysis and Investment, Ted R. Miller, Stephen Luchter, and C. Philip Brinkman, Vol. 21, No. 4, August 1989, pp. 303-316.

   The authors point out that economic analyses of highway safety traditionally has been based on the costs of crashes to society and that rational safety investment levels should reflect what people routinely pay for small increases in their safety and health. These values substantially exceed costs. This paper presents new data on both the costs of motor vehicle crashes and the amount the public rationally should invest to reduce crashes and injuries. Estimates are presented by injury severity, along with more detailed estimates of the costs and investment levels for severe head and spinal cord injuries.

   Monetary costs can be divided into five major categories: property damage; medical care; losses in household and work place productivity; police, fire, and ambulance services; and other administrative and legal activities. This paper presents the costs-per-crash and the total costs for 1986, describes the source and magnitude of the costs by category, and derives costs that the

authors believe more accurately reflect the costs that should be used as a basis for benefit-cost analysis.

Injury crashes cost society more than $38 billion annually. Expending up to $2.3 million to prevent one fatal crash appears to be rational public policy, although the crash costs society only $500,000. Prevention of severe, non-fatal head and spinal cord injuries warrants even larger expenditures. The estimated rational investment to prevent an average non-fatal injury crash is $22,000, while society's cost is $8,000. Rational investment levels for increased safety are estimated by summing the amount individuals typically pay for small increases in their safety and the cost the rest of society bears when someone is killed or injured, including transfer payments.

7. **Cost of Injury in the United States, A Report to Congress, 1989**, Dorothy P. Rice, Ellen J. MacKenzie and Associates, produced by Institute for Health & Aging, University of California, San Francisco, and Injury Prevention Center, School of Hygiene and Public Health, Johns Hopkins University, for National Highway Traffic Safety Administration, U.S. Department of Transportation, and Center for Disease Control, U.S. Department of Health and Human Services, 1989.

This report is the third in a series focusing attention on injury as a critical public health issue. This report recognizes that injury is costly to the nation in productive life years lost due to premature death and long term disability; in medical resources used for care, treatment, and rehabilitation of injured persons; and in pain and suffering of the injured persons, their families and friends.

The greatest economic losses are caused by motor vehicles, accounting for $49 billion, or 31% of the $158 billion lifetime cost for the 57 million persons injured in 1985. This economic cost does not take into account the cost associated with pain, suffering, and reduced quality of life. Motor vehicle crashes are the leading cause of injury death, resulting in 45,923 deaths, or 32% of total fatalities in 1985. They also comprise the second leading cause of both injury hospitalizations (523,028, or 22%) and less severe, non-hospitalized injuries (4.8 million or 9%).

The average cost-per-person injured by a motor vehicle is $9,062. The average cost-per-fatal motor vehicle injury is $352,042; for a hospitalized person, $43,409; and for a injured non-hospitalized person, $1,570.

The total economic costs are divided into: direct costs (29%), morbidity costs (the value of goods and services not produced because of injury-related illness and disability) (41%), and mortality costs (30%). Of the total $44.8 billion of the direct cost of injuries, $41.7 billion is distributed by source of payment. The remaining $3.1 billion includes amounts spent for ambulance, helicopter, attendant care, and other expenses, for which source of payment data is not available. About 72% of these direct costs is borne by private sources (private health insurance, workers' compensation, uninsured care, and other private sources); public sources (federal, state, and local governments) account for 28%.

The morbidity cost totaled $64.9 billion. Losses for persons injured and disabled in 1985 amount to 5.1 million life-years, or 9 life-years lost per-100 injured persons.

The mortality cost is derived by applying expected lifetime earnings by sex and age to the 155,665 deaths, including deaths in years subsequent to the initial injury. This results in a loss of 5.3 million life years, or 34 years per death. These deaths represent a cost of $47.9 billion to the economy at a six percent discount rate, or $307,636 per death.

Transfer payments, which represent a transfer of funds from one payer to another and do not represent new goods or services produced, amounted to $52.6 billion for 1985 excluding lost taxes. Auto insurance paid $22.9 billion or 44 percent of all transfer payments.

The above economic costs were determined by the human capital approach, which measures the value of lost output due to reduced productivity of the individuals killed, injured, or disabled. There is another method of calculating costs, willingness to pay, which reflects the value placed on health and life by individuals, and measures how much people are willing to pay for a safer and healthier life. This method incorporates the value of pain and suffering and loss of quality of life associated with injury.

Based on studies, the willingness to pay method indicates that the expenditures to save one life range from $1.0 million to $3.1 million, with a mean of $1.95 million. Estimates to avoid moderate to critical injuries range from $31,000 to $1.5 million, and estimates to avoid severe head injuries involving total impairment, quadriplegia, or very severe burns range from $2.6 million to $3.2 million.

A very small amount of research funding is being allocated to injury. Comparison of federal research expenditures for FY 1987 indicate that injury research spending ($160 million) amounts to 11 percent of the National Cancer Institute obligations, and 17 percent of the National Heart, Lung, and Blood Institute obligations.

The number of severe injuries could be substantially reduced by greater application of current knowledge. The potential savings, net of the cost of injury control programs, are in the billions of dollars for interventions for which data is available.

8. **Efficient Highway User Charges -- Appendix E to the Final Report on the Federal Highway Cost Allocation Study**, Douglass Lee, U.S. Department of Transportation, Transportation System Center, Cambridge, MA, May 1982.

Because the accident is, in part, a random event, the price is based on expected values rather than actual accidents. As long as the level of traffic is high enough to permit the possibility of two or more vehicles having an accident, some kind of charge is applicable, even though there is no detectable delay or increased operating cost. The marginal cost for each vehicle is the total expected cost of accidents, not just a portion, and each vehicle added to the traffic stream increases the probability of accident. The functional relationship between traffic volumes and accidents is separate from the expected cost per accident, i.e. $/VMT = $/accident x accidents/VMT.

X. CONGESTION

Congestion in both ground and air travel has become commonplace in recent years and will likely become more problematic in the future. Consequently, the causes, measurement, impact assessment and damage costing have received considerable attention from the public, government, and the transportation community. Many pricing and other abatement/mitigation strategies have been suggested and some have been implemented with varying degrees of success. One general consensus that has emerged from transportation and planning experts is that the solution to congestion ills cannot be solved merely by ever expanding the infrastructure. While new technologies will offer some relief, strategies must be developed to better manage and utilize the existing systems.

A. CAUSE/EFFECT - MEASUREMENT:

1. **"The Commuting Paradox: Evidence from the Top Twenty,"** Peter Gordon, Harry Richardson, and Myung-Jin Jun, Journal of the American Planning Association, Vol. 57, No. 4, Autumn 1991.

   It is generally assumed that traffic congestion is indeed getting worse. Consequently, if the proportions in the work trip origin-destination matrix remain the same, then inevitably travel times must become longer. However, a comparison of auto commuting trip durations from the 1985 American Housing Survey to data from the 1980 census for the twenty largest metropolitan areas suggests that during the study period average trip times either fell by a significant amount or remained the same.

   Therefore, a paradox may exist in the widespread reports of congestion in spite of stable average trip durations. The authors suggest that perhaps average commute times are contained by the location adjustments that households and businesses make due to perceived congestion. As such, these spontaneous relocation decisions of firms and households do a very nice job of achieving balance and keeping commuting times within tolerable limits without costly planning interventions.

   In the authors view, the data indicates that the increasing emphasis on congestion doomsday scenarios is overblown. They suggest that the appropriate role for planning agencies and local jurisdictions should be to facilitate the decentralization of jobs. This could be accomplished by: relaxing zoning restrictions that limit commercial land uses in residential communities; assisting in land assembly; providing economic infrastructure; and discouraging growth control initiatives.

2. **Winds of Change: Domestic Air Transport Since Deregulation**, Special Report 230, Transportation Research Board (TRB), National Research Council, Washington, DC, 1991.

   Beginning in 1975, administrative reforms of the Civil Aeronautics Board gave carriers greater freedom in discounting prices and serving new markets. The Airline Deregulation Act of 1978 removed restrictions on entry, pricing, and routes. One of the areas the TRB committee examined was airport and airway capacity, including airport congestion.

