CONTRACT NO. 92-316
FINAL REPORT
NOVEMBER 1996

Transportation Pricing Strategies for California:

An Assessment of Congestion, Emissions, Energy, and Equity Impacts

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

AIR RESOURCES BOARD
Research Division

Transportation Pricing Strategies for California:
An Assessment of Congestion, Emissions, Energy, and Equity Impacts

Final Report

Contract No. 92-316

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Cambridge Systematics
DeVenuta Associates
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Energy and Environmental Analysis
KT Analytics
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November 1996

Acknowledgments

This report was submitted in fulfillment of ARB Contract Number 92-316, "Air Quality, Congestion, Energy, and Equity Impacts of Market-Based Transportation Control Measures" under the partial sponsorship of the California Air Resources Board. Work was completed as of November 1996.

Disclaimer

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Transportation Pricing for California: An Assessment of Congestion, Emissions, Energy, and Equity Impacts

Abstract

This study investigated five categories of transportation pricing measures - congestion pricing, parking charges, fuel tax increases, VMT fees, and emissions fees. Advanced travel demand models were used to analyze these measures for the Los Angeles, Bay Area, San Diego, and Sacramento metropolitan areas. The analyses indicate that transportation pricing measures could effectively relieve congestion, lower pollutant emissions, reduce energy use, and raise revenues. For example, a combination of congestion pricing, employee parking charges, a 50 cent gas tax increase, and mileage and emissions fees would reduce VMT and trips by 5-7 percent and cut fuel use and emissions by 12-20 percent, varying by region. Because auto use and its impacts are quite inelastic to price, sizable increases in revenue can be obtained with relatively little effect on travel; conversely price increases must be large to obtain sizable reductions in travel and its externalities.

Citizen reactions to prototype transportation pricing measures were explored in focus groups, and feedback from public officials and private organizations was obtained through meetings and interviews. First reactions were skeptical, but many were more favorably inclined after considering alternatives to pricing. Public acceptance would be increased by earmarking revenues for transportation improvements and providing independent oversight of revenue collection and expenditure.

Federal and state laws govern and in some cases restrict the implementation of pricing strategies, and these and other institutional and administrative issues would have to be resolved before proceeding with specific measures

"Transportation Pricing for California: An Assessment of Air Quality, Congestion, Energy, and Equity Impacts"

A study coordinated and managed by the Air Resources Board for the Statewide Working Group on Market-Based Transportation Control Measures (TCMs)

In 1991, several air districts and transportation agencies included, or were contemplating including, market-based transportation control measures (TCMs) as long-range components of their air quality plans. To understand the potential effectiveness of these measures, Air Resources Board staff initiated, at the suggestion of local agencies, a Statewide Working Group on Market-Based TCMs. As it was evident to the group that market-based TCMs would impact far more than just air pollution, a research proposal was developed to analyze the air quality, congestion, energy and equity impacts of five market-based TCMs:

- Congestion pricing
- Parking charges
- Fuel tax increases
- Vehicle miles traveled (VMT) fees
- Emissions fees

The contract was awarded to the firm of Deakin, Harvey, Skabardonis, Inc., which used transportation and emission models, socioeconomic data, focus group interviewing, and current studies and literature to provide the following for the five measures:

- Emissions, congestion, fuel-use, and equity impacts (for metropolitan Los Angeles, San Francisco, San Diego, and Sacramento)
- Analysis of social and economic burden, including mitigation strategies
- Evaluation of the current legal and political barriers
- Implementation approaches and general assessment

This is the most comprehensive of a recent generation of reports evaluating the effects of transportation pricing. The report's statements and conclusions do not necessarily reflect those of every member organization of the statewide working group, nor is it a declaration of support for any particular market-based pricing strategy or strategies evaluated in the report. This report provides a foundation for further research and public policy debate on market-based solutions.

Statewide Working Group on Market-Based Transportation Control Measures

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California Air Resources Board
California Department of Transportation
Federal Highway Administration
Los Angeles County Metropolitan Transportation Authority
Southern California Association of Governments
San Diego Association of Governments

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Summary and Conclusions

Transportation pricing measures are receiving increasing attention in the U.S. and abroad as potential ways to better manage our transportation systems. This study presents a detailed analysis of a set of transportation pricing measures designed to reduce traffic congestion, improve air quality, lower energy consumption, increase transportation revenues, and in general increase transportation systems' efficiency and effectiveness. The study describes what transportation pricing measures are and how they might work, analyzes their effectiveness at meeting public policy objectives, assesses their equity impacts, explores their political acceptability, and reviews key legal issues and institutional factors that would need to be dealt with in designing an implementation strategy.

The transportation measures considered in this study use prices to provide signals to consumers about the costs of their behavior, rather than attempting to steer behavior through regulation of what may be produced or consumed. Examples of such measures include tolls that vary with the level of congestion, parking charges set to reflect parking costs, vehicle registration fees set to capture the costs of emissions, fuel taxes set to cover the impact of carbon loading of the atmosphere, and road use fees set to cover the costs of building, maintaining, and operating the roadways. Such transportation pricing measures are designed to preserve choices for consumers while providing them more accurate signals on the costs of their choices. In response to transportation pricing measures, consumers may elect to pay the more accurate price, generating revenues to cover the costs they impose and permitting corrective actions to be taken; or they may choose a variety of means to reduce their costs directly or indirectly, for example by consuming less or by reducing the impact of their consumption.

Five categories of transportation pricing measures have been analyzed in detail in this study:

- **Congestion Pricing** - Vehicles are charged a price, or toll, for traveling during peak hours on congested routes. Drivers who continue to travel on these routes during peak periods will pay more, but experience a faster, easier trip. Others will defer trips to off-peak hours, shift travel to less congested roadways, switch to transit, carpools, or vanpools, reduce trip frequency, or over time, alter their choices of location for home, work, and other activities.

- **Parking Charges** - Free parking is a large but mostly hidden subsidy for auto use. Charging users for parking would reduce this subsidy and might provide sufficient economic incentives to encourage some to switch to ridesharing or public transit. The price could be set to cover the cost of providing the parking, or could be designed as a surcharge structured to roughly cover certain social costs of auto use, such as emissions, noise, or congestion. Charges could be imposed on all parking or only on commuter parking.

- o **Fuel Tax Increases** - Current fuel taxes cover only a portion of the costs of motor vehicle use. Additional charges at the pump could be established to pay for highway maintenance and improvements, fund other transportation facilities and services, cover the public costs of securing petroleum supplies, support programs for mitigating air pollution and greenhouse effects, and pay for a portion of accident costs. The resulting increases in at-the-pump charges also would induce some travelers to combine trips, reduce trips, take more public transit, and buy cleaner, safer, more fuel-efficient vehicles.

- o **VMT Fees** - These fees would be based on the vehicle miles of travel (VMT) driven in a particular period. They could be billed and collected in a variety of ways: as part of a vehicle registration fee, based on a schedule of typical miles driven by model year; as part of vehicle inspection-maintenance programs, based on actual odometer readings; or with the introduction of vehicle monitoring devices, based on actual accumulated VMT and charged at the pump or even billed to the owner. VMT fees would be a better measure of overall road use, accident exposure, etc. than fuel taxes, because fuel use is only roughly related to emissions or to miles driven. Motorists could be expected to drive somewhat less and take other steps to lower the costs of vehicle ownership and use. However, VMT fees could not be reduced by purchasing or using a more fuel efficient vehicle, and so would have relatively little impact on the type of autos that are owned or used.

- o **Emissions Fees** - These fees could be based on the emissions produced by a vehicle As with VMT fees, they could be paid as a vehicle registration fee, at the pump, or via separate billings. One example is a fee which would increase with the number of miles driven each year and the vehicle's measured emissions, reflecting the costs imposed on the public. A traveler using a highly polluting vehicle would pay more than a person who travels the same amount in a clean car. The traveler with the highly polluting vehicle would have an incentive to reduce emissions by improving the vehicle's emissions controls, replacing the vehicle with a cleaner one, or traveling less. Customers seeking to purchase a vehicle would have a monetary incentive to seek one with low emissions, and manufacturers would have an incentive to develop cleaner cars that could offer a cost savings to their purchasers.

Numerous variations of each of these strategies were identified, and a set of prototypical strategies was developed. These prototype strategies then were analyzed using data and models, interviews and focus groups for four major metropolitan areas - Los Angeles, the Bay Area, San Diego, and Sacramento.

The study found that properly designed and implemented, transportation pricing strategies could yield important benefits; in the four California areas alone, billions of dollars of savings each year would result from the reduced delay and air pollution pricing measures would deliver. Revenues could be used to fund new transportation investments, to cover the costs of pollution abatement and accidents, or to otherwise upgrade or enhance transportation facilities and services. In cases where pricing measures would have adverse distributional consequences for lower income households, such consequences could be offset using a portion of the revenues if the political climate would permit such a transfer.

A major question is whether decision-makers would be willing to test pricing measures and whether the public would be willing to accept higher direct costs in return for large, but somewhat abstract, benefits to the overall economy and in many cases, to themselves. Focus group and interview results suggest that citizens would be far more supportive than their elected officials have thought likely, especially if information on the options is provided. Because of the uncertainties, however, demonstration projects may be the best way to develop feasible strategies and to test them in practical applications.

Recommendations

Recommendations are as follows:

1) Local support is a critical element if transportation pricing measures are to move forward. For many of the measures, the next step would be to assess whether such support exists and is strong enough that further work would make sense.
2) Further research on transportation pricing implementation issues, and especially the political and institutional aspects of implementation, is highly recommended.
3) Further study of equity issues deserves support.
4) All transportation pricing demonstration projects in the state, including those which are in the preliminary planning stages, should be monitored closely and evaluated, and information exchange programs should be established.
5) Regional and local agencies should take the lead on projects that would be implemented at the regional or local levels.
6) Regional agencies should be encouraged to develop advanced modeling systems capable of addressing transportation pricing measures.
7) State agencies should sponsor research on advanced technologies which would aid in the implementation of pricing strategies, including on-board and roadside monitors.
8) Certain transportation pricing measures should be evaluated for potential implementation on a statewide basis. Measures designed primarily for revenue generation could be evaluated by Caltrans, for example.

1. Introduction

1.1 The Growing Interest in Transportation Pricing Measures

Transportation measures which rely on the use of price signals to alter consumer choices and reduce adverse impacts have received increased attention in the last few years as potential public policy instruments. This study presents a detailed analysis of a set of transportation pricing measures designed to reduce traffic congestion, improve air quality, lower energy consumption, increase transportation revenues, and in general increase transportation systems' efficiency and effectiveness. The study describes what transportation pricing measures are and how they might work, analyzes their effectiveness at meeting public policy objectives, assesses their equity impacts, explores their political acceptability, and reviews key legal issues and institutional factors that would need to be dealt with in designing an implementation strategy.

The use of pricing to better manage demand in large systems is not a new concept. The telephone industry has long used pricing to manage peak loads, and airlines routinely set ticket prices to regulate seasonal, day-to-day, and time-of-day demand. Pricing has worked well in these applications, reducing congestion and increasing the efficiency of system operations. Despite this success, however, such strategies have not been widely implemented in transportation systems such as highways and transit. Instead, these transportation modes have relied on a combination of special and general taxes and user payments to cover capital and operating costs, and for the most part have covered other costs (such as the costs of accidents, pollution, and other externalities) "off-line". While the specifics vary from state to state and among the metropolitan areas, it is generally agreed that the result has been a complex tangle of subsidies, cross-subsidies, and hidden costs in the surface transportation modes.

Partly because the prices consumers pay for transportation are not clearly aligned with costs, funding shortfalls have plagued both highways and transit for the past two decades.