   For the hub-and-spoke system to work with a minimum of passenger time lost during connections, numerous flights must arrive and depart in a relatively short period of time, creating congestion at hub centers. Airport runway capacity is not a fixed value. It varies with changes in weather and visibility, the combinations of runways in use, the mix of aircraft using the airport, the timing of arrivals and departures, and air traffic control (ATC) rules, procedures, and safety precautions. Estimates of delay provide a proxy for the extent to which demand is approaching capacity. Delay, however, can result from numerous causes, including bad weather.

On the basis of the Federal government's estimates of demand and supply, delays can only be expected to worsen at many airports in the years ahead. The Federal Aviation Administration projects that the number of arrivals and departures by major commercial domestic carriers will increase by one third between 1988 and 2000. Expansion of major airports is unlikely in some cases because of limited space, but in most cases because of community opposition to noise. Given the difficulty of expanding supply at congested airports, more emphasis will be needed on finding ways to use existing airports more efficiently and encouraging use of currently underused airports with excess capacity. Modification of ATC procedures, replacement of outmoded ATC technology, systems approach to demand management, and marketplace strategies - congestion pricing - to encourage greater efficiency are discussed.

Recommendations for expansion and better use of airport and airway capacity are made. "Congestion pricing of runways could reduce congestion, encourage the use of underused airports, and provide additional revenues for enhancing capacity." TRB recommends experimentation with congestion pricing and evaluation of this by independent researchers and research on simulation modeling of airport and airspace capacity so as to manage capacity more effectively.

3. **Traffic Congestion: Federal Efforts to Improve Mobility**, Report to the Chairman, Subcommittee on Transportation and Related Agencies, Committee on Appropriations, U.S. Senate, U.S. General Accounting Office, Washington, DC, December 1989.

   The General Accounting Office (GAO) presents a comprehensive view of the U.S. Department of Transportation's (DOT) efforts to reduce highway traffic congestion. GAO suggests that DOT's efforts could be categorized under three strategies: 1) road construction and reconstruction; 2) transportation systems management; and 3) advanced technology. Of these strategies, the bulk of the funds are being devoted to road construction and reconstruction. GAO suggests that the DOT Secretary set forth guidance and establish appropriate effectiveness evaluation mechanisms to ensure a coordinated Federal strategy toward improving highway mobility.

4. **Traffic Congestion, Trends, Measures, and Effects**, Report to the Chairman, Subcommittee on Transportation and Related Agencies, Committee on Appropriations, U.S. Senate, U.S. General Accounting Office, Washington, DC, November 1989.

   In this overview of the traffic congestion problem, the General Accounting Office (GAO) found there has been little empirical investigation into the effects of traffic congestion. However, certain relationships are thought to hold, including those between congestion and higher business costs, poorer air quality, and behavior change. GAO suggests that while the Federal Highway Administration is taking aggressive steps to assess the present and future magnitude of traffic congestion, additional attention to this area is warranted.

   GAO identified six forces that shape traffic congestion: 1) suburban development trends (movement of families, services and jobs away from the central city and into suburban areas); 2) economic trends (changes in the employment base away from manufacturing and towards services, changes in communication technology, increases in the amount of discretionary travel, etc.); 3) labor force trends (the overall growth in the labor force and women entering the workplace); 4) automobile use trends (growing automobile availability and use); 5) truck traffic trends (greater use of trucks, increases in truck size and weight, and increasing numbers of heavy truck accidents); and 6) highway infrastructure trends (increasing traffic without a corresponding increase in infrastructure capacity). GAO indicates that it is unclear how much truck-related delays contribute to the overall traffic congestion problem. However, heavy trucks have increased in number and size thus occupying more road space and taking longer to accelerate/decelerate. This has added to recurring congestion problems.

5. **Efficient Highway User Charges -- Appendix E to the Final Report on the Federal Highway Cost Allocation Study**, Douglass Lee, U.S. DOT Transportation Systems Center, Cambridge, MA, May 1982.

   The major component of the increase in congestion cost is excess travel time or delay. Using traffic engineering relationships, average travel time curves can be constructed from different road types. Traffic engineers have accumulated a large amount of structural information about vehicle flows and road capacities, but the information is not so robust that it leads to a unique mathematical relationship between volume and delay on a given facility. The estimation procedure is as follows: 1) estimate vehicle volumes of traffic, 2) convert estimates into passenger car equivalents (PCE) volumes, 3) estimate PCE distribution by congestion levels, and 4) construct volume-delay curve.

B. MITIGATION STRATEGIES:

1. **Traffic Congestion: Activities to Reduce Travel Demand and Air Pollution Are Not Widely Implemented**, Report to the Chairman, Subcommittee on Transportation and Related Agencies, Committee on Appropriations, U.S. Senate, U.S. General Accounting Office, Washington, DC, November 1992.

   The report presents the General Accounting Office's (GAO) review of the Federal effort to promote more efficient management of the highway system through transportation systems management (TSM) techniques. TSM can be characterized as either supply or demand management, embracing a variety of low-cost approaches designed to maximize roadway efficiency or lower roadway demand for the purpose of meeting air quality goals. Supply management includes traffic signal synchronization and accident management/motorist aid programs, while demand management includes ridesharing and high occupancy vehicle lanes. GAO investigated the Federal TSM planning efforts through a survey of 119 metropolitan planning organizations (MPOs) and on-site visits to three metropolitan areas.

   GAO reports that most MPOs (97%) included TSM activities in their plans and generally placed greater emphasis on supply (49%) as opposed to demand (17%) activities. MPOs including demand activities were generally those in areas where the population exceeded 1 million. Demand management activities were accorded a lower priority for a variety of reasons. The two most frequently mentioned were lack of funding and/or local officials unwilling to discourage single-occupancy vehicle (SOV) ridership.

   GAO notes that planning TSM measures did not guarantee their implementation, and this was particularly true of demand management activities. Only 13 percent of all MPOs reporting indicated placing at least moderate emphasis on implementation of demand management activities, while 54 percent indicated placing the same level of emphasis on supply management techniques. According to some MPOs, demand management activities are difficult to market because they involve changing commuter behavior.

   Most MPOs (70%) indicated that air quality concerns were not integrated into the transportation planning process. In fact, only 15 percent of MPOs with severe ozone pollution indicated that air quality concerns played a major role in transportation planning and implementation decisions.

   GAO concludes that demand management activities have been given relatively little emphasis in both local transportation planning and implementation. Furthermore, until the 1990 Clean Air Legislation was enacted, there was little joint air quality and transportation planning other than in a few very large metropolitan areas. GAO recommends that Federal policy and practices need to foster local planning and implementation of these activities.

2. **"Lessons for Transportation Demand Management from Utility Industry Demand-Side Management,"** Ruth L. Steiner, Transportation Research Record No. 1346, Highway Operations, Capacity, and Traffic Control, Transportation Demand Management, Washington, DC, 1992.

   Electric utility demand-side management (DSM) is compared with transportation demand management (TDM) to make recommendations about the implementation of TDM. The regulatory environment of these two sectors and the types of demand-side measures are described. The demand management strategies can be summarized in three categories based on how they reduce demand: a) load management strategies attempt to decrease the variation in the level of activity, b) trade-offs in the quality of service reduce reliability in exchange for other benefits such as less congestion, and c) strategic demand reduction occurs through measures affecting trip generation and mode choice for transportation activities. The conclusions reached about TDM based on DSM are: a) congestion pricing gives proper price signals to move people out of automobiles; b) many people hope for a technological fix for poor air quality and transportation congestion; c) for TDM efforts to be meaningful, they need to be implemented in a whole region and simultaneously address the multiple reasons for their implementation: air quality, congestion, energy, and land use.

3. **"Research Needs for Analyzing the Impacts of Transportation Options on Urban Form and the Environment,"** Daniel Brand, Transportation, Urban Form, and the Environment, Proceedings of a Conference, Special Report 231, Beckman Center, Irvine, CA, December 9 - 12, 1990.

   The paper describes the increasing costs of urban congestion because of individuals who make travel decisions without confronting the full costs of their individual choice behavior. Thirty-three percent more trips per person were taken in 1983 than in 1969.

   There are options for maintaining urban mobility in the future that will ensure the efficiency of future urban transportation systems. The options fall into six categories: 1) travel information - advanced traveler information systems allow people to make informed choices; 2) information for managing system operation and travel behavior; 3) capacity increases; 4) new technology - higher speeds and closer vehicle spacings; 5) pricing; and 6) telecommunications and regulation - trip elimination.

4. **"Suburban Congestion: Recommendations for Transportation and Land Use Responses,"** Thomas F. Humphrey, Transportation, Vol. 16, 1990.

   Transportation congestion is reaching intolerable levels in many urban and suburban areas in the U.S. Reliance on traditional responses, such as transit and new highway capacity, is not solving the problem. There are a number of alternatives that must be considered in developing solutions and numerous examples of both short and long term solutions are given.

   There are a number of possibilities available, particularly for the short run. Transportation actions can be taken where there are opportunities for getting more out of the existing systems. Land use/growth management actions, which will result in more rational land use-transportation interactions, could be employed. Financial incentives to encourage or discourage appropriate actions can be implemented. More comprehensive and systematic land use and transportation planning can also be encouraged.

   However, to deal with congestion in the long run, other actions may have to be considered. Changes in land use development and management policies are needed as are changes in lifestyle and business practices. Improvements through technological innovation are possible as are changes

in the traditional ways of providing transportation services. Expanded research and development will also be needed.

5. **Evaluation of Travel Demand Management Measures to Relieve Congestion**, prepared for the Federal Highway Administration by COMSIS Corporation, reprinted by the Research and Special Programs Administration, Report Number DOT-T-90-14, Washington, D.C., 1990.

   The report summarizes the results of a research study to investigate the effectiveness of Travel Demand Management (TDM) programs. This investigation consisted of the evaluation of a number of existing TDM programs located throughout the United States. The programs, many of which are well known, are primarily employer-sponsored and site specific. These programs are varied in size, setting, motivation, and accomplishments. Some additional programs are featured that present TDM in a central business district environment and in freeway corridors. Together, all the TDM programs presented comprise a fairly representative cross section of contemporary experience with TDM.

   The study directly measured the quantitative impact of the TDM programs on reducing low-occupancy vehicles trips. The approach was to evaluate each program as a separate case study, using the same set of evaluations tools and guidelines. Vehicle volumes and mode choice evaluations of the programs were prepared whenever data was available. Comparisons were made and inferences drawn between sites that do have a TDM program and those sites that do not. The report presents these case studies as well as overall conclusions on the impact that TDM has on reducing the number of low-occupancy vehicle trips.

   Guidance materials to assist the public and private sectors with implementing TDM programs are being prepared and will be ready for publication this summer (1993).

6. **Airport System Capacity, Strategic Choices**, Special Report 226, Transportation Research Board, National Research Council, Washington, DC, 1990.

   The report indicates that growth in air transportation is outstripping the capacity of the airport and air traffic control system, resulting in congestion and delays. In 1987, congestion and delays at 21 major airports amounted to more than 20 thousand hours in flight delays and this is expected to increase to between 50 and 100 thousand hours by the year 2000. These delays have many causes, including adverse weather (the single largest cause), air traffic control separation requirements, and flight scheduling. The hub and spoke operational system also can contribute to the congestion problem. Traffic peaking occurs as flights from several origins are scheduled to arrive at, and depart from, a single intermediate airport within a short span of time. This peaking is necessary so that passengers can make connections and continue to their destinations. However, traffic peaking can increase delays and, in bad weather, can result in extreme delays and affect other network airports hundreds of miles away from the problem.

   Only two methods are available for attacking airport delay problems, increased capacity or managed demand. These methods give rise to several options, including: airport infrastructure improvements; demand management techniques; and new aviation and high-speed ground transportation technologies. These strategies can be used singly or in combination to solve the congestion problem.

   Construction of entirely new facilities is discounted since, in the last twenty years, only two completely new airports have been built (Dallas-Ft. Worth and Southwest Florida Regional) with one more (Denver) nearing completion. It appears unlikely that any more will be built soon. Incremental capacity improvements appear more feasible. These include physical changes such as

new runways/taxiways and changes in the air traffic control system. New hubs could be created at presently underused airports to spread peak loads over more locations. The development of new airports could be dedicated as transfer points. This would shift connecting traffic away from major cities.

Demand management options emphasize managing how system components are utilized. The strategies include use of administrative and regulatory techniques and economic measures (pricing). The new aviation and high-speed ground transportation technologies include new aircraft, air traffic control systems, high-speed rail, magnetically levitated trains, or advanced superhighways. The surface transportation strategy is seen as an alternative to air trips of up to 500 miles if speeds of 150 to 200 mph could be attained.

The "best" solution must be made after considering technology, social, economic, and political inputs. Overall, the recommendations included in the report center on planning, setting future goals, making incremental capacity improvements at existing airports, and expanded research and development efforts. This would include improved airport and aircraft design, improved real-time management of airspace and airports, and advanced ground transportation systems.

7. **"Jobs-Housing Balance and Regional Mobility,"** Robert Cervero, Journal of the American Planning Association, Vol. 55, No. 2, Spring 1989, pp. 136-150.

Cervero discusses a variety of reasons for the increase in the distance suburban dwellers travel to work. His data indicates that for 40 major suburban employment centers where a severe job-housing imbalance exists, high levels of congestion occur on connecting freeways, and there is a low share of workers making walking and cycling trips. His findings indicate that major connecting freeways tend to be most congested around suburban centers with large amounts of office-commercial space, high employment densities, and large jobs-housing imbalances. He suggests that improving the jobs-housing balance can provide at least some level of congestion relief.

One method for improving the jobs-housing balance is to increase the cost of transportation via higher fuel prices (using a fuel tax), tolls, and parking fees, either singly or in some combination. The fuel tax increase could be funneled into improved public transit or affordable housing to offset the disadvantage to lower income groups. He suggests that it is no coincidence that European nations with high fuel taxes also have a jobs-housing balance, limited sprawl and heavily patronized transit services.

C. COSTING/PRICING STRATEGIES:

1. **Searching for Solutions, A Policy Discussion Series: Examining Congestion Pricing Implementation Issues**, Federal Highway Administration (FHWA), U.S. Department of Transportation, Number 6, Washington, DC, December 1992.

The report summarizes the results of a symposium on congestion pricing implementation issues sponsored by the FHWA on June 10-12, 1992. The symposium was designed to move the discussion of congestion pricing from the academic tone of scholarly discourse to a more practical exchange of ideas about the problems and prospects for real world demonstrations of congestion pricing concepts.

Congestion pricing has been proposed as a "market-responsive" alternative to more prescriptive command-and-control "demand-management" regulations. Despite its widespread acceptance among economists, congestion pricing has not really entered the public domain as an instrument of transportation policy. This lack of public acceptance may result from the failure of transportation

professionals to clearly articulate the objectives and the likely effectiveness and distributional consequences of congestion pricing, or it may be that not enough is known about the consequences of congestion pricing to convince people that "win-win solutions" exist. Consequently, symposium participants selected the problem of selling the concept of congestion pricing to the public as the most critical issue to be addressed in implementing congestion pricing projects.

Another key issue was the need to understand and address the question of who wins and loses as a result of congestion pricing. The use of congestion pricing revenues to compensate those who may be adversely affected was seen by many symposium participants as an important consideration.

2. **Economic Fundamentals of Road Pricing - A Diagrammatic Analysis**, Timothy D. Hau,Transport Division, Infrastructure and Urban Development Department, The World Bank, Washington, DC, December 1992.

   The author's analysis of traditional arguments about road pricing shows why implementing congestion pricing as practiced in the past has encountered obstacles. Partly, it is because both types of road users - the tolled and the tolled off (those who avoid the road to shun a toll) - are shown to be worse off under a constant value of time. ...Unless congestion tolls revenues are earmarked and travelers perceive that the money is channeled back in reduced taxes, lower user charges, or improved transport services, neither the tolled or the tolled off will support road pricing. Only where there is hypercongestion is everyone better off with congestion pricing. He recommends setting up a transportation fund (or road fund) and pursuing marginal pricing in all its dimensions as a way to satisfy World Bank general guidelines to implement efficiency pricing, meet economic viability, meet (to a considerable extent) financial viability, achieve (to some degree) fairness among beneficiaries, and attain (somewhat) managerial efficiency of the public authority.

3. **Congestion Charging Mechanisms for Roads, An Evaluation of Current Practice**, Timothy D. Hau, Transport Division, Infrastructure and Urban Development Department, The World Bank, Washington, DC, December 1992.

   This paper explores 20 criteria for a "good" road pricing system and presents case studies illustrating the costs, revenues, and benefits of alternative congestion charging mechanisms.