For example, fuel tax revenues not only failed to keep pace with rising construction costs, but also failed to keep up with demand, as evidenced by vehicle miles of travel and other indicators, once the vehicle fleet became more fuel efficient in the 1970s and '80s. The results were soon evident in many states, as the gap between proposed transportation investments and available funds widened. Today, growing maintenance needs vie with needs for new investments, ongoing operations and services, mitigation of adverse environmental impacts, and safety improvements (an especially acute concern in states such as California, where the threat of earthquakes makes reconstruction and retrofits a top priority.)

In response to the transportation revenue crisis, many states have turned to a variety of sources for additional funding, including sales taxes, property taxes, developer impact fees, and special assessments. While tax increases and earmarked levies from these sources have provided some relief from the immediate pressures for revenues, the taxes also have been criticized for inadequately aligning fees with costs. For example, the use of sales tax for transportation finance has been questioned, not only because of the tenuous correlation between retail purchases and transportation consumption, but also on practical grounds because of sales tax volatility in the face of economic fluctuations. In many states taxpayers are strongly opposed to the expanded use of property taxes to finance government programs, and in several states property tax increases are strictly circumscribed, limiting the availability of this option. Developer impact fees are increasingly scrutinized by the courts, who are insisting on a close and proportional relationship between the fees exacted and the impact imposed. And special assessments are both limited in their scope in most states and are practical only where the properties or users to be assessed can afford the requested payments.

Fuel tax increases have been adopted in a number of states as well as by the federal government in the past few years, but in most cases the increases have fallen short of estimated revenue needs. As a consequence, in areas across the country, a search has been underway for additional ways to pay for needed transportation facilities and services. In some states, this has led to renewed studies of the actual costs of transportation, with an eye to setting taxes and fees to better cover the full costs. Additional fuel taxes and other use fees are being evaluated, along with increases in vehicle registration fees and licenses. In other cases the focus is on new sources of revenues to supplement or replace existing sources. New highways are being built as toll facilities in several states, including California, Texas, and Virginia. Added lanes on State Route (S.R.) 91 in southern California, built and operated as a public-private partnership, are the first in the nation to include a congestion pricing component. In the San Francisco Bay Area, higher peak period tolls matched by enhanced transit services have been under consideration for the Bay Bridge. In Washington State, the Department of Transportation, at the behest of the Legislature, has evaluated six private infrastructure projects, several incorporating congestion pricing options, and are currently refining a project proposal for Tacoma. In Oregon and several other states, policy-makers have considered vehicle registration fees which vary with the pollution emitted and/or the miles[1] driven each year.

In addition to concerns about transportation finance, several other factors have stimulated new interest in transportation pricing. First, congestion has persisted as a major urban and suburban problem despite programs of highway building and transit investment, and most observers have concluded it is technically, financially, and politically infeasible to build enough capacity to improve overall system performance. Second, transportation agencies are facing stringent requirements to reduce air pollution from motor vehicle emissions, and are searching for effective means of meeting this mandate. Third, greenhouse gas emissions, about twenty-five percent of which are from motor vehicles, raise concerns about the potentially negative consequences of climate change and point to the desirability of reducing fossil fuel use. Transportation pricing has the advantage that, properly applied, it can reduce congestion, lower emissions, and cut fuel use - at the same time it raises substantial revenues.

[1] Throughout this report we have used English units (miles, gallons, etc.) rather than metric units. There are two reasons for this: 1) transportation planning is still largely done in these units, and their use here is necessary for ready comprehension of the report, and 2) the California Air Resources Board EMFAC data used in this study report many items in English units. Those who wish to convert to metric units should use the following equivalencies: 1 kilometer = .62 miles; 1 kilogram = 2.2 pounds; 1 liter = .91 quarts = .23 gallons.

Previous discussions of transportation pricing often stalled when implementation was considered. One roadblock was that mechanisms for measuring costs and collecting fees seemed too complex and costly. New technologies, however, are rapidly removing barriers to the implementation of pricing strategies. For example, automatic vehicle identification (AVI) and electronic toll collection (ETC) using credit or debit cards now permit road pricing and parking pricing to be implemented easily and inexpensively. Vehicle monitoring technologies and other on-board devices are being developed which would allow charges for miles traveled or emissions produced to be read and billed at the pump or at periodic inspections. Roadside monitoring equipment that can identify a vehicle with very high emissions - or whose registration is out of date - is already in the demonstration phase. Because of these innovations, pricing strategies that at earlier times seemed out of the question are now being examined closely.

There remain, however, other significant concerns about the use of pricing as a policy instrument in transportation (and in other fields.) Many questions must be answered before new transportation pricing approaches are likely to achieve broad acceptance or move toward widespread implementation:

- Are people sensitive enough to transportation prices that significant changes in behavior would occur at economically justifiable price levels? Would pricing strategies be effective enough at achieving environmental, social, economic, and operational objectives to warrant the substantial political, legal, and institutional effort required for implementation?

- Would transportation pricing strategies have a disproportionate effect on some groups and interests, such as lower-income households? Could the impact of higher prices on these groups be mitigated in a way that is both ethically sound and economically justifiable?

- Would changes in transportation pricing policy alter land use and development patterns and location choices? What kinds of changes might result, and with what consequences?

- In light of historical resistance to tolls and fees and current attitudes opposing taxation, what is the chance that public opinion would support transportation pricing in the near future?

- What legal issues would have to be considered and dealt with in designing a specific program of transportation pricing reforms?

- What other organizational and administrative issues would have to be included in implementation plans for transportation pricing?

These questions are addressed in detail in the chapters that follow.

1.2 Transportation Pricing Measures: An Overview

The transportation measures considered in this study use prices to provide signals to consumers about the costs of their behavior, rather than attempting to steer behavior through the use of regulatory mandates regarding what may be produced or consumed. Examples of transportation pricing measures include, but are not limited to, tolls that vary with the level of congestion, parking charges set to reflect parking costs, vehicle registration fees set to capture the costs of emissions, fuel taxes set to cover the impact of carbon loading of the atmosphere, and road use fees set to cover the costs of building, maintaining, and operating the roadways and mitigating adverse impacts.

These transportation pricing measures preserve choices for consumers while providing them more accurate signals on the costs of their choices. Rather than barring certain actions or requiring others, transportation pricing measures indicate the cost of an action, then let consumers elect to pay that cost or take other action. Consumers who choose to pay the higher price generate revenues to cover the costs they impose, and these revenues permit corrective actions to be taken. Alternatively, consumers may choose a variety of means to reduce their costs directly or indirectly, for example by consuming less or by reducing the impact of their consumption.

The term "market-based" has come to be applied to many transportation pricing measures, and this "market based" approach is often contrasted to a "regulatory" or "command-and-control" approach. The "market-based" terminology is somewhat misleading, however, since only a few applications actually create or rely upon a true market. (Some variants, e.g., private toll road, might do so, but few projects to date are literally market-based.) Rather, the strategies are market-based in the sense that they are based on market principles, emphasizing consumer choice, user responsibility for costs imposed, and the linking of prices to costs. Furthermore, the contrast to regulatory approaches may not hold up, either, since in many cases regulations or other government interventions are needed to implement a transportation pricing policy; for some of the measures the set of regulatory changes may in fact be quite extensive.

For these reasons we have chosen to use the more general term "transportation pricing" to describe the measures considered in this study. However we do not address every conceivable pricing strategy. The measures which are the focus of the study use prices set to reflect a number of the costs imposed by the use of the transportation facilities or services. These costs may include the actual public and private costs of supplying facilities and services (such as the cost of building, maintaining, and operating a road, or providing parking), or they may include, in addition or in the alternative, the social costs of using the facilities and services - estimated costs of congestion and air pollution, for example. The measures are designed to give consumers the option of paying the "true" costs of their travel choices, or seeking less costly alternatives.

An additional category of strategies is sometimes discussed under the general rubric of transportation pricing: subsidies to transit, ridesharing, and non-motorized modes of travel. Although subsidies do use price to affect behavior, they do not do so in a way that sends signals to consumers about the costs being incurred on their behalf. Hence, we have not included these subsidy measures as a specific category in this study. Instead, we consider these measures as ones which might be implemented as complements to the measures considered here, primarily as possible mitigation for those who might be priced out of certain transportation options. We note, however, that subsidies to transit and other transportation alternatives are sometimes justified as "second-best" strategies to offset the impacts of auto subsidies, when rectifying the auto subsidies (clearly a more efficient approach) is deemed infeasible.

Five categories of transportation pricing measures have been analyzed in detail in this study:

- **Congestion Pricing** - Congestion is a major social and economic cost. With congestion pricing, vehicles would be charged a price, or toll, for traveling during peak hours on congested routes. Drivers who continue to travel on these routes during peak periods would pay more, but experience a faster, easier trip. Others could defer trips to off-peak hours, shift travel to less congested roadways, switch to transit, carpools, or vanpools, reduce trip frequency, or over time, alter their choices of location for home, work, and other activities.

- **Parking Charges** - Free parking is a large but mostly hidden subsidy for auto use. Charging users for parking would reduce this subsidy and might provide sufficient economic incentive to encourage some to switch to ridesharing or public transit. The price could be set by owners or operators (both private and public) to cover the cost of providing the parking, or could be designed as a public sector surcharge structured to roughly cover certain social costs of auto use, such as emissions, noise, or congestion. Charges could be imposed on all parking or only on commuter parking, and could be general charges or charges based on the time of day that the vehicle enters or exits the parking facility.

- **Fuel Tax Increases** - Current fuel taxes cover only a portion of the costs of motor vehicle use. Additional charges at the pump could be established to help pay for highway maintenance and improvements, fund other transportation facilities and services, cover the public costs of securing petroleum supplies, support programs for mitigating air pollution and greenhouse effects, and pay for a portion of accident costs. The resulting increases in at-the-pump charges also would induce some travelers to combine trips, reduce trips, take more public transit, and buy cleaner, safer, more fuel-efficient vehicles.

- **VMT Fees** - As an alternative way to pay for road use and related impacts, fees could be based on the vehicle miles of travel (VMT) driven in a particular period. The fees could be determined and collected in a variety of ways: as part of a vehicle registration fee, based on a schedule of typical miles driven by model year; as part of vehicle inspection-maintenance programs, based on actual odometer readings; or with the introduction of vehicle monitoring devices, based on actual accumulated VMT and charged at the pump or billed to the owner based on roadside monitor readings. VMT fees would be a better measure of overall road use, accident exposure, etc. than fuel taxes, because fuel use is only roughly related to emissions or to miles driven. With a VMT fee, motorists could be expected to drive somewhat less and take other steps to lower the costs of vehicle ownership and use. However, VMT fees could not be reduced by purchasing or using a more fuel efficient vehicle, and so would have relatively little impact on the type of autos that are owned or used.

- **Emissions Fees** - Emissions are another serious cost to society for which motorists pay only indirectly. Fees based on the emissions produced by a vehicle could be charged directly to each vehicle owner. As with VMT fees, emissions fees could be based on measurements for each vehicle or could be estimated based on vehicle characteristics; they could be paid as a vehicle registration fee, at the pump, or via separate billings. One example is a fee which would increase with the number of miles driven each year and the vehicle's measured emissions, reflecting the costs imposed on the public. A traveler using a highly polluting vehicle would pay more than a person who travels the same amount in a clean car. The traveler with the highly polluting vehicle would have an incentive to reduce emissions by improving the vehicle's emissions controls, replacing the vehicle with a cleaner one, or traveling less. Customers seeking to purchase a vehicle would have a monetary incentive to seek one with low emissions, and manufacturers would have an incentive to develop cleaner cars that could offer a cost savings to their purchasers.

For this study, numerous variations of each of these strategies were identified, and a set of prototypical strategies was developed. Each of these prototype strategies then was analyzed in detail for four major metropolitan areas, all in California - the San Francisco Bay Area, Sacramento, San Diego, and the South Coast (Los Angeles) region.