   Hau argues that electronic approaches to direct road use charging are superior to manual approaches for road users, road authorities, and society as a whole. He points out that rapid progress in microelectronics, cryptology, and microwave technologies will continue to yield large-scale economies in the manufacturing of automatic vehicle identification (AVI) equipment, read-write transponders, smart cards, and the hardware and software that go with them.

   He ranks electronic road pricing by time of day with AVI (an off-vehicle recording system) alone higher than electronic road pricing with smart card-type AVI, based on an unweighted index of all criteria. He finds the area licensing scheme, whereby vehicles entering the central business district during peak hours are required to prominently display a monthly or daily license, superior to cordon pricing. An important criteria from society's point of view is that the toll-tax incidence of the road pricing system be publicly perceived as fair for it to be politically acceptable. He maintains that unless toll revenues are plowed back into the transport system in the form of a) a reduction in first registration taxes, annual license fees, or fuel taxes, etc., b) more and better roads, and/or c) improved public transportation, it is inconceivable that congestion pricing would take off.

4. **Green Fees: How a Tax Shift Can Work for the Environment and the Economy**, Robert Repetto, Roger Dower, Robin Jenkins, Jacqueline Geoghegan, World Resources Institute, Washington, DC, November 1992.

   The authors suggest that charges (taxes) on environmentally damaging activities such as air pollution and traffic congestion can generate tax revenues in such a way as not to depress the economy. They argue that "green fees" substituted for some existing taxes would produce a cleaner environment while reducing the economic disincentives of the current tax system. Such fees could shift some of the tax burden from actions we should encourage (working and investing) onto activities we should discourage (pollution, inefficiency and waste). Green fees would be more efficient than regulations and could raise tens of billions in revenues.

   The authors suggest such green fees as rush-hour tolls and carbon taxes would reduce congestion and consumption and encourage energy efficiency. In their analysis, they estimate that the U.S. could generate $100 billion to $200 billion from all types of green fees while cutting pollution and waste. Of this, they estimate that congestion tolls on urban highways could yield $40 billion to $100 billion. Additionally, congestion tolls could save $50 billion in future construction outlays for highway expansion by arresting urban traffic deterioration.

   Traffic congestion affects nearly 70% of the nation's rush hour traffic, and, in L.A., congestion produced time delay and excess fuel consumption costs are estimated to be $6 billion (1986). If the congestion tolls were set to recover all costs, tolls would average $.36 per mile and, using 1989 estimates, produce welfare gains of $10.8 billion.

5. **"Congestion Pricing: Its Promise and Its Limitations,"** C. Kenneth Orski, Urban Mobility Corporation, in Transportation Planning, American Planning Association's Transportation Planning Division Newsletter, Summer 1991.

   This article discusses the growing support for testing congestion pricing. Credit is given to the U.S. Department of Transportation's 1990 National Transportation Policy and two reports, one by the Bay Area Economic Forum - Market Solutions to the Transportation Crisis, and a United Kingdom report - Paying for Progress - for refocusing on congestion pricing opportunities and issues. The article identifies major obstacles to implementation.

6. **Searching for Solutions, A Policy Discussion Series: Exploring the Role of Pricing as a Congestion Management Tool**, Federal Highway Administration (FHWA), U.S. Department of Transportation, Number 1, Washington, DC, March 1992.

   This report summarizes a July 23, 1991 FHWA seminar. The seminar provided participants an opportunity to discuss a variety of policy issues related to highway congestion pricing. Congestion pricing includes direct charges for roadway use varying by time, location, occupancy, etc. in response to level of service, environmental or cost recovery policy objectives.

   The publication includes the views and comments of many participants. While no overall consensus on congestion pricing emerged, there was general agreement on several points: 1) the use of revenues generated by congesting pricing must be well thought out and presented in advance; 2) compensation for those adversely affected must be addressed early in the planning process; and 3) reasonable alternatives to priced roads must be made available.

7. **"Total Cost for Air Carrier Delay for the Years 1987-1990,"** U.S. Department of Transportation, Federal Highway Administration, APO-130, Washington, DC, January 1992.

   This analysis presents updated costs of delay for air carriers for the years 1987-1990. Various cost items for both operating and passenger costs are presented. Each item is documented giving data sources.

8. **"Introducing Congestion Pricing on a New Toll Road,"** Robert W. Poole, Jr., Transportation Research Record No. 1359, Economics, Finance, and Administration, Transportation Research Board, National Research Council, Washington DC, 1992.

   In this paper, the author suggests that congestion pricing should be tested using an urban area demonstration project, such as the new toll road being planned for Orange County, CA. A demonstration project would add to the current knowledge about the effectiveness of congestion pricing and address political and other public acceptance implementation barriers. The project would measure traffic flow (on both the toll road and unpriced alternate routes) and ridesharing behavior and calculate emission reduction effects.

   Rather than charge a single flat toll, the transportation agency could charge peak and off-peak tolls, making use of automatic vehicle identification to facilitate toll collection. Peak charges would be increased each year for a 10 year period until toll revenues declined below the levels forecast under a flat-rate toll alternative. Peak charges would rise by 10 percent per year, beginning at a rate of $.13 per-mile. However, the off-peak tolls would remain constant at $.10 per-mile, an initial 33 percent differential between peak and off-peak toll rates. By the fifth year, the peak period toll would have risen to $.19 per mile (a nearly 100% differential between peak and off-peak rates). It is estimated that a congestion priced toll road could permit traffic to flow smoothly even during peak periods. This could reduce emissions per trip by up to 70 percent and has the potential to reduce the total number of trips as well.

   The author believes that successful demonstration of a well designed congestion pricing demonstration project may attract support from different political factions. Conservatives would be interested in the potential to make highways self-supporting. On the other hand, liberals would be interested in leveling the playing field between highways and transit.

9. **"Road and Parking Pricing: Issues and Research Needs,"** Kiran U. Bhatt and Thomas J. Higgins, Transportation Research Record, No. 1346, Highway Operations, Capacity, and Traffic Control, Transportation Demand Management, Washington, DC, 1992.

   Road and parking pricing are of increasing interest to transportation and air quality planners as ways to reduce automobile use and traffic associated with pollution. Three such pricing concepts are examined: 1) facility pricing - highways; 2) areawide pricing; and 3) parking pricing. Effectiveness, feasibility, legality, acceptance, and implementation are evaluated on the basis of experience and research. Specific issues surrounding each pricing alternative are discussed.

10. **"Paying for New Highway Capacity Through the Imposition of Peak Period Tolls",** Patrick DeCorla-Souza and Anthony R. Kane, Federal Highway Administration, in Transportation Planning, American Planning Association's Transportation Planning Division Newsletter, Summer 1991.

    The article notes a shift toward public acceptance of peak period tolls and considers the economic rationale for this strategy. The general scale of toll charges that might be justifiable is discussed

as are the effects of the strategy on traffic congestion, air quality, and economic development. Also included are comments on the shortfalls that a congestion pricing strategy may create in the revenue needed to fund transportation infrastructure needs.

The article points out that highway users are not confronted with the full social costs of their individual decisions on whether, when, and where to drive. This is especially true during peak travel periods. Consequently, roadways are often overused, resulting in traffic congestion, economic inefficiency, and waste of scarce resources.

The paper also considers the marginal social cost of congestion and the direct costs of highway investments not covered by user fees. Additional coverage is given on the external costs imposed by accidents, air pollution, water pollution, noise pollution, policing, emergency medical service, and municipal administration. Ways of estimating the magnitude of needed tolls are also included.

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

(Also see this title under Section I, Air Pollution.) In this report, it is estimated that modest changes (totalling an estimated $5 to $6 per day) in the pricing for use of single occupancy vehicles would yield significant congestion benefits. Travel times (expressed as vehicle hours per passenger) would decrease by 24 percent, from an average of 1 hour 18 minutes to 59 minutes. Roadway speeds would increase by 27%. The reductions are from the estimated 2010 baseline case and were obtained through use of a newly designed computer model that was designed to estimate drivers' responses to congestion and emission fees.

CURRENT RESEARCH NOW UNDERWAY

There are a number of research efforts recently initiated or not yet completed that will provide useful information on measurement, mitigation, and costing of environmental impacts. There may be others germane to these issues that are not included in this section, because information about them was not known at the time of publication. We would appreciate receiving information, summaries, and status of any additional relevant studies not incorporated in this section.

A. CAUSE/EFFECT - MEASUREMENT:

1. **Development of a Multimodal Framework for Freight Transportation Investment: Consideration of Rail and Highway Trade-offs**, Texas Transportation Institute, for the National Cooperative Highway Research Program (NCHRP), Transportation Research Board (TRB), Project 20-29. Anticipated completion: November 15,1993.

   With few exceptions, public planning and investment decisions are usually made independently by mode. Modally oriented planning and investment have been shown to be economically inefficient and generate fewer social benefits than might be achieved under a multimodal approach. This study's objective is to develop a framework for efficient and effective multimodal investment practices, demonstrate the viability and applicability of the framework, identify obstacles to implementation at the state and local levels, and develop strategies for implementing improved practices. The research will evaluate various examples of transportation investment trade-offs, focusing on rail-highway trade-offs in state rail program activities. While the focus is on direct costs, indirect costs, such as economic impacts, energy use, productivity, air quality, and safety impacts, may also be included in the framework.

2. **Impact of Urban Congestion on Business**, Cambridge Systematics for the NCHRP, TRB, Project 2-17(5) FY 91. Anticipated publication: September 1993.

   The objective of this research is to assess and quantify the impact of congestion on the cost of doing business. The impacts of interest include those generally associated with delivery of goods and services, access to customers, transport costs, business output, access to labor supply, extensions and restructuring of delivery systems, and lost markets. The research will include estimates of national and regional costs of congestion (particularly as they pertain to local business activities) and industry studies of internal and external costs attributable to congestion.

3. **The Baseline Study**, Special Projects Office, TRB, NCHRP, Project 20-31. Anticipated completion of Phase One: September 1994.

   There is a need to develop "baseline" knowledge about the extent to which current policies foster efficient use of the freight system; and the extent to which current use by mode differs from the use that would be expected if no public subsidies were provided and each mode was responsible for any external costs (such as air pollution) it imposes on the public at large. As a first step to developing this information, the TRB is convening a committee to explore the potential usefulness and feasibility of a comprehensive baseline study of freight transportation to measure the subsidies provided to the freight modes and the external costs of freight transportation, and to assess the consequences of such subsidies and external costs on the amount of freight traffic and its distribution among modes. This first phase of the study is to result in a report reflecting the deliberations of the committee, including specific recommendations for further studies of important issues in conducting a substantially larger effort. TRB has made a tentative selection of the committee members.

4. **Assessment of the Effects of Proposed Locomotive Regulations on Goods Transport Modes and Locomotive Emissions**, Request for Proposals by the State of California Air Resources Board (ARB), El Monte, CA, February 1, 1993. Contract being negotiated. Duration: 9 months.

   Locomotives contribute substantially to California's air pollution problem, with 1987 emissions of 160 tons per day of NOx, nearly five percent of the mobile source inventory. ARB has determined that substantial emission reductions from locomotives are both necessary and feasible. Few or no neutral analyses comparing the emissions of different modes of goods transport have been conducted, however, and neutral analyses of the potential for market shifts under various regulatory scenarios have not been performed. Furthermore, market potentials for mobile source credits are unknown at this time.

   This research is intended to determine the direction and magnitude of any shifts in the goods transport arena resulting from locomotive emission regulations and to ascertain how to best compensate for such shifts within the regulatory framework. It is also to determine how best to set up an active market in locomotive emission reduction credits, assuming a bubble program for locomotive emissions is adopted.

   The ARB may be interested in developing a goods transport policy, promoting those forms of goods transport that have the least adverse effects on air pollution. A thorough and unbiased assessment of the relative contributions of each mode of goods transport must be developed. Some of the tasks will be to: acquire emission inventories and factors for the various modes based on a common unit of measurement, such as revenue ton-mile; determine current market share for each goods transport mode; compare per-mile emissions from each goods transport mode, given the current regulatory arena; assess changes in emissions under various regulatory strategies under consideration by ARB; review and critique previous emission credit programs that may be appropriate for the railroad industry; and design an emissions trading procedure to maximize market activity.

5. **Assess Transportation Emission Trends and Violation of the National Ambient Air Quality Standards (NAAQS)**, Federal Highway Administration (FHWA). Anticipated completion: February 28, 1994.

   This FHWA effort will produce a review of NAAQS violations for carbon monoxide, ozone, and dust (PM_{10}) and determine the role of mobile sources in those violations. FHWA will also explore methods of reducing and eliminating mobile source contributions.

6. **Trip Type Emissions Estimates**, FHWA. Anticipated completion: June 30, 1993.

   In this effort, the FHWA will develop emissions estimates for various trip types and lengths by commonly available modes. FHWA will include door-to-door travel times and energy requirements.

7. **Development of Guidelines for Estimating the Secondary Impacts of Proposed Transportation Projects**, NCHRP, TRB, Project 25-10. Two-year project, to begin in October 1993.

   Guidelines are needed for estimating secondary impacts of proposed transportation projects. These impacts include induced traffic, land development, and greater levels of activity. The term secondary impacts should be defined as should related terms, such as induced impacts or induced development. There is a need to improve the understanding of the causes of secondary impacts,

and guidelines need to be developed identifying techniques and data requirements for estimating the different secondary impacts.

8. **Measuring and Valuing Transit External Benefits and Disbenefits**, National Cooperative Transit Research Program (NCTRP), TRB, Project H-2. Anticipated completion: January 1995.

   A comprehensive compilation and comparison of transit benefits and disbenefits is needed with measures, values and an understanding of the range of these values. This TRB project will: review past efforts to quantify externalities; analyze these past efforts, to determine where improvements or enhancements are possible or where data is non-existent or poorly developed; propose a work plan for improvements; undertake research and analysis to develop improved or additional information; and develop principles and techniques for benefit/disbenefit measurements in the context of the Intermodal Surface Transportation Efficiency Act's planning requirements.

9. **Manual of Transportation-Air Quality Modeling for Metropolitan Areas**, prepared by Deakin Harvey Skabardonis (prime contractor) with Cambridge Systematics, COMSIS, Dowling Associates, Gary Hawthorn Associates, Parsons Brinckerhoff Quade and Douglas, and Ann Stevens Associates, for the National Association of Regional Councils (NARC) with funding provided by the Environmental Protection Agency, the Federal Transit Administration, and the Federal Highway Administration. Anticipated publication: Summer 1993.

   Recent changes in the context of transportation planning have increased the importance of regional transportation analysis methods. In particular, the Clean Air Act Amendments of 1990 set forth detailed requirements for planning and analysis which apply to numerous metropolitan areas. This manual is designed to help regional agencies, especially metropolitan planning organizations, respond to the issues raised in carrying out transportation modeling for air quality planning efforts.

   The manual reviews the state of transportation modeling today, focusing primarily on travel demand forecasting, and suggests strategies for responding to specific analysis needs and for overcoming common problems. The emphasis is on identifying issues which regional agencies should consider in reviewing their models, and on recommending sound options for addressing such issues in accordance with local objectives and resource availability.

10. **University Transportation Centers Project Abstracts Fiscal Year 1992**, U.S. Department of Transportation, Research and Special Programs Administration, April 1992.

    This publication contains several abstracts of research in progress as well as a list of research results of past efforts. Two relevant entries are described below; others may also be useful.

    "Transportation Of Hazardous Materials and Wastes," by Leon Moses, Northwestern University, Evanston, IL.

    In the proposed research a large sample of trucking firms will be studied to determine whether firms that carry hazmat differ from those that do not carry such goods in terms of size of firm and accident experience. The investigation will reveal which of the hazardous cargos tend to be associated with a greater number and whether certain characteristics have a significant influence on accident rates of those firms that carry hazardous materials.

"Energy And System Costs Evaluation Of Truck Size And Weight Changes," by B.F. McCullough, University of Texas, Austin, TX.

This project would evaluate several sources of data on the various components of a full transportation system evaluation and provide a hierarchy of impacts, including those associated with energy, which would follow significant changes in truck size and weight legislation. It is anticipated that this project will be completed by August 1993.

11. University Transportation Centers Project Abstracts Fiscal Year 1993, U.S. Department of Transportation, Research and Special Programs Administration. In the process of being published.

This publication will contain several abstracts of research in progress as well as a list of research results of past efforts. Three relevant entries are described below; others may also be useful.