1.3 Analysis Approach

The analysis approach was designed to account for a number of the questions raised about transportation pricing measures. We began with an examination of previous work on transportation pricing. We then outlined the key issues to be addressed, which we identified through a series of meetings and discussions with key policy-makers and their staffs and with key interest groups, some of whom sat on an advisory committee established for the study. We then designed the set of prototype pricing measures to be evaluated. Using data and models calibrated for each of the four case study areas, we carried out detailed quantitative analyses to assess the measures' transportation impacts as well as their potential contributions to congestion relief, air pollution reduction, energy conservation, greenhouse gas emission reduction, and revenue generation. We examined the distribution of impacts on various income groups through a series of additional analyses using both

Census data and travel survey data. We used the modeling results together with theoretical considerations and empirical evidence to assess likely land use and location impacts. We then used a series of interviews, meetings, and discussion groups to assess the acceptability of the measures, considering their broad social, economic, and environmental impact, both to citizens and to decision-makers. Finally, we identified the steps that would have to be taken to implement the measures, including legal and institutional considerations.

As this description indicates, we used a variety of methods in carrying out the overall analysis:

- **Literature Searches and Reviews:** We reviewed the theoretical literature on the economics of transportation pricing and on travel and location behavior, and considered evidence on the performance of pricing strategies gleaned from implementation experiences and previous empirical studies, to establish the background for the study. We also used literature searches as the basis for our analyses of legal considerations and for identifying key land use impacts and implementation issues.

- **Interviews and Meetings:** We carried out interviews and participated in meetings and discussions to set up the framework for the policy analysis, as well as to obtain feedback on our findings from state and local agency staff members, elected officials, and representatives of the private sector. We used focus groups to explore citizen reaction to the measures and to identify possible mitigation measures and implementation strategies.

- **Modeling:** We set up advanced transportation models for each of the four case study areas, and used the models, along with travel survey and network data for each region, to evaluate the effects of alternative transportation pricing strategies on the number and length of trips made, the mode of transportation used, the destinations chosen, the time of day of travel, and, over the longer run, the number and types of vehicles used and the locations chosen for home and work. We also used the models to estimate the effectiveness of the pricing measures in obtaining congestion relief, emissions reductions, fuel savings, and revenue generation.

- **Data Analysis:** We used data from the US Census and from household travel surveys conducted in each of the four metropolitan areas to explore in detail the travel patterns by household type and income group, and applied the travel models in a data analysis framework to look at differences in the impacts of transportation pricing among income groups.

1.4 Organization of the Report

This report is organized in three parts, containing a total of thirteen chapters.

Part I, Introduction and Research Approach, presents this overview chapter as well as five others which describe the types of pricing measures considered here, consider the theoretical basis for transportation pricing, review previous experience with transportation pricing, identify key policy issues, and outline the analysis methods used in this study.

Chapter 2, **A Typology of Transportation Pricing Alternatives**, presents a general description of each of the five categories of measures examined in this study. For each type of measure, a description of key features and policy objectives is presented, variants of the measure are described, pricing levels or ranges are discussed, likely impacts are outlined, and the key issues raised are noted.

Chapter 3, **Travel Behavior and the Economics of Pricing,** begins with a discussion of what is known - and not known - about traveler responses to transportation prices. It next reviews key considerations in setting prices in transportation, then turns to the issue of policy evaluation, identifying the key factors that must be taken into account in assessing the benefits and costs of transportation pricing measures.

Chapter 4, **The Effects of Transportation Pricing: A Review of the Evidence**, presents a brief overview of the effects of transportation pricing measures studied or implemented both in the U.S. and abroad. Some of the evidence comes from of direct experience with pricing measures, but much comes from research and planning studies.

Chapter 5, **Framework for Policy Analysis,** spells out what transportation pricing means in the context of this study. The chapter presents an overview of key issues raised about transportation pricing, and discusses the implications of these issues for the study design.

Chapter 6, **Analysis Methods and Analysis Approach,** presents an overview of alternative approaches which could be used to examine the effects of transportation pricing measures, then describes the methods selected for use in this study to assess travel demand, congestion, emissions, fuel consumption and equity impacts. (An appendix describes the key travel models in STEP, the chief analysis tool used in the study,) The chapter also presents a detailed discussion of the specific assumptions made in the setting up the analyses of each of the five pricing measures.

Part II, Analysis, presents the findings of the modeling applications and impact assessments for the five categories of transportation pricing measures. It is organized into three chapters.

Chapter 7, **Impacts of Transportation Pricing Strategies**, examines in turn the impacts of congestion fees, parking fees, fuel taxes, VMT fees, and emissions fees for the four largest metropolitan areas of California - the Bay Area, Los Angeles, Sacramento, and San Diego. The chapter presents forecasts for a base year (1990-91) and a future year (2010) for each of the prototypical pricing measures as applied to each metropolitan area.

Chapter 8, **Equity,** assesses the distribution of impacts for a subset of pricing strategies. Using data from the US Census as well as from regional travel surveys, the impacts of pricing measures on different income groups, demographic groups, and geographic areas are examined. Case examples are presented for each region: congestion pricing in the Bay Area, parking fees in Sacramento, emissions fees in San Diego, and VMT fees in Los Angeles.

Chapter 9, **Land Use Impacts**, considers how various transportation pricing measures may affect consumers' location choices - where to live, where to work, where to shop, where to locate a business. The chapter discusses basic theoretical considerations, empirical evidence, and their implications, and presents findings from interviews with key actors.

Part III, Implementation Issues, identifies important factors that would have to be taken into account in moving ahead with transportation pricing policies such as these. It also includes a general assessment of transportation pricing measures and their prospects.

Chapter 10, **Politics and Public Opinion,** presents findings on citizen and policy-maker reactions to transportation pricing measures, derived from a series of focus groups, interviews, and small group meetings. The chapter begins with a discussion of the focus group research methodology used in the study to assess the political viability of pricing measures, then presents findings drawn from nine focus group meetings in which over 100 persons participated. (The list of topics, schedule, script and outline of questions used in the focus groups are presented in an appendix.) The chapter then presents findings from interviews and small group meetings. Both potential barriers to the implementation of pricing measures and possible ways to overcome the barriers are identified.

Chapter 11, **Legal Issues**, outlines the legal concerns that transportation pricing measures raise and presents a preliminary analysis of key issues that would have to be addressed in detail in designing a specific transportation pricing proposal. These issues include the current ban on tolls on most federal-aid highways and the implications of designing the transportation pricing measures as a tax or an impact fee. In addition, the chapter discusses a number of specific considerations raised by constitutional and statutory provisions in California, especially the super-majority requirements and other restrictions on tax increases and expenditures imposed by voter initiatives.

Chapter 12, **Implementation,** presents an overview of the elements of an effective implementation plan, including clear assignments of responsibility for plan development and implementation, a reasonable schedule for action, procedures for monitoring performance, enforcing policy, and making revisions as necessary, and adequate funding to support the process. Specific issues in designing an implementation plan for the types of transportation pricing measures are discussed, including implementation steps and time frame, possible assignments of lead responsibility, and technology that might be required in some implementation approaches.

Finally Chapter 13, **Assessment**, offers a synthesis and interpretation of the findings.

1.5 Summary of Findings

The study shows that transportation pricing measures have considerable potential to simultaneously reduce adverse impacts of transportation and generate significant revenues. In essence, the quantitative elements of the work confirm that pricing strategies could yield important efficiency benefits; in the four California areas alone, transportation pricing measures could produce billions of dollars of savings each year in reduced delay, air pollution, and energy use. Land use impacts would be modest but mostly positive, with increased densities and more efficient development patterns a likely result. For most transportation pricing measures Implementation could proceed in a number of ways, involving public agencies, the private sector, or both, and utilizing either advanced technology or low tech approaches. Program designs keeping administrative costs to a small fraction of revenues could be easily fashioned, assuring very high cost-effectiveness. Net revenues could be used to add new transportation facilities and services, to cover the costs of pollution abatement and accidents, or to otherwise upgrade or enhance transportation facilities and services. In cases where pricing measures would have adverse distributional consequences for lower income households, a portion of net revenues could be used to mitigate or ameliorate these impacts.

Perhaps a bigger question is whether the public would accept higher direct costs in return for a large, but more abstract, benefit to society, and in many cases, to themselves. Focus group and interview results suggest that members of the public would be far more supportive than their elected officials have thought likely, especially if information on the measures and other alternatives is provided. Tying revenues to transportation improvements and providing public oversight are two elements that would increase public support for pricing measures. Still, without more visible, intensive, and organized support for a change than has appeared to date, elected officials are likely to remain skeptical about pricing measures.

More work remains to be done in future studies. This study has examined prototype measures; the next steps are to select specific measures for further consideration and to proceed with detailed analyses. Once specific measures have been selected, further analyses appropriately would include the detailed design of an implementation strategy (only outlined here and on developing detailed cost and revenue projections tied to the measures' implementation plan. An active program of public information and public involvement would be a necessary component of any actual implementation effort.

2. A Typology of Pricing Alternatives

2.1 Overview

Diverse strategies for improving the pricing of transportation have been proposed in recent years. Among them are conventional tolls; use of congestion pricing techniques to allocate space on crowded urban highway facilities; area entry tolls charged for bringing a vehicle into a congestion-prone or environmentally sensitive area; cost-based or impact-based pricing of parking; elimination of favorable tax treatment for subsidized parking; gas tax increases to cover the costs of externalities such as accidents and emissions, encourage fuel conservation, and/or generate additional revenues; taxes, fees, and rebates based on the fuel efficiency of vehicles, the type of fuel they use, and/or their emissions characteristics; emissions fees added to the cost of vehicle registration in areas which have not attained air quality standards; and emissions fees based on the amount of pollution actually generated in the use of each vehicle. Of the many possibilities, five types of transportation pricing measures are examined in detail in this study:

- congestion pricing
- parking charges
- fuel tax increases
- VMT fees
- emissions fees.

Within each of these categories a number of specific strategies could be defined; in turn, many of these strategies could be implemented in a variety of ways. In this chapter we review some of the key options. We present a general description of each type of measure and its key objectives; identify variants of the measure; describe typical pricing levels, revenues, and costs; list major impacts; and outline key issues that are raised by the measure. The review is intended to set the stage for more detailed discussions in later chapters.

2.2 Congestion Pricing

Description and Key Objectives

Congestion pricing refers to prices, or tolls, which are imposed on facilities experiencing significant delays. The prices are implemented at times of day when congestion is prone to occur and are set at levels sufficient to reduce the congestion by impelling some travelers to use other routes, travel at other times of day, switch modes, switch destinations, or in some cases to reduce trip-making.

The key objective of congestion pricing is to reduce time losses at bottlenecks in the transportation system and hence increase economic efficiency (reduce social cost). Other objectives may include: 1) to prevent queues at bottlenecks from expanding to hinder flows on adjacent facilities; and 2) to smooth traffic flows for increased fuel economy, reduced pollutant emissions, and improved safety.

Congestion pricing works because the physical process behind congestion is highly non-linear and because not all travelers are equally sensitive to the cost of travel. Prices at a bottleneck or in a generally congested system can be raised to divert the most cost-sensitive travelers, and it generally is sufficient to achieve a 5-10 percent reduction in traffic on the affected facilities during the targeted period.

Variations in cost sensitivity arise from two distinctly different phenomena. First, a traveler will value each trip differently depending on such factors as the degree of flexibility in the timing of the trip and the extent to which the origin and destination activities are discretionary. For example, travelers will pay higher per mile costs for airport access trips (where there may be a severe penalty for missing a flight) than for, say, local recreational or shopping trips. Thus, one effect of pricing is to clear facilities of less important trips in favor of more important trips. (Note that importance here is measured by the traveler's willingness to pay for the trip.

Variations in cost sensitivity also stem from differences in income. High income individuals have greater ability to pay a given price in a given situation than low income individuals. Hence, on average, a greater proportion of low income travelers will be affected by any pricing scheme.