"Port/Landside Interactions," Carlos Daganza, University of California, Berkeley, CA.

The study examines the economies of scale of transport technology in inland connections between a port and its hinterland and shows how these affect port development. It also investigates the advantages and problems that can be expected from higher levels of integration between railroads and ports including effects on the surrounding community, such as reduced congestion and land requirements.

"Larger Combination Vehicle Safety," Paul Jovanis, University of California, Berkeley, CA.

This study looks at the larger combination vehicle safety debate. Accident rates per-vehicle-mile, ton-mile, and cubic-volume-mile will be used to assess vehicle safety. In addition to overall accident rates, injury severity and type of collision will be modeled. Data will be controlled for driver experience, management, and roadway type.

"Understanding and Forecasting the Growth Rate of Auto Travel," Charles Lave, University of California, Berkeley, CA.

The two main goals of this research are: 1) to analyze and seek to validate or challenge the unprecedented jump in vehicle miles travelled (VMT)/driver shown by the 1990 Nationwide Personal Transportation Study (yearly VMT/driver jumped by 24 percent between 1983 and 1990); and 2) to formulate a demographically based model of VMT growth using several promising new data sets that have recently become available.

12. Federal Aviation Administration (FAA) planned research efforts:

Development of Noise Emissions Prediction Methodology
Improved analytical and modeling capabilities for environmental impact assessment.

Community Noise Impact
Joint research effort with NASA to discover more accurate relationships between aircraft noise exposure and community response.

Environmental Assessment Techniques/Methodologies
Effective means of addressing aviation's environmental consequences.

Enroute Aircraft Noise Model (EANM)
A model to be used by FAA to analyze aircraft noise exposure in the terminal and enroute areas.

Airplane and Rotorcraft Noise Certification and Analyses
Provide technical support for the agency's noise certification program.

Engine Emissions Certification and Analysis
Provide technical support for the agency's engine emissions certification program.

High Altitude Pollution Research (HAPR)
Develop capabilities to demonstrate the effects of aviation on the ozone layer and global climate change.

13. Guidance Manual for Transit Noise and Vibration Impact Assessment, U.S. Department of Transportation, Federal Transit Administration (FTA). In the process of being published.

This manual presents the recommended methods and techniques for assessing noise and vibration impacts of proposed mass transit projects. Both bus and rail modes are covered The manual offers a screening technique that can be used to focus on areas where noise and or vibration could likely be problems. Methods are presented for a more generalized assessment appropriate during the systems planning steps when different surface transportation modes and alignments are being considered. The manual also covers procedures and methods for detailed site-specific noise and vibration analysis which would be accomplished after a specific mode and alignment have been selected. Other chapters cover noise mitigation, assessment of noise and vibration during the construction phase, and guidance on documenting the results of noise and vibration analyses in FTA's environmental documents.

14. Guidance for Site Specific Air Quality Analysis of Transit Projects, University of Tennessee, University Research Program. Anticipated completion: September 30, 1993

This project involves site-specific air quality analysis for transit projects. The report will describe appropriate methods and air quality models to use in evaluating the air quality effects of typical types of transit projects, such as: bus terminals; HOV lanes; commuter rail terminals; park-and-ride lots; and transit malls. Another objective of the research is to determine whether or not a threshold can be established for proposed major fixed guideway projects below which it would not be necessary to complete site-specific air quality analysis. A main focus is on assessing the degree to which smaller transit projects can produce localized PM-10 (small particulates) "hotspots" and potential violations of the national ambient air quality standards.

B. MITIGATION STRATEGIES:

1. Cost and Efficiency of Transportation Control Measures (TCMs): A Review and Analysis of the Literature, Apogee Research, Inc., Bethesda, MD, for the Clean Air Project of the National Association of Regional Councils, co-sponsored by the Federal Highway Administration, Federal Transit Administration, and the Environmental Protection Agency. Anticipated completion: Symposium, Summer 1993, with publication, Fall 1993.

The contractor is to prepare a White Paper - essentially a handbook - on TCMs that presents ordered, comparative, quantitative estimates of the ranges of effectiveness and cost-effectiveness of various classes of TCMs. Because the work is being performed on a tight timetable, estimates of comparative TCM effectiveness must rely on readily available analyses and information. The

project will combine a review of available, relevant work (both through reading the literature and through discussion with current practitioners) with the organization and synthesis of these results.

The paper will be revised after holding a symposium of 15-20 participants, including practitioners, consultants, and academics, and 15-20 observers - heavily weighted towards practitioners. The proceedings and revised White Paper, which will include recommendations for other actions and research, will be published and widely distributed, principally to local and state officials involved in applying TCMs.

2. **Long-Term Availability of Multimodal Corridor Capacity**, NCHRP, TRB, Project 8-31, The Urban Institute. Anticipated completion: May 1995.

   Objectives are to evaluate the scope and severity of current and future capacity problems and constraints on transportation corridors and to recommend strategies to ensure the long-term availability of multimodal corridor capacity. Options for increasing capacity must not be limited to the major highways in the corridor, but must also include parallel roads and rail, transit, water, and other modes where available. The study will identify, evaluate, and summarize studies of corridor problems, capacity preservation and expansion strategies (including intelligent vehicle highway systems, congestion pricing), methods of corridor administration, and shipper, carrier, and traveler responses to congestion.

3. **Assessment of Highway Particulate Impacts**, FHWA. Project will be underway by end of FY 93.

   The FHWA will assess PM_{10} particulate concentrations in the air and determine the role of highway transportation in producing these concentrations. If appropriate, FHWA will develop techniques to quantify and mitigate highway system impacts.

4. **15 Percent Volatile Organic Compound Case Studies**, FHWA. Anticipated completion: June 30, 1993.

   In this project, the FHWA will develop predictive emission control case studies of a representative number of urban areas that are currently in nonattainment for ozone and carbon monoxide (moderate and above). The case studies would include: 1) historic and current demographic, travel, air pollution, emission statistics, and size of area measured; 2) emission reductions required to reach attainment; 3) impact of expected regional growth on emissions; 4) reductions possible from technology; 5) net emission reductions creditable to the area under the Clean Air Act; and 6) potential reduction in vehicle use needed to meet a mobile source fair share emission reduction requirement.

5. **Implementing Effective Travel Demand Management Measures**, being prepared for the FHWA and the Federal Transit Administration by COMSIS Corporation and the Institute of Transportation Engineers, Washington, D.C. Anticipated completion: August 1993, with publication Fall 1993.

   The products of this research are a set of materials, statistics, guides, and tools that will give individuals in the public and private sectors an understanding of Transportation Demand Management (TDM), its components, and how to design and evaluate effective measures.

   The following products have been developed through this research and will be available to anyone with planning, policy, or operational interest in TDM: 1) Overview of Travel Demand Management Measures; 2) Implementing Effective Travel Demand Management Measures: main report containing reference materials and a synthesis of findings; 3) Employer-Based Guidance

Manual to assist the private sector with implementing TDM measures; 4) a Government-Based Guidance Manual to assist the public sector with implementing TDM measures; 5) a Market Research Guidance Manual to assist the public and private sector in collecting information that is necessary to properly design and evaluate TDM measures; 6) TDM Evaluation Model to enable the public and private sector to analyze the travel impacts of a TDM measure(s) using a microcomputer procedure; and 7) a video to promote the concepts of TDM to upper management in the public and private sectors.

6. University Transportation Centers Project Abstracts Fiscal Year 1992, U.S. Department of Transportation, Research and Special Programs Administration, April 1992.

This publication contains several abstracts of research in progress as well as a list of research results of past efforts. Three relevant entries are described below; others may also be useful.

"A Methodology For Selecting Appropriate Accident Countermeasures through Multiobjective Analysis," by Nicholas J. Garber, University of Virginia, Charlottesville, VA. Anticipated completion: September 1993.

A major concern in traffic operations is the continuing high accident rates on our nation's highways. Although several research projects have been undertaken to identify factors that significantly affect accident rates, it has been difficult to prioritize countermeasures developed from these studies, because the resulting effects have not been quantified. This study will develop a methodology for selecting appropriate safety countermeasures through the optimization of multiple objectives.

"Telecommunicating-Transportation-Energy Interactions: Potential For Reducing Transportation Energy Consumption Through Telecommuting," by Hani S. Mahmassani, University of Texas, Austin, TX. Anticipated completion: Fall 1993.

The aim of this project is to address the travel behavior implications of telecommuting and determine the potential of telecommuting to improve urban mobility and reduce fuel consumption.

"The Energy Value Of A Transit Station," by Mark Euritt, University of Texas, Austin, TX.

This study addresses how valuable transit stations are to conserving energy used in everyday trips that would otherwise be made by automobile. A ranking or energy value will be assigned for different types of transit stations based on the land use and development changes that occur within the station's zone of influence.

7. University Transportation Centers Project Abstracts Fiscal Year 1993, U.S. Department of Transportation, Research and Special Programs Administration. In the process of being published.

This publication will contain several abstracts of research in progress as well as a list of research results of past efforts. Three relevant entries are described below; others may also be useful.

"Analysis of the Impacts of Urban Transportation Policies on Energy Consumption and the Urban Environment," Vulkan R. Vuchic, Pennsylvania State University, University Park, PA.

In most cities around the world, there is a trend of physical dispersal of residences and business activities, with consequent growing reliance on travel by private automobile. On the other hand, the populace is demanding improvements of quality of life in cities and prevention of further environmental degradation. In addition, most countries face very high expenditures for energy imports. This research will examine policies and specific measures proposed or introduced in different cities for reconciling these conflicts.

"An Improved Methodology for Considering Safety in Road Investment Decisions," David J. Forkenbrock, Iowa State University, Ames, Iowa.

This study is designed to address two interrelated questions that are central to transportation planning: 1) What kinds of changes to Iowa's secondary and primary road systems would constitute the most cost effective means for reducing serious motor vehicle accidents? and 2) What is the most appropriate means for taking safety improvements into account when making road investment decisions? This research is limited to the state's road network. The focus will be on rural roads and highways, because over 80 percent of all fatal accidents involving motor vehicles occur outside Iowa's municipalities.

"Land Use Policies and Design Guidelines for Transit Friendly Environments," Anastasia Loukaitou-Sideris, University of California, Berkeley, CA.

The focus of this research is the urban commercial corridor and the relationship between vehicle transportation routes and surrounding land use and development patterns. This project will examine case study corridors in Los Angeles and will investigate land use and policy frameworks, zoning regulations, and design guidelines that can better support existing and future transit.

8. Federal Aviation Administration (FAA) planned research efforts:

Subsonic Jet Source Noise Reduction Research
A joint program with NASA to identify new airplane noise reduction technologies.

Rotorcraft Noise Reduction Research
To identify new noise reduction technologies.

Engine Emissions Reduction Research
To identify new engine emissions reduction technologies.

Development of Environmental Assessment Techniques/Methodologies
Effective means of addressing aviation's environmental consequences.

C. COSTING/PRICING STRATEGIES:

1. **Research Strategies for Improving User Cost-Estimating Methodologies**, NCHRP, TRB, Project 2-18. Anticipated publication: late Fall 1993.

Vehicle operating cost estimates are based on research conducted in the 1970s and 1980s. As a result of changes in technology, use, fuel costs, congestion, etc., there is a need to reassess the validity of established relationships. The TRB study is to examine validity of the data, concepts,

assumptions, components and methods currently used. It will identify improvements that are possible and propose actions to be taken.

2. **Microcomputer Evaluation of Highway User Benefits**, NCHRP, TRB, Project 7-12. Anticipated software development completion: October 1993.

   The study's objective is to develop a comprehensive, microcomputer program capable of using new and updatable support data and the best practical procedures for conducting highway user benefit-cost analysis and related noise and air pollution emission analyses and be applicable to improvements to new roads. The program would include the procedures from the 1977 Association of State Highway and Transportation Officials manual or other analyses as appropriate and would be updatable. The program would be capable of life cycle cost analysis, use default or user provided inputs, and update support data and parameter values to the analysis year.

3. **Congestion Pricing - Pilot Program Guide**, K.T. Analytics, Inc. for the Federal Highway Administration (FHWA), Office of Policy, Transportation Studies Division. In the process of review for final publication.

   This FHWA Guide is intended to assist local and state governments in their decision to apply for support under the Congestion Pricing Pilot Program established by the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). The Guide summarizes eligible Pilot Program congestion pricing concepts; provides information on congestion pricing experience and issues important to weigh before applying under the program; suggests key considerations important to comparing congestion pricing options; provides monitoring and evaluation guidance; and provides pertinent references for planning, implementation, and evaluation. A bibliography of relevant publications is included.

4. **Development of Cost-Effectiveness Analysis Procedures for Comparison of Multi-Modal Transportation Alternatives**, K.T. Analytics, Inc. and Cambridge Systematics, Inc. for the Federal Highway Administration, Office of Environment and Planning. Course handbook will be available in December 1993 after two pilot courses have been conducted.

   The Federal Highway Administration (FHWA) is developing a training course to provide assistance to metropolitan planning organizations (MPOs) in making cross-modal comparisons of "costs" as well as "effectiveness" of transportation alternatives. The Course is called "Estimating the Impacts of Transportation Alternatives." Cross-modal accounting will require full accounting of all costs for each alternative -- including private and public costs, environmental, energy, and socio-economic costs, and financial and institutional costs. The handbook being developed for the course will include a recommended approach for assessing the overall merit of transportation alternatives, including calculation of "net present value" for all benefits and costs that can be expressed in monetary terms, while presenting other impacts that cannot easily be converted to monetary terms in balanced level of detail and emphasis.

   The project includes a literature review, assessment, and a selection of the most appropriate data and procedures for "sketch planning: estimation of the impacts of multi-modal transportation alternatives at the system, corridor, and project levels. The products will be: 1) an annotated bibliography of reviewed literature; 2) a handbook which consolidates the most appropriate procedures and methodologies; 3) microcomputer software and users guide; course materials including draft visual aids, a draft student workbook, and an instructor's guide; and 4) two 3-day pilot courses, followed by final course materials. The course in intended to provide the menu of effectiveness and cost measures from which MPOs can choose the options that best fit their needs.

5. **Application of Pricing Strategies to Congestion Management**, National Cooperative Highway Research Program, Transportation Research Board, Planned Completion Date: March 31, 1994.

   A committee will be formed to commission reviews of, and prepare papers on, prior research about the design and objectives of alternative congestion pricing strategies, the impacts of these strategies, and technical, legal or other barriers to introducing peak-hour pricing. The committee will present the papers at a symposium and will issue a final report on the role that alternative urban pricing strategies might play in the U.S., identifying key policy choices and decisions and recommending research projects and field experiments.

6. **International Survey of Roadway Pricing**, NCHRP, TRB, Project 20-5, Topic 24-02.

   A synthesis of international highway pricing practices is needed, separated between those pricing practices adopted for general revenue collection purposes and those adopted as user fee collections (for transportation agency cost recovery, congestion relief, environmental improvement or social cost internalization). User fee collection structures would be of particular interest, and the synthesis should compare pricing approaches of the various industrialized countries with that taken by developing nations. Effort should be made to discern specific problems in road pricing studies in each country and to report on research underway.

7. **Air Quality, Congestion, Energy and Equity Impacts of Market-Based Transportation Control Measures**, California Air Resources Board, with CalTrans, the Southern California Association of Governments, Los Angeles County Transportation Commission, San Diego Association of Governments, and the Federal Highway Administration. Anticipated completion: August, 1994.

   The objective of this research is to develop, thoroughly analyze, and refine market-based transportation control measures (TCMs). Four separate categories of market-based TCMs will be evaluated: congestion pricing; smog-based emission fees; parking supply and pricing; and at-the-pump charges (including gas taxes and including auto insurance charges with the gasoline price). The analysis of equity and socio-economic impacts on various segments of the population, stratified by income and transportation needs, is an important part of the objective. The results of the research may be used to seek legislative authority for implementation of market-based TCMs.

   The four groups of market-based TCMs will be analyzed for Metropolitan Los Angeles, San Francisco, San Diego, and Sacramento. Other categories of TCMs may be suggested for further study. TCMs of any type have multiple effects.. Reducing trips and VMT also alleviate traffic congestion and reduce fuel use. Market-based TCMs can result in monetary transfers, potential inequities, and other socio-economic effects. For the purpose of this research, "impacts" means changes in any of the following: 1) vehicular trips; 2) vehicle miles travelled; 3) person trips; 4) person miles travelled; 5) traffic congestion; 6) emissions of NOx, SOx, Hydrocarbons, carbon monoxide, and particulate; 7) fuel consumption; 8) fuel production; and 9)land used patterns.