Overall, then, congestion pricing will have the greatest effects on low value trips and low income people. Trip shifting is not limited to low income travelers - many "low value" trips are made by people with high incomes - but the income effect is strong enough to raise significant questions about the distributional equity of transportation pricing. Equity analyses, and assessments of the need for and effectiveness of mitigation measures, must be central to any assessment of implementation feasibility.

Variants of Congestion Pricing

Some of the variants that have been suggested for congestion pricing include the following:

- Charge vehicles fees for the use of any significantly congested facility, during the peak periods only or at whatever hours congestion occurs
- Price only key facilities such as bridges and tunnels (gateway facilities)
- Provide a guaranteed free-flow lane to bypass bottlenecks for a fee during peak travel hours
- Permit any vehicle to use an HOV lane for a fee
- Exempt certain classes of vehicles from the fee, e.g., zero emissions vehicles
- Exempt carpools and vanpools from the fee.

Congestion Pricing Levels, Revenues and Costs

Economists generally advocate setting the price at the short run marginal cost (which under optimal pricing is equal to the long run marginal cost). Some propose 'dynamic" pricing, i.e., prices that change as a function of actual traffic conditions including accidents. Others recommend a simpler, though perhaps less accurate, form of pricing for "typical" levels of congestion, with periodic adjustments. However, in practical applications prices can be expected to deviate from this level. A simple approach often advocated by transportation specialists is to set prices to maintain level of service (LOS) D - smooth but heavy flow at or near the speed limit.

Actual prices could range from a penny a mile to a dollar a mile or more, with specific prices for a roadway link depending on the conditions there. In most metropolitan regions, the typical motorist traveling during the peak would incur costs averaging over the course of a trip from zero to 15 cents per mile. Prices would have to be adjusted periodically in order to account for shifts in demand, changes in supply, and the effects of inflation.

Even at the low end of this range, congestion pricing could generate significant increments of funding. A variety of uses of the revenues could be devised, subject however to constraints imposed by federal or state law. Among the uses commonly proposed - not all of which are necessarily economically efficient - are the following:

- Pay for the costs of maintaining and operating the facility, including costs of toll collection, planning and administration, and enforcement
- Earmark funds for expansion of the priced facility to accommodate demand (or expand other facilities in the corridor)
- Add toll revenues to existing transportation accounts to expand revenues available for the overall transportation program

- Earmark funds to provide alternative means of transportation (or telecommunications alternatives) for those priced off the facility or system, to cover added costs to other modes etc.
- Use toll revenues to replace other funds, e.g., retire a transportation sales tax and use toll revenues instead (no net revenue increase).

Costs associated with the implementation of congestion pricing include the costs of toll collection and the costs of enforcement. In addition, depending on the design of the application, roadway monitoring systems and variable message signs may be needed. An ongoing public information program will be necessary, at least in the first applications.

Potential Impacts of Congestion Pricing

As its name implies, congestion pricing is intended primarily to reduce congestion and associated costs, especially travel time losses. Other social, economic, and environmental costs also should be reduced, including fuel consumption and other vehicle operating costs, air pollutant emissions, and greenhouse gas emissions.

Time savings and vehicle operating cost reductions are of economic benefit to both travelers and to freight operators. Congestion relief also produces broader social benefit, often saving time and expense for others affected by congestion and its byproducts.

The elasticity of VMT with respect to congestion price has been estimated to be on the order of -.05 to -.1.[1] This is quite low, reflecting the fact that some travelers will change time of travel rather than reduce VMT. The elasticity of emissions with respect to congestion pricing is higher, about -.15, and the elasticity of fuel use is higher yet, on the order of -

[1] Unless otherwise stated, elasticities reported in this chapter are derived from work by Harvey for San Francisco Bay Area agencies.

.2. These higher elasticities reflect the fact that shifting trips to less congested periods results in an improvement in the conditions under which they are made.

Because the impacts of congestion pricing result from a variety of travel changes, including changes in route choice (losses or gains from parallel facilities), time of day of travel (hence activity scheduling and peaking), mode choice (increased demand for alternatives and service impacts), and destination choice, a variety of secondary impacts could result. Route choice and destination choice may have land use and economic development impacts (via choice of location for activities such as shopping in the short run, and work in the longer run; impact on sales in the short run, land development in the long run). Diverted traffic may produce its own set of benefits and costs. What is done with the revenues could make vast differences in the ultimate costs and effectiveness of a congestion pricing program.

Finally, differential incidence of impacts must be noted. Travelers with high values of time will benefit; those with low values of time will change behavior if the alternative is preferable to paying the new price, or will be forced to pay more if they have no acceptable alternative.

Key Issues Raised by Congestion Pricing

Legal restrictions are a key barrier to congestion pricing and more generally to tolling of roads. Since the early years of the century, federal law has prohibited the imposition of tolls on federal aid highways, with specified exceptions for toll bridges and tunnels, roadways originally built as tollways and, since 1991, certain federally approved congestion pricing demonstration projects. State laws also restrict the imposition of tolls and the amount of toll that can be charged (e.g., in California, bridge toll increases require currently require state legislation). Finally, the use of revenues from tolls may be restricted or designated for specific categories of expenditure (as is the case, e.g., with the toll revenues from the San Francisco-Oakland Bay Bridge).

Public acceptance of the congestion pricing concept is a second major issue. Opposition to increases in taxation or fees for government services appears to extend to toll increases as well. Lack of experience with congestion pricing also complicates public attitudes toward the concept. Congestion pricing has rarely been used in highway or transit applications, although many consumers do have experience with variants of congestion pricing in transportation. Taxis, for example, often charge by both time and mileage; the time component works much like a congestion toll. In addition, airlines use a rough form of congestion pricing, charging higher fares during peak summer and holiday seasons and at peak times of day. Consumers also have experience with peak/off-peak pricing in telephone service and electric utilities, where both time of day and day of week price differentials are commonly used. Whether the connections can be drawn between congestion pricing for roadways and these established, accepted applications is not certain.

Social equity is a third major issue. Potential equity issues may arise depending on users' ability to pay and their ability to make use of other travel choices. The effects of congestion pricing on low income groups, persons who use their cars for their jobs, and persons whose employers require that they report to work at a fixed time during the peak travel period all have the potential to become lightning rods for opposition to congestion pricing.

Additional concerns that are raised in discussions of congestion pricing (and tolling) include:

- delays caused by toll collection, if automated systems are not used
- how to set, monitor, and from time to time adjust prices
- how to handle the transition from the peak to the off-peak toll level
- mode shifts and their impact on other modes' operation, revenues, etc.
- economic and social impacts of traffic diversion to or from priced routes; effects on local communities, neighborhoods, businesses
- land use and economic development issues raised by accessibility changes, i.e., increased dollar costs and/or reduced time costs to specific locations
- impact on freight traffic and on port and airport access.

While none of these concerns is necessarily a barrier to congestion pricing, and indeed some of the impacts may be favorable, each would need to be addressed.

2.3. Parking Charges

Description and Key Objectives

Free parking is a large but mostly hidden 'subsidy" for auto users. It has been estimated by the U.S. Department of Transportation and others that 90 percent or more of the parking spaces designated for commuters, and an even higher percentage of the parking spaces designated for visitors, clients, and customers, are provided without charge to the user. Indeed, except in central cities and a few other locations, parking charges are fairly rare. However, parking is often quite expensive to provide (costing $5000 to $10,000 or more for a surface space and $10,000 - $20,000 or more for a space in a structure). Charging users for parking would reduce the auto subsidy and might provide sufficient economic incentive to encourage some to switch to ridesharing or public transit.

Specific policy objectives vary with the kinds of spaces to be priced (especially, employee parking vs. all parking) and with who is doing the pricing - a private owner/operator or a public regulatory body. Owner/operators presumably evaluate the costs of providing the parking, including tax consequences, consider what the competition is doing, and assess the tradeoffs that may be involved in imposing pricing (including administrative costs, potential backlash from tenants and customers, and so on.) Public regulatory bodies might instead design a tax or surcharge structured to roughly cover certain social costs of auto use, such as emissions, noise, or congestion, or to reduce peak period congestion by focusing on commuter parking.

Individual operators' pricing strategies may be ineffectual if competing spaces offer lower prices or none at all. Policies implemented in parking garages and lots will not work very well if a large supply of unpriced on-street spaces is available nearby. Local governments can meter or restrict the use of on-street spaces, but this may not have the expected impacts if private operators respond by providing free off-street parking. Government does have the authority to regulate much privately owned parking, however, and could do so through direct means (e.g., levying a tax or an impact fee on parking spaces within its boundaries) or indirectly, by means of incentives or disincentives directed toward private owners of parking (e.g., treating free parking provided to employees as a taxable benefit; requiring parking costs to be separately identified and optional in future leases.) One way government could promote market rates for parking would be to remove regulations requiring its ample provision in most developments.

Free or discount parking is commonly used today to subsidize certain travelers, e.g., carpoolers and park-and-ride users. In this study, we pay only secondary attention to these parking subsidies, focusing instead on strategies designed to remove subsidies which mask the cost of auto use.

Parking Pricing Variants

Parking pricing strategies include the following:

- fees for all parking
- elimination of discounts for daily or monthly parking
- flat hourly rates with no maximum
- fees or higher rates for parking in excess of, e.g., three hours
- free parking for shoppers only with validation
- lowered fees for high-occupancy vehicles
- bans on provisions of free parking to employees

- parking cash-out provisions
- commute allowances rather than free parking for employees
- reduction or elimination of tax deductibility for employee parking
- parking taxes and surcharges (with or without exemptions for HOVs and short term parking)
- peak period parking surcharges
- requirements that parking be identified as a separate cost item in rental agreements and leases and/or that parking rental be optional

A major consideration is whether to apply these strategies to all parking spaces or to spaces used by particular user groups such as peak period travelers.

In addition, parking supply strategies could be used as quasi-pricing strategies either on their own or in tandem with direct pricing approaches. Strategies that restrict parking supply can be thought of as imposing a "shadow price": scarcity will increase the time to find a parking space as well as the access time to parking, resulting in shifts in mode, time of travel, or destination. In some cases parking supply strategies also may produce market responses in the form of increased parking charges. Strategies in this category include:

- eliminating local government parking requirements, allowing building owners to determine the parking needed based on market considerations
- establishing parking maxima (reflecting, e.g., traffic capacity or environmental carrying capacity) instead of or in addition to minima in parking codes, zoning ordinances, etc.
- establishing parking caps or parking freezes for a jurisdiction or area
- restricting hours of operation of parking facilities (e.g., to after 9:30 am) to reduce consumption of spaces by commuters
- establishing time limits and prohibitions on meter feeding to restrict all-day parking and increase parking availability for short-term users
- fees for, and/or bans on, non-resident parking in residential neighborhoods

- reserving close-in parking for HOVs (increasing access time for others)
- reserving close-in parking for short-term users (increasing the access time for long-term users, primarily employees).

The price effects of these parking supply measures are highly uncertain. It is reasonable to expect parking operators to increase the price they charge when parking supply is restricted, and there is some evidence to indicate that this in fact occurs (though slowly.) Similarly, private operators may be more inclined to charge (pr charge more) for parking when they are not competing with a large, publicly owned and subsidized parking supply. On the other hand, artificial constraints on parking supply and price can backfire or be circumvented, as consumers and suppliers both seek ways to increase the effective supply of parking. For example, operators may implement tandem or stacked parking to increase the capacity of facilities; entrepreneurial homeowners may rent out driveway space.

Parking Pricing Levels, Revenues and Costs

Parking prices could be set to reflect or approximate market rates or to recover costs of land, improvements, maintenance and operation. In a more regulatory style, parking prices could be set to reduce travel to a predetermined level, to make transit and other modes cost competitive, or to raise a specified amount of revenue.

A parking pricing strategy should pay for itself and generate surpluses. This does not mean that all parking can be priced effectively. Private providers may decide that free parking is important to attract tenants and customers. Public agencies may decide that pricing streets or lots with light demand is not an effective use of resources, consisting more for parking personnel than revenues would justify. A well designed strategy would price parking in those locations where doing so would be cost-effective..

Use of revenues accruing to public agencies may be restricted by provisions in parking codes, bond provisions, or tax and spending limitations. Private providers also may have restrictions in financial instruments which dictate the use of revenues, but otherwise can use the revenues as they wish.

With supply restrictions there is not the same potential for revenue production (since price responses to scarcity are uncertain), except possibly in cases where parking formerly used for discount employee parking would be heavily used for short-term parking at higher rates. Costs of implementing, monitoring, and enforcing the strategies can be substantial.

Potential Impacts of Parking Pricing

Parking pricing has been found to be effective in reducing drive-alone commuting. In Bay Area studies, employee parking price elasticities have been found to be in the range of -.1 to -.2. Parking pricing also would reduce vehicle use for other trip purposes, resulting in trip consolidation, changes in destination, higher vehicle occupancy, and use of alternate modes of travel. Price elasticities are in the range of -.4 to -.6 for non-work travel.

Most analyses assume the traveler bears the cost of parking, all else being equal. Obviously if another party pays the cost (e.g., if a building owner or employer absorbs the costs of a parking surcharge or impact fee rather than passing it through to the employee or customer) the effect will be misstated. The use of commute allowances, which may be an alternative to free parking in some instances, can be taken into account as an income increase, but if the income increase is less explicit or is extended to some travelers and not others it again will be difficult to produce an accurate estimate of impact.

Strategies that affect only a subset of the parking supply, e.g., parking restrictions that apply only to large employers or only to off-street parking, have the potential to cause parking to relocate or spill over into unregulated areas, a behavior not captured in models but readily observed. For this reason parking controls and enforcement may need to be rather widely scoped.

Labor agreements may include parking provisions or otherwise make changes in parking a matter subject to "meet and confer" rules. In general, employee resistance to parking pricing can be expected unless there are clear benefits conferred in return or other obvious needs for the price imposition.

Parking may be included as part of a lease agreement with or without being separately identified as a cost item. Some leases may be long term and difficult to modify, and opposition to policies which intrude into leasing arrangements may be considerable.

Developers sometimes say that lending institutions strongly prefer plentiful and easily accessible parking and consider restricted or highly priced parking a problem. They also say that it is much harder to market space in a building without parking or with strict parking restrictions, all else being equal. There is anecdotal evidence to support both concerns but not enough to draw firm conclusions about the overall impact of parking pricing on development loans or marketability.

Parking pricing may in some cases increase the effective supply of parking for shoppers by freeing up spaces that had been occupied by workers. This may result in increased non-work trip making and VMT to the affected area, and increased economic activity.

Key Issues Raised by Parking Pricing

Local governments' subdivision and zoning ordinances typically require provision of substantial amounts of off-street parking and in some cases require that it be provided free of charge. Policies that restrict parking or discourage its use are a major change in direction. In some communities the two sets of policies coexist despite the apparent conflict; in others there is resistance to policies that would alter the preference for plentiful and easily accessible parking.

Increases in parking price or restrictions on parking supply may result in parking spillover into other areas or unaffected facilities. Spillover parking can be a great annoyance to residents of neighborhoods near major trip generators (and in some cases, to the owners of off- street parking such as grocery stores and shopping centers).

Re-use of surface parking lots is a possibility in some communities but not in others, either because there is little market for development or because floor-area ratio maxima or other density/intensity regulations would prevent additional development. Re-use of parking garages can be done in some cases (primarily for above-ground structures, street frontage, etc.) but there are both structural issues and design problems to contend with.

Local governments are sometimes reluctant to implement parking pricing or other parking management policies unless neighboring jurisdictions do so as well, fearing a competitive advantage would be created for the area continuing to offer free parking. In particular, local governments are likely to be concerned about parking charges affecting shopping, especially in areas with weak economies (where shops may be faltering) or in areas with where there are perceived to be few or no practical alternatives to the car for shopping trips. Opposition may be mounted by merchants, shopping center interests, and consumers

Legislation would be needed to alter income tax deductibility of parking. Legislation also would be useful in providing or strengthening other policy directives (e.g., parking cash-out policies), but is not strictly necessary for many of the strategies.

2.4. Fuel Tax Increases

Description and Key Objectives

Both federal and state fuel taxes are currently levied on transportation fuels, but these fuel taxes cover only a portion of the costs of motor vehicle use. Additional charges at the pump could be established to pay for additional highway maintenance and improvements, fund other transportation facilities and services, cover the public costs of securing petroleum supplies, support programs for mitigating air pollution and greenhouse effects, and pay for a larger portion of accident costs, policing, and emergency services. The resulting increases in at-the-pump charges also would induce some travelers to combine trips, reduce trips, take more public transit, and buy cleaner, safer, more fuel-efficient vehicles.

Fuel Tax Variants

The fuel tax rate itself is the principal element that could be varied. Most fuel tax increases under discussion have been on the order of 5-10 cents per gallon, but increases $2-$3 per gallon would be necessary to bring U.S. fuel taxes up to the levels paid in Europe or Japan.

Fuel taxes could be levied on a per-gallon basis, as is done in most places today. Another option would be to increase the sales tax on fuels or to move to a hybrid tax structure.

Fuel Tax Pricing Levels, Revenues and Costs

A wide range of estimates of the externality costs of urban auto use have been published over the last two decades, with most authors noting the difficulties of producing reliable numbers. Translated into equivalent costs per mile, externality costs are typically estimated to range from a perhaps half a cent to nine cents a mile, or about $.12 - $2.25/gal. Some sources estimate much higher costs, on the order of 20 cents per mile. Note that many of these externality costs are not strictly related to VMT.

At current prices fuel costs per mile average about 5.5 cents, with the highest fuel costs for personal vehicles at about 15 cents per mile. During the last energy crisis in the late 1970s, fuel cost soared to about 20 cents per mile (in current dollars) for the average vehicle. Hence fuel taxes increased to account for mid-range externality costs would fall within the observed range of actual costs per mile experienced by U.S. drivers.

The costs of implementing a fuel tax increase would be relatively low because the mechanisms for collecting the taxes are in place. However, especially if the fuel tax increase were large, collection, monitoring and enforcement costs could increase. Concerns have been raised by law enforcement personnel about the potential increase in tax evasion if very high taxes were imposed. Fines and penalties could be set to recover costs as well as to act as a deterrent.

Revenues would increase by the amount of the tax minus losses due to shifts to other modes of transport and reductions in VMT. Over time, improvements in the fuel efficiency of the vehicle fleet would erode revenues unless adjustments to tax rates were made. Note that if the objective of the tax is to recover the cost of externalities, the tax would require periodic adjustment as externality reductions and costs change.

Potential Impacts of Fuel Taxes

Estimates of elasticities of fuel use with respect to price are in the -.2 to -.3 range. In the short term, reduced fuel use comes primarily from a decrease in VMT. In the longer term a portion of the reduction is due to the use of more fuel-efficient vehicles.

Analysts disagree over the long-term price elasticity of the fuel efficiency of the vehicle fleet. Estimates range from -.05 to -.22. The lower estimate would mean that over the long term, most of the impact of a fuel tax would continue to come from VMT reductions. The higher elasticity would mean that in the long term the impact on VMT would decline and fuel savings would increasingly be due to the fleet being more efficient. The consequences for pollutant emissions and congestion relief are smaller with the high-elasticity scenario than with the low-elasticity scenario.

Key Issues Raised by Fuel Taxes

Consumer resistance to tax increases and legislative hesitancy to impose them are significant barriers to a gas tax increase, whether established at the federal or state level or permitted via local vote, as a gallonage tax or a sales tax on fuel. If the proposed tax increases would be substantial, the resistance and hesitancy can be expected to be large. Fuel suppliers and gas station owners can be expected to voice strong concerns about the potential loss of business and jobs due to lowered demand for fuel. The characterization of at-the pump charges as fees rather than taxes may remove certain legal complications but is unlikely to change basic concerns about government-imposed costs and their impacts.

Fuel price increases designed explicitly to reduce consumption have been found to be less acceptable to public officials or to the general public than increases designed to finance infrastructure plans. Hence expenditure plans for the revenues could be critical elements in offsetting concerns about price increases.

Concerns about equity, especially with regard to low and moderate income commuters, those with poor alternatives to the auto, and those whose business or job depends on heavy amounts of travel would be major issues. Concerns about geographic disparity of impact (e.g., impact on relative economic competitiveness) also would arise if fuel price increases were to be imposed at local option; for this reason these taxes are almost always discussed as regional or statewide.

Changes in the vehicle fleet to offset fuel price impact might result in changes in safety (e.g., the incidence of fatalities and injuries might go up with smaller, lighter cars; total accidents might decline because of price-induced VMT reductions.)
Very large fuel price increases probably could not be offset with currently available vehicle technology and would link this strategy to the debates over alternate fuels and new vehicle technologies.

Some additional issues that might be raised about substantial fuel tax increases include the following:

- whether gas stations will alter their prices to offset the sales reductions likely to result from higher fuel taxes.
- the potential for tax avoidance via out-of-state purchases, under-reporting of sales and use, etc.
- possible increases in black market activities, smuggling, hijacking of fuel shipments, nonpayment for refueling, etc.

2.5. VMT Fees[2]

Description and Key Objectives

Fees based on the number of vehicle miles of travel (VMT) driven in a particular period have been suggested as a means of charging for road use as well as for the externalities of vehicle use. VMT fees would be a better measure of overall road use, accident exposure, etc. than fuel taxes, because fuel use is only roughly related to miles driven. Conversely, VMT fees would be a rough measure of fuel use impacts. VMT fees are only

[2] For purposes of this discussion VMT and VKT can be used interchangeably. See footnote 1 in Chapter 1 for conversion factors.

indirectly related to emissions because of the high share of emissions due to cold starts, evaporation, etc. VMT fees also are only indirectly related to congestion impacts, since the VMT may or may not be generated under congested conditions.

VMT Fee Variants

Major variations would involve the magnitude of the fees, the basis for their calculation, and the frequency of collection.

The magnitude of the fees could be set to raise a specified amount of revenues or could be based on an estimate of VMT impact. The former requires a VMT estimate for the area in which the fee will apply (revenues to be raised divided by total VMT equals the fee per VMT); the latter requires an estimate of the cost of impacts on a per-VMT basis. In the short term, a half-cent VMT fee would be the equivalent of a ten cent gas tax.

VMT fees could be based on average VMT estimates for a given vehicle age, or could be based on actual VMT. In the latter case, actual VMT could be reported by the owner (e.g., at the time of vehicle registration), read from the odometer at the time of vehicle inspection-maintenance testing, or measured and reported using other forms of on-board or off-board technologies. In the future, for example, the introduction of vehicle monitoring devices might make it possible for VMT charges based on actual accumulated VMT to be charged at the pump or billed directly to the owner.

Additional variations could be introduced to address certain social or economic concerns. Among the variants are:

- a means-tested ("lifeline") rate for low income travelers

- exemption of a portion of the VMT (e.g., first 5000 miles) from fees to provide for a "lifeline" level of travel
- different rates for private and business travel
- fees levied, in part or in whole, on a household basis rather than a vehicle basis
- surcharges on very high levels of annual VMT (e.g., over 20,000 miles per vehicle or per adult).

In addition, a VMT fee could be looked at as an alternative to the gas tax or other taxes now used for transportation (sales taxes, property taxes, etc.) Replacing the gas tax with a VMT fee seems especially attractive when the possibility of a fleet operating on a variety of fuels, including electricity, is considered.

The frequency with which the fee is collected may make a difference to its utility in reducing VMT and associated impacts versus a more straightforward revenue measure. An annually levied fee - especially if it is modest in magnitude - would be easy for the vehicle owner to forget in day-to-day usage decisions, making it more difficult to rely on such a mechanism to reduce VMT. Immediately-variable user charges - such as at-the-pump fees - would be likely to have a more direct effect on day-to-day behavior.

VMT Fee Levels, Revenues and Costs

Appropriate price levels and resulting revenues for a VMT fee would depend entirely on its objectives (raise revenues for infrastructure maintenance and expansion, capture externality costs, replace other taxes, etc.) Possible uses of the revenues also would vary with its objectives and design.

Costs of implementation would depend in large part on whether the program would be a simple add-on to an existing program such as vehicle registration or inspection/maintenance, or a new program designed specifically to collect, monitor, and enforce the VMT fee. In addition, program designs requiring new technologies (on-board monitors, at-the-pump readers, etc.) would be more costly but potentially more accurate and effective than the other options.

Potential Impacts of VMT Fees

Bay Area and Los Angeles studies indicate that the price elasticity of VMT with respect to a VMT fee is in the -.2 to -.25 range. In response to a VMT fee, motorists could be expected to drive somewhat less and take other steps to lower the costs of auto ownership and use. However, VMT fees could not be reduced by purchasing or using a more fuel efficient vehicle, and so would have relatively little impact on the type of autos that are owned or used.

As noted earlier, benefits would accrue from reduced air pollution, fuel use, and greenhouse gas emissions, but the relationship between VMT and these factors is a rough one.

Key Issues Raised by VMT Fees

VMT fee proposals will undoubtedly raise concerns about consumer resistance to fee increases and legislative hesitancy about imposing them. if the fee is a replacement for an existing tax, however, opposition may diminish. Concerns about impacts on low income households also could be expected, though again would lessen if the fee is a replacement for existing taxes.

Enforcement issues would be another concern. For example, if the VMT fee is based on odometer readings, odometer tampering and odometer malfunction will be issues. In addition, VMT fees paid with vehicle registration could lead to an increase in unregistered vehicles, and if the fees vary by location (e.g., are implemented on a regional basis), to falsified out-of-state or out-of-region addresses for registration.

2.6. Emissions Fees

Description and Key Objectives

Emissions fees charge motorists directly for the costs their emissions impose on society; their objective is to encourage motorists to reduce emissions. Motorists could reduce their fees by improving the vehicle's emissions controls, replacing the vehicle with a cleaner one, or traveling less. Customers seeking to purchase a vehicle would have a monetary incentive to seek one with low emissions, and manufacturers would have an incentive to develop cleaner cars that could offer a cost savings to their purchasers.

As most commonly proposed, emissions fees would vary with emissions per mile and VMT. The emissions per mile estimate could be based on government data on fleet emissions characteristics by vehicle age, or might be based on direct measurement. VMT likewise could be based on government estimates by vehicle age, or could be taken from odometer readings or other measurements.

Emissions Fee Variants

The method of calculating the emissions fee, the means by which it is collected, and the frequency of payment are major variables. For example, an emissions fee based on the vehicle's measured emissions could be determined as part of an annual or biennial test, basing miles driven on an odometer reading done at the same time. The fee then could be paid as part of the inspection fee or could be billed separately. Alternatively, the fee could be based on a look-up table classifying vehicles into emissions categories (perhaps determined by the emissions standards for the vehicle's model year and its age) and typical mileage for the vehicle age, and directly billed as part of the vehicle registration. A third option would depend on new technologies: on-board equipment would log emissions and the totals would be read and billed periodically, perhaps at the pump or through direct billings.

Fees could be based on one or more pollutants, or one key pollutant could be the used as the basis for calculating the fee. While it would seem to be more rigorous to account for all pollutants in the fee calculation, the reality is that this is extremely difficult to do properly. The varied interactions of VOCs and NOx to form smog, the fact that the effects of emissions depend not just on their volume but on when and where they are released into the atmosphere, and the role of cold starts and evaporative emissions in the overall level of auto emissions are just some of the complicating factors. Taking all these factors into consideration, a simple method for estimating the fee may be more in keeping with its overall level of accuracy.

A number of other variants could be considered:

- a new car fee or rebate according to the vehicle's specific emissions characteristics
- a fee that depends on emissions levels but not mileage, e.g., a super-emitter fee or clean car rebate
- a fee based pm am estimate of miles driven in the "home" air basin, with provisions for exempting or rebating fees for out-of-region VMT
- means-tested ("lifeline") fees
- exemption of a portion of the VMT (e.g., first 5000 miles) from fees to provide for a "lifeline" level of travel.

Emissions Fee Levels, Revenues and Costs

Setting the price for emissions is a fairly complex undertaking. In a typical procedure, the cost of air pollution would be determined for each area in which the fee is to be applied. (Costs would include health costs, productivity losses, and property damage.) The portion of these costs due to motor vehicles then would have to be determined, using emissions inventories and possibly dispersion models (to account for spatial and temporal factors and differential exposure levels.) An estimate of total VMT would then be needed to determine a per-mile emissions fee. Costs would have to be recalculated frequently to account for changes in emissions inventory, vehicle fleet composition, and VMT.

Estimates of the costs of air pollution vary widely. Calculations expressing the costs on a per-mile basis range have produced results ranging from 0.2 cents per mile to 8-10 cents per mile depending on the region and the input data used.

Revenues would depend on the fee level and the extent to which exemptions, rebates, etc. are part of the program design. Characterized as a fee for emissions, the revenues would likely be earmarked for pollution clean-up programs (which could range from programs to enforce emissions controls to programs to retire dirty vehicles to commute alternatives programs.)

Some versions of the emissions fee could impose especially high costs for additional vehicle maintenance or vehicle replacement, though there also may be cost savings associated with better maintenance or a better quality vehicle. Government costs would depend on whether the fee was added onto an existing program or a new program created, but in any event enforcement costs would be a major consideration for such a program, especially if the emissions fees depended on vehicle inspection/maintenance test results and odometer readings. Fines and penalties presumably could be established such that enforcement activities would be self-supporting.

Potential Impacts of Emissions Fees

Benefits of an emissions fee would accrue from reduced air pollution. Beyond that, the effects on VMT, fuel use, congestion, and greenhouse gas emissions would depend heavily on the specific design of the program.

Emissions fees are likely to reduce VMT by a small amount. Bay Area studies, for example, estimate that the elasticity of VMT with respect to emissions fees is on the order of -.15. The VMT effect is small because vehicle owners can substitute a cleaner car to reduce the fees.

The elasticity of emissions with respect to emissions fees are estimated to be considerably higher, perhaps in the -.5 range. The higher elasticity is due to the fees being effective at altering the composition of the in-use vehicle fleet by influencing vehicle maintenance, scrappage, and purchase decisions.

Key Issues Raised by Emissions Fees

The primary issue raised about emissions fees is whether a fair and reasonable implementation procedure can be devised and implemented. Grave concerns have been raised about the meaningfulness of vehicle emissions readings at the time of inspection / maintenance tests; it is felt that the tests themselves are too often inaccurate, that testing is sometimes poorly done, that consumers get cars fixed to pass the test (and sometimes then get them re-adjusted to run better), that there is a certain amount of fraud in the program. Similarly serious concerns have been raised about the accuracy of odometers and the fact that they can break or be turned back, disconnected, or replaced. The fairness of an emissions fee based on current-style emissions tests or odometer readings could be cast in doubt because of these concerns.

A program based on average emissions and VMT (derived from separate studies), might be both simpler and more practical, but would be less accurate for any specific vehicle and would do nothing to identify and discourage the use of very high emitting vehicles. It also could substantially overcharge for low-use vehicles. A composite program using average emissions and VMT data together with inspection results and perhaps roadside monitoring (remote sensing) presumably could be devised as an alternative.

In the future, a program based on the specific emissions of each car could be devised using emerging technologies. All cars could be equipped with sealed devices to monitor tailpipe emissions and maintain a cumulative record for each pollutant, then charged a per gram fee for the annual (or monthly) total. In-vehicle emissions diagnostic systems, currently being introduced in new cars, would warn motorists of malfunctions of emissions equipment and would be an important asset if a fee based on emissions measurements were to be implemented.

Emissions fees also would raise questions about equity for low income households, since older cars are more likely to have higher emission levels than newer ones and the low income households are more likely than others to depend on older cars for basic transportation. Compensatory measures including financial assistance for vehicle repairs and vehicle buy-back programs probably could overcome much of this concern.

3. Travel Behavior and the Economics of Pricing[1]

3.1 Overview

Previous chapters have introduced five transportation pricing strategies - congestion pricing, parking charges, fuel tax increases, VMT fees, and emissions fees - and have presented a brief review of their objectives and likely impacts, costs and revenues. In this chapter, we set forth the basic concepts underlying travel pricing in greater detail, and review the economic principles which provide the framework for much of the subsequent analysis of pricing measures.

We begin with a discussion of the current understanding of how transportation prices affect travel demand, considering the types of changes in travel behavior and location choice that could be expected to result from changes in transportation prices. We then consider the concept of price elasticity and its implications for the magnitude of travel changes that might be expected. We examine some of the issues associated with setting efficient prices. Finally, we discuss a number of issues of particular concern in transportation pricing - how to value time for both travelers and freight operators, how to account for changes in externalities such as air pollution, how to evaluate the impact on alternative modes, how to assess land use changes resulting from transportation changes - and we review key issues in assessing the overall benefits and costs of transportation pricing strategies.

3.2 Price and Travel Behavior

Understanding the impacts of transportation pricing requires an understanding of possible demand responses. Hence we begin with a discussion of travel behavior and the role of price in determining travel choices.

1. This chapter combines material prepared for the project by Randall Pozdena, Greig Harvey, and Elizabeth Deakin.

An implicit "theory" of travel behavior has emerged over the last 40 years through the adaptation of concepts from economics and psychology, as well as from practical efforts to forecast travel demand. Travel behavior is understood to result, for the most part, from the pattern of activities undertaken by individuals under constraints imposed by income, personal characteristics, interpersonal relationships (such as household responsibilities), scheduling requirements, the quality of the transportation system, and the spatial pattern of activity opportunities. Critical elements of this theory are the roles of time and cost - and the compensatory relationship between the two - that follow from conventional utility maximization in the face of time and budget constraints. A hierarchy of behaviors is suggested, ranging from the route choices made as a trip is carried out, to the more basic daily or weekly activity choices that set a pattern of desired tripmaking, to the even more far-reaching location and lifestyle choices that determine a household's living arrangements.

Under this paradigm of travel behavior, price could have noteworthy effects at many levels of the behavioral hierarchy:

- **route choice** - Tolls and congestion fees influence the "impedance" of each route, which will produce changes in path choices as fees are differentially changed and congestion shifts or abates.

- **time of travel** - Fees that vary by time of day (for instance, peak period parking surcharges or, in most cases, congestion prices) will induce some drivers with scheduling flexibility to shift to lower cost periods. Others with high time values may shift into previously congested periods (higher-cost periods that are less congested as a result of pricing).

- **mode choice** - Out-of-pocket costs are an important consideration in travelers' choice of mode for all travel purposes; for example, increasing fuel taxes or parking charges will make auto use relatively less attractive relative to other modes (transit, ridesharing, walking, biking).

- **destination choice** - Differential price increases or decreases will cause a shift in destination choices, from higher cost destinations to lower cost destinations. A general price increase could lead to shorter trips overall (although individuals with high values of time might make longer trips). The behavioral process is quite different for work and non-work trips. In the case of work trips, people have fixed origins (residences) and destinations (places of employment) in the short run, but can change either or both in the long run. For non-work trips, e.g., shopping, recreation, people often have the option to shift locations immediately or with a very short lead time if travel times, travel costs, or other elements of attractiveness change.

- **trip chaining** - Price increases could induce individuals to link together trips for more efficient travel. On the other hand, congestion relief resulting from pricing might reduce some travelers' need to schedule trips explicitly, resulting in fewer linked trips.

- **trip frequency/activity selection** - For work trips, a significant price increase (either differential or general) could foster strategies to reduce trip frequency, such as work-at-home policies or four-day work weeks. A price increase also could reduce the frequency of discretionary tripmaking, especially among lower-income households. Activities such as shopping and recreation might be reorganized (buying groceries once a week rather than two or three times a week, for example, or putting greater emphasis on mail order or tele-shopping) or replaced with ones that do not require travel (watching TV instead of going to the movies, cooking at home rather than eating out.) Declining time or dollar costs would have the opposite effect.

- **auto ownership** - Measures that directly or indirectly raise the cost of auto ownership or increase the cost of auto use could reduce the incentive for multiple auto ownership, an effect that would be most noticeable among lower-income households. Congestion relief (lower time costs) or declining fuel prices (lower dollar costs) might induce the opposite effect, especially among higher income households.

- **residential and employment location** - Significant transportation price changes may cause working households to seek alternative workplaces or residential locations. For example, a sharp increase in the cost of travel might induce a household to look for housing closer to work. Conversely, reductions in congestion may enable households to locate farther from their workplaces.

- **residential and commercial construction** - Pricing-induced changes in residential demand or workforce availability might shift the locus of regional growth, or perhaps alter the overall rate of regional demographic and economic change.

The same hierarchy of effects could be postulated for other large changes in the transportation system, such as the cumulative impact of congestion as it increases gradually over a long period or the effects of major additions to the transportation network such as new interstate links. Transportation pricing changes the dollar costs of travel; congestion increases the time costs and added capacity may reduce time costs.

Two common threads run throughout this paradigm of travel behavior. One thread is accessibility, which is a function of both time and cost. The second thread is the traveler's income (or more generally, that of the household), since responses to price differ with income.

This observation has important implications for travel demand analysis. It has been customary to let travel time (usually by auto) serve as a proxy for accessibility; when auto operating costs are primarily a function of distance, this proxy works reasonably well. But in a situation where the cost of travel no longer is necessarily correlated with time and distance - as would be the case under many congestion pricing options, or where parking prices vary substantially with location - cost must be accounted for explicitly. Thus a demand analysis for pricing requires models that incorporate price throughout the choice hierarchy. And it is not enough to use price alone; price coefficients should reflect income variations - either by incorporating different coefficients for several income categories, or by explicitly estimating a cost coefficient including some transform of income.

3.3 Transportation Price Elasticities

The magnitude of changes in travel and location resulting from transportation price changes depends on the elasticity of demand with respect to price - that is, on the amount of change in demand that results from a change in price. In broad terms, demand is considered elastic when a change in price results in an equal or larger change in demand (with both changes expressed as percentages). Conversely, if demand is price inelastic, a smaller change in demand would result from a price increase or decrease.

A large body of research has explored the effects of transportation price changes on travel behavior, both in the short run and in the longer run. In addition, considerable evidence has accumulated about the effects of transportation price changes under U.S. conditions, ranging from toll increases on bridges and turnpikes, to fuel price increases, to transit fare changes, to employer-based parking fees and ridesharing subsidies. In general, both the research and the empirical evidence suggest that travel is fairly inelastic with respect to price, with short term elasticities in the range of -.1 to -.3. (See, e.g., papers in TRB, 1994) Such elasticities mean, for example, that a doubling of transportation price would reduce travel demand by perhaps 10 to 30 percent in the short run. Long term price elasticities tend to vary over a wider range (-.05 to -.8, depending on the specific context), reflecting consumers' increasing ability over time to adjust their behavior and their circumstances to the new conditions. For example, over the longer term consumers can respond to higher fuel costs by replacing their vehicles with more efficient ones; this would produce a relatively high elasticity in terms of fuel use but also would result in a fairly low long run elasticity of travel.

While transportation price elasticities tend to be small, they are not zero - an important point in light of the concerns which often emerge in discussions with policy-makers and the public. There is a popular understanding that many travelers - especially commuters - do not have realistic options for the trips they now make, and hence will exhibit little or no sensitivity to a broad range of changes in price. Such a view leads to an expectation that pricing would not produce significant changes in travel volumes, would not accomplish such goals as congestion relief, pollution reduction, or fuel conservation, and hence would amount to little more than a tax on unavoidable behavior.

Such an assertion is, however, incorrect. Consider a toll bridge which is congested during peak periods. Increasing the toll from $1 to $2 would raise the total out-of- pocket cost of a 10 mile auto trip by about 50percent. If the price elasticity of demand is about -.1 to -.2, then the toll increase would reduce the number of auto trips by 5-10 percent. For most facilities such a reduction would be sufficient to improve operations from, say, a level of service E (stop and go) to a level of service D (heavy but moving traffic.) Next, consider an area which needs to reduce carbon monoxide emissions in its CBD by 15 percent in order to achieve air quality standards. A $3.00 surcharge on all-day (commuter) parking, which amounts to an out-of-pocket cost increase of about 150 percent, would by itself accomplish this reduction. In other words, the observed price elasticities in transportation are sufficient to produce important changes in travel behavior.

There are several possible reasons why this is not readily apparent to, or accepted by, the casual observer. First, those who assert that travel behavior is unlikely to change in response to price may be overlooking some of the options available to travelers. For example, to avoid a peak period parking charge, travelers could switch modes, travel outside the peaks, or switch destinations. Even a worker with a rigid work schedule, family constraints, and no transit option has some freedom to change the conditions of travel to avoid an onerous price, for example by sharing a ride.

Second, it can be hard to directly observe changes in travel behavior resulting from a policy initiative, because other changes in the urban system can confound the effects. Consider the toll bridge example. Growth in overall travel in the corridor could mask reduced per capita bridge use resulting from a toll increase. Moreover if there is latent demand, the toll-induced reduction in congestion might be partially offset as people formerly discouraged by the excessive delays decide to use the facility as a result of improved travel times. Reductions in the real cost of travel resulting from increased vehicle efficiency and lower fuel prices also could offset the effects a toll increase. Because of countervailing influences such as these, sophisticated analyses are often required to sort out the impacts of pricing.

Third, expressions of disbelief concerning transportation price elasticity may sometimes be a shorthand of sorts for a broader set of concerns about the nature, magnitude, and distribution of benefits and costs of pricing. Average price elasticity measures may mask substantial differences in price elasticities by income group, travel purpose, geographic location, and so on. These differences may in fact be more important to policy-makers and interest groups than the average responses captured in simple price elasticities. Here, too, sophisticated analyses may be needed to examine the incidence of impacts.

Finally, differences in context make it necessary to use extreme caution in applying the elasticities derived from one study or case to another situation. Simple elasticity measures reflect the broader context from which they are derived, including important economic, spatial, technological, and demographic factors. They cannot be assumed to apply to substantially different circumstances, nor will they necessarily work if the policy under consideration extends far beyond existing experience. In short, while elasticities are adequate indicators of the general direction and magnitude of change under pricing, they will rarely provide sufficient detail to respond to more exacting questions of magnitude, net benefit, and distributional consequences.

Despite these concerns and limitations, there remains a great deal of value in looking at evidence of price elasticities, as the following conclusions from the literature indicate.

Reinke's work on BART fare elasticity (Reinke, 1988) provides strong evidence on the degree of variability with time-of-day and trip length. He found that price elasticities varied with trip length from -.2 to -.4, with the higher elasticities for longer trips. In addition, and contrary to conventional assumptions, he found that BART's off-peak ridership is less sensitive to price than its peak ridership. The likely reason for this latter finding is that express buses and casual carpooling provide high quality alternatives in the peak (but are not available in the off-peak). This BART work serves as a warning that simple rules of thumb on elasticities (e.g., that off-peak travel is more elastic than peak travel) should not be casually applied to all pricing contexts. Outcomes are highly dependent on the characteristics of the pool of travelers affected and on the quality of the alternatives they face.

Shoup, et al.'s work on parking (Shoup, 1980, Willson and Shoup, 1992) offers an indication of travel price elasticity with respect to parking costs. The work suggests that, while employee parking demand is quite inelastic with respect to price (e.g., -.05 to -.2), elasticities nevertheless are high enough to make parking price a significant instrument for influencing travel behavior. Shoup's work also indicates that an income supplement to compensate for a newly-imposed parking price apparently does little to diminish the effect of the price, probably due to the small magnitude of the resulting change in total income.

The body of evidence on bridge toll increases requires careful interpretation. In several instances, toll increases have not appreciably affected observed volumes on congested urban facilities, and some have argued that this indicates that toll increases have little effect on congestion. However, in some cases the toll increase was simply too small to be distinguished from other influences such as demographic changes, fuel prices, and the condition of the regional economy. In the case of the San Francisco-Oakland Bay Bridge, for example, the toll was increased from $0.75 to $1.00 (westbound direction only). Previous modeling studies indicated an elasticity of about -.1, so the expected decrease in volume was about 3% - close to the average annual increase in Bay Bridge volume over the past two decades. In other words, taking into account long-term trends, along with measurement variability and all of the other potential influences, there is little reason to think that a 33 percent increase in toll would have a distinguishable effect on Bay Bridge volume. It does not follow that more significant toll increases - say, to $2.00 or $3.00 - also would have unmeasurable effects, and indeed the studies indicate that such toll increases would reduce traffic congestion by 20-40 percent.

An analysis of the Golden Gate Bridge toll increases from 1975 to 1993 found a long term price elasticity of total bridge traffic in the range -.1 to -.2 (Harvey, 1993). Because early toll increases were small or negligible in real terms and because travel in the North Bay-to-San Francisco corridor served by the Bridge grew steadily, the impact of the early toll increases was masked. However when significant toll hikes (from $1 to $2 to $3) were implemented in a short period, a substantial drop in traffic occurred.

Trans-Hudson facilities to Manhattan are said to exhibit low elasticities. However one apparent reason for these low elasticities is that the highly-congested facilities serve a pool of high income, high time-value users who already pay substantial costs for parking. For such users even $4-6 daily tolls represent a small percentage change in total travel cost and a minor percentage of income. In this situation, actual price elasticities (in terms of the total price of travel) could be quite high and still remain consistent with toll bridge observations.

Evident in these examples, and indeed in the entire literature, is the wide variability of possible outcomes from transportation pricing. There clearly is a price response, ranging from moderately-inelastic to highly-inelastic in most situations. Equally clear are the reasons for uncertainty and variability of outcomes. They stem from the wide range of potential behavioral responses identified in Section 3.2, and the way that each set of circumstances can lead to a different mix of responses.

3.4 Setting Transportation Prices

Given our understanding of travel behavior and transportation price elasticities, how should we go about setting appropriate prices in transportation? While some basic principles of economics offer general guidance on efficient pricing, actual applications, including selection of policy instruments, can be complex.

In general, economists advocate setting prices to cover short run marginal costs. But how are these costs determined? For transportation, these costs would include both a facilities and operations component and a component to reflect the costs of externalities such as congestion (which can be thought of as creating excess time costs), air pollution and noise.

In the case of congestion pricing, the basic concepts have been written about extensively (see, e.g., Knight, 1924, Vickery, 1969, Hau, 1992, Small, 1992). In essence, tolls should be set at the short run marginal cost of accommodating an additional vehicle on the roadway, determined by the value of additional time expended by all users in the increment of congestion caused by the next added vehicle. Hau (1992) shows the relationships among cost elements and demand. While traffic engineering research on capacity, speed, and flow relationships have made the estimation of the marginal cost of congestion feasible (e.g., AASHTO, 1977, HCM, 1985), estimation of the demand curve is considerably more complex. Demand elasticities provide some inkling of the average slope of the demand curve, but as the discussion in the preceding section indicates, it is difficult to generalize from the many varied elasticity studies to any particular facility. Both income and trip purpose are strong determinants of demand, and there are different mixes of vehicles on the facility (carpools, transit vehicles, trucks) with different impacts on capacity and different demand functions, both factors that need to be considered. Moreover if the road network includes competing untolled routes, one must take into account the effects on traffic and congestion on the competing untolled facilities. Because of these complexities, detailed modeling is typically needed to approximate the appropriate prices.

Similar principles apply to the pricing of other externalities such as vehicular emissions, noise, etc.; once these costs are determined they could simply be added to a user fee, e.g., as part of a tax or toll. Again, however, determining the price of these externalities is not a simple matter. For example, studies on the health and other costs of air pollution show a wide range of values, making the appropriate price highly uncertain. In addition, costs may vary substantially by urban area and facility or site (as in the case of noise.) In most cases the best course of action seems to be to evaluate a range of cost estimates for the various externalities.

In the case of parking, the pricing issue is often even more basic - to establish a price for parking, which in most locations today is provided free despite a substantial cost of providing it. There are two possible approaches here: to impose a charge to cover the actual (average) cost of providing parking, and/or to add a charge to reflect externality costs of auto use.

On the issue of charging to recoup the costs of providing parking, we should first ask why so much parking is provided free of charge, since its owners, pubic and private, are in position to charge for it if they wish. For employee parking, Shoup (1994) argues that the tax code is largely responsible for the prevalence of free parking, because parking is treated as a tax-exempt benefit if the employer pays for it but is not deductible if employee-paid. While this favored treatment is hard to justify on policy grounds, the tax code has proven to be difficult to change on this matter. In addition, it is usually the case that parking is required by local codes and hence employers themselves pay for parking only in indirect ways, as part of their rent or lease arrangements or in the case of owner-occupied buildings as part of their capital and operating costs. Here, too, changes in public policy (such as eliminating parking requirements imposed by local governments) could make a difference but have generally been very difficult to achieve. On the other hand many retailers argue that free parking is necessary to attract customers, and many building owners and operators echo the same belief with regard to leasing or renting office space in a competitive market; removing government regulations might well reduce the amount of free parking provided but in many areas probably would not do so in substantial quantity.

Parking charges to reflect externality costs might be in addition to cost recoupment or could be separately levied. For example, a peak period surcharge on parking could serve as a rough alternative to peak period congestion pricing, or could be set to reflect the costs of, say, bringing a car into an area with a carbon monoxide problem. Here setting the price is again subject to the same difficulties as discussed earlier - i.e., difficulties in estimating the demand function and the costs of externalities such as pollution. There are added difficulties, however: some of the cars being parked may not, in fact, use a congested roadway to get to the parking, there could be vast differences in the number of miles driven and hence the amount of congestion or pollution created, and so on. In addition, issues may arise concerning spillover to unpriced parking.

In summary, setting prices to cover short run marginal costs is not likely to be a straightforward exercise and quite likely will require considerable data analysis and modeling in the planning stages. Explicit recognition of uncertainties concerning the costs of certain elements, and a willingness to make adjustments to policies based on actual experience with implementation, also will be important.

3.5 Assessing Costs and Benefits

As the previous discussion has suggested, a proper evaluation of transportation pricing policies (or other transportation policies, for that matter) must account for both public and private costs. Introduction of a pricing strategy, like any other change in the transportation system, affects both the quantity of transportation services demanded by the public, and the total cost of supplying those services. In other words, both consumer and producer surpluses are affected.

A distinguishing feature of transportation services is that the consumer (the traveler) is also a producer. Travelers as consumers "buy" transit and roadway services; as producers they contribute their time and in most cases, as auto users, also supply the vehicle and fuel. Thus, a tally of the costs and benefits of transportation projects must account for five components:

- o Consumer surplus changes in reaction to explicit price changes;
- o Consumer resource changes as the result of changes in the time expended;
- o Consumer resource changes resulting from changes in consumer operating expenditures (gas, oil, etc.);
- o Resource changes associated with other producers (such as a road or transit authority);
- o Resource changes associated with externalities.

The assessment is complex. First, the prices charged in transportation (such as bridge tolls and gasoline taxes) typically bear little resemblance to average production costs, so careful cost accounting is necessary. To evaluate the costs and benefits of a road pricing policy, for example, the excess revenues accumulating with the road authority and the increased subsidies associated with diversions to subsidized transit service both would have to be taken into account.

Second, price changes can have significant effects throughout the transportation network, and these effects must be appraised. The network-wide balance of trip-making by various modes, and the changes in cost and service characteristics associated with trip adjustments, must be inventoried, a task generally done with detailed transportation planning models.

Third, changes in transportation costs can change land value and land use in the affected region. To the extent that these effects are simply capitalization of the transportation benefits or disbenefits of a policy, they need not be accounted for separately (except to consider their equity and possibly to derive mechanisms of compensation.) However, it also is possible that there are externalities associated with abrupt, significant changes in the viability of particular locations that must be accounted for.

Some of the more frequently encountered issues in the evaluation of transportation pricing proposals are reviewed in the paragraphs that follow. More detailed treatment of these issues can be found in Pozdena (1994), Small (1992), and TRB (1994), among other sources.

The Value of Travelers' Time

Transportation pricing measures which reduce congestion save travelers time. There is broad agreement that this time has value, but there is active debate about how specifically to value various types of time savings or costs across individuals who differ in their personal characteristics and job purpose. Small (1992), summarizing findings from revealed preference studies, reports the following:

- The average value of in-vehicle time for the journey to work is 50 percent of the gross wage rate, with a range of 20 to 100 percent across the various studies;

- The average value of waiting and walking time is two to three times that of in-vehicle time;

- There is ambiguity in the data as to whether business-related trips and recreational trips display the same or different implicit time valuations;

- Marginal values of time may differ from the average values of time by 20 percent or so.

These data allow the calculation of a rough estimate of the value of time; for example, if the hourly average wage rate is about $12, the average value of time (per hour) might be about $6. A delay of 20 minutes then would be "worth" about $2.

Advanced travel models permit more sophisticated evaluation of time changes, and values, and hence are invaluable in assessing the benefits and costs of pricing measures.

Time Value of Freight Transport

Travelers' time is not the only travel time of value in the transportation system; time expenditures in the shipping of commodities, including driver salaries and delays imposed on shipments, also have significant economic value. In calculating this time value, It is appropriate to incorporate the driver's gross, benefit-loaded wages at full value. The costs of delay of goods in transit are then added to this amount.

Delay imposes an inventory cost that is roughly equal to the hourly interest rate times the value of the shipment; one study estimated that, at a nominal interest rate of 10 percent (roughly 0.0011 percent per hour), delay adds about $1.60 per hour for a $140,000 truck shipment (Bay Area Economic Forum, 1990). Commodities which are valuable or perishable will of course have different inventory time costs.

Few travel models explicitly represent truck travel, and so most estimates of the time value of freight transport must be handled as separate calculations if the transportation pricing policies in question affect trucking. Unfortunately, data on truck movements and shipment values are scarce, and in many instances only gross estimates are feasible unless special-purpose studies are conducted.

Shifts in the Time of Travel

Certain kinds of transportation pricing, including congestion pricing and peak-period parking charges, will stimulate shifts in the timing of trip making. Travelers often prefer certain departure and arrival times, determined by the rhythm of household, business and recreational activity, and existing patterns of congestion. A policy that increases the cost of traveling at a preferred time, perhaps compelling a shift of the travel to a different time of day, is imposing a cost on the traveler. Congestion pricing may do this, although travelers will shift their time of travel only if the costs of shifting are less than the costs of continuing to travel at the originally-preferred time. However, it is important to note that congestion itself also may compel shifts in the time of travel; it does this by imposing a time cost that can be avoided only by traveling during a less-preferred time. In other words, shifts in the time of travel due to transportation pricing could work both ways - some will shift out of the peak because the dollar cost is too high, while others will be able to travel at their preferred times because the time cost is lower. Overall, these shifts should have the effect of enhancing the net benefits of the pricing policy.

Relatively little work has been done to model time of travel shifts, and most travel models treat time of day as fixed. Work by Small (1982, 1992) and Harvey (1995, Appendix B) are notable exceptions.

Impacts on Transit and Other Modes

Transportation pricing measures are likely to impel mode shifts. In turn, as travel demand shifts between modes, changes in their service characteristics may have significant effects on the perceived costs of travel by the various modes.

Pricing policies may produce a higher demand for transit. If transit operators are able to respond to the higher passenger loads, service may improve - operators could decrease headways, add routes, and/or provide express service between particular origin and destination pairs, for example. Further, pricing-induced reductions in congestion may improve bus travel times. Since users place considerable value on the resulting decreases in waiting time, access time, transfers, and in-vehicle times, the effect is a significant reduction in the overall cost of transit use (out-of-pocket plus time costs.) In essence, economies in the scale and scope of transit service could be captured by users. Operators in turn may find it possible to provide service with fewer vehicles (or increase the number of passenger runs each bus can make during a peak period.)

Carpools and vanpools also should experience economies with increased demand density. With more people looking for ridesharing partners, the likelihood of finding a match increases and the time spent waiting for pool members to gather at a park and ride lot, or in picking up and dropping off pool members, should decline. In addition, the feasibility of three and four member carpools (or full vans) should increase, which usually would reduce each member's out of pocket costs.

Reductions in out-of-pocket and time costs of transit and ridesharing would have several important benefits. First, they should buffer potentially negative impacts for those who switch modes. Second, they should produce benefits for travelers who originally used transit or ridesharing and continue to do so.

The transit benefits, however, depend on the transit agency being able to respond to new opportunities in a fashion akin to a private service provider. If the optimal response to increased transit demand cannot be supported out of farebox revenues alone, and access to public funding is restricted, agency response may be slowed or stopped. Similarly, if a region restricts entry by commercial bus and vanpool ventures, the potential for synergistic improvements in transit service characteristics is reduced (Viton, 1982, Glaister, 1991).

Finally, union regulations regarding work hours, split shifts, and other constraints may affect the ability of transit systems to respond optimally.

Travel demand models do not ordinarily estimate optimal supply responses for transit and other modes. Instead, the typical model takes service proposals, e.g., reduced headways, faster travel times, shorter access distances, and translates them into time and cost data. The analyst then can run the models to estimate changes in ridership. Ridesharing is handled more crudely than transit in many models; reductions in access time and out-of-pocket cost for ridesharing generally would be estimated separately and used in the more developed models to provide a rough estimate of impact.

Environmental Costs

Transportation produces emissions, noise, and other environmental impacts which are not fully accounted for in current user charges. However, there is considerable uncertainty and disagreement about the costs of these impacts.

In the case of emissions, a full accounting would have to consider emissions not only from vehicles but from also from power production (electric power plants, oil extraction and refining) and other required inputs, and would have to account for effects not only on human health but also on the productivity and health of plants and animals, the costs of maintenance of buildings and other infrastructure, and so on. In practice only a subset of the key impacts directly attributable to transportation activity usually are considered., and even then, disagreements over the valuation are sometimes severe.

While transportation noise is a serious problem in many areas and its economic impacts are felt in both health and remediation expenditures, very little work is done in most areas to measure noise levels (except around airports) and consequently the calculation of costs and benefits can at best be analyzed using simple models and cost assumptions.

Hedonic price analysis has been used to measure the impact of various levels of noise or pollution exposure on the value of the affected real estate. Hedonic price studies rely, however, on the assumption that individuals buying or selling real estate themselves value fully the effects of exposure to noise or emissions. If individuals poorly estimate these effects (long-term health effects, for example), then epidemiological studies also are required.

Energy Consumption

Because the price of energy does not represent the full cost of producing energy, energy consumption may be said to produce externality costs, but there is considerable debate about what to count as energy externalities and how to evaluate them. Greenhouse gases are but one of the energy production and consumption externalities under discussion at present. Hoeller, Dean, and Nicolaisen (1991) survey recent attempts to quantify greenhouse effects and economic impacts associated with fossil fuel, hydroelectric, and nuclear power production.

Public Services

Services such as police, fire, and ambulance are important to transportation activity, but the associated costs are not always financed through direct charges on the users of transportation services. Consequently, changes in the amount of travel, or