   The report will include: a description of each measure and variants; significant local and statewide issues and problems associated with the measure; implementation steps for each measure; suggested pricing levels or range; the required technology to implement the measure; and the specific responsibility(ies) of each agency involved. The research will also document, analyze, and summarize the current literature to determine state-of-the-art for market-based TCM implementation and political acceptability.

8. University Transportation Centers Project Abstracts Fiscal Year 1992, U.S. Department of Transportation, Research and Special Programs Administration, April 1992.

   This publication contains several abstracts of research in progress as well as a list of research results of past efforts. A relevant entry is described below; others may also be useful.

   "Feasibility of Congestion Pricing as an Energy Conservation Measure," by Jeffrey L. Memmott, Texas A&M University, Austin, TX. Anticipated completion: May 1994.

   This project will study the feasibility of using congestion pricing strategies (tools) to reduce highway related energy use. The idea is to charge users for use of major highway facilities during heavily congested periods. This induces more efficient use of the facilities, reducing both energy use and vehicle emissions, by encouraging some motorists to change the time of the trip or to use another mode, such as public transit. There are a few places where congestion pricing has been implemented or is planned. This project is anticipated to be completed in May of 1994.

9. University Transportation Centers Project Abstracts Fiscal Year 1993, U.S. Department of Transportation, Research and Special Programs Administration. In the process of being published.

   This publication will contain several abstracts of research in progress as well as a list of research results of past efforts. Two relevant entries are described below; others may also be useful.

   "A Comparative Analysis of Liquefied Natural Gas (LNG) and Compressed Natural Gas (CNG) in Two Texas Transit Agencies," Naomi W. Lede, Texas A&M University, Austin, TX.

   This study proposes to analyze fuel cost, fuel facility cost, parts cost and labor costs, as well as mileage and performance characteristics of CNG and LNG. The main objectives of the study are to respond to community and environmental concerns from an emissions and health impact perspective and to impose mandatory alternative fuels use in selected public transit.

   "Social Cost Analysis of Alternative Transportation Systems and Fuels," Gloria Helfand, University of California, Berkeley, CA.

   The project will examine social costs associated with gasoline and diesel fuel, methanol, compressed or liquefied natural gas, and hydrogen for heat engines; battery- or fuel-cell powered electric vehicles; and buses, light-rail trains, and heavy-rail trains. It will also look at the macroeconomic costs of importing fuels, costs of spills at sea, and of leaks from storage tanks into ground water. For all uses of energy and for all systems, the study will estimate the costs of air pollution. Further, it will estimate government subsidies for all fuels and systems. It will also examine costs associated with motor-vehicle use.

GLOSSARY OF TERMS

Acetaldehyde: a colorless, flammable liquid, C_2H_4O.

Automatic Train Control System (ATCS): a computerized safety and operating system used to maintain separation between trains.

Biomass: the amount of living matter (as in a unit area or volume of habitat).

British thermal unit (Btu): the quantity of heat needed to raise one pound of water by one degree fahrenheit.

Carbon Monoxide (CO): a poisonous gas that is the product of the incomplete combustion of fossil fuels.

Carbon Dioxide (CO_2): a colorless, odorless, incombustible gas that is the product of the combustion of fossil fuels. Carbon dioxide is considered to be the principal greenhouse gas.

Chlorofluorocarbon (CFC): a molecule containing chlorine that tends to migrate into the stratosphere. When the chlorine atom is released (through a photochemical reaction), it acts to destroy stratospheric ozone.

Clean Air Act Amendments (CAAA): a Federal statute enacted in 1990 which contains numerous changes to the Clean Air Act.

Compressed Natural Gas (CNG): natural gas in a compressed form.

Decibel (dB): a relative measurement of sound power expressed on a logarithmical scale where each sound level is 10 times greater than the previous one.

Diurnal: pertaining to a time each day; daily.

Electromagnetic Fields (EMF): an energy field created when electricity is used.

Fuel Cell: an electrochemical cell in which the reaction between a fuel (such as liquid hydrogen) and an oxidant (such as liquid oxygen) are converted into direct current (electricity) energy.

Greenhouse Effect: a theory that holds that the temperature of the earth's surface and atmosphere will rise as the concentration of certain gases increase in the atmosphere. These gases are believed to trap solar radiation that would otherwise be reflected into outer space. This could cause a rise in sea levels and other climatic changes.

Hazardous Materials (Hazmat): various chemical compounds whose properties have caused them to be classified as hazardous to humans or the environment.

High Occupancy Vehicle (HOV): a passenger vehicle carrying two or more individuals. In many areas special highway lanes are set aside for HOVs. These lanes may require more passengers, such as 3 (HOV-3) or 4 (HOV-4).

High-Speed Rail (HSR): a steel-wheel-on-steel-rail form of surface transportation capable of speeds in excess of 125 MPH, far higher than is now commonly in use in the U.S. Several steel-wheel-on-rail trains (the French TGV, the Japanese series 300 Shinkansen, and the German ICE) have top speeds of 167 to 186 MPH. The Swedish X2000 (a train with an active car body tilting system, allowing high speed through curves) is now being tested in the U.S. and has a top speed of 150 MPH.

Intelligent Vehicle Highway System (IVHS): a concept where communication and information would be exchanged between the highway and the vehicle through the use of on-board and way-side computers linked by satellites or other communications systems.

Intermodal Surface Transportation Efficiency Act (ISTEA): a Federal statute enacted in December 1991.

Liquified Natural Gas (LNG): natural gas that has been cooled until it liquifies.

Magnetically Levitated Transportation (Maglev): a surface transportation system characterized by non-contacting vehicles, suspended, guided and propelled above a fixed guideway by magnetic fields.

Metropolitan Planning Organization (MPO): the organization, together with the state(s) involved, designated as being responsible for carrying out the metropolitan planning provisions of the ISTEA. The MPO, which serves an urbanized area population of at least 50,000, is the forum for cooperative transportation decision-making. The MPO is to include representation of officials of local purpose government and operators of major modes of transportation.

Morbidity Cost: The value of goods and services not produced because of injury, disease, illness, and disability.

National Ambient Air Quality Standards (NAAQS): Federal clean air legislation established ambient air quality standards for six pollutants: ozone, carbon monoxide, nitrogen dioxide, particulates, sulfur dioxide, and lead.

Nitrogen oxides ($N0_x$): compounds formed by high temperature and pressure during the incomplete combustion of petroleum based fuels. NO_x includes nitric oxide (NO) and nitrogen dioxide ($N0_2$), precursors to ozone and acid rain.

Nonattainment Area: a geographic area within the U.S. that the Environmental Protection Agency has designated as failing to meet the standard for a particular NAAQS pollutant and, consequently, is in "nonattainment" with the Federal standard.

Ozone (0_3): in the troposphere, ozone is almost entirely a secondary air pollutant, formed by a photochemical reaction involving reactive hydrocarbons (HC) and nitrogen dioxide ($N0_2$) in the presence of sunlight. In the stratosphere, ozone is considered to be beneficial, as the molecule has a special ability to absorb the band of ultraviolet (UV) radiation that is especially damaging to living cells. Therefore, stratospheric ozone has the role of keeping harmful UV radiation from reaching the earth's surface.

Single Occupancy Vehicle (SOV): a motor vehicle, an automobile or light truck, carrying only the operator.

Smog: a term commonly used to describe air pollution.

Stratosphere: the area of the atmosphere between approximately 10 and 30 miles above the Earth's surface.

Transportation Control Measures (TCM): measures which include elements of both transportation system management (TSM) and transportation demand management (TDM). Often, TCM, TSM and TDM are used interchangeably. TSM refers to low capital-intensive transportation improvements that increase efficiency of facilities and services including car or van pools, HOV lanes, and bicycling. TDM refers to policies, programs and actions directed towards increasing HOV use (including transit, car or van pools), bicycling, and walking. TDM can also include encouragement of driving outside congested peak hours or telecommuting.

Troposphere: the lowest region of the atmosphere located between the earth's surface and about 6 to 10 miles high.

Vehicle Miles Traveled (VMT): the total number of miles that one or more motor vehicles traveled in a time period, usually in a given area or on a particular facility.

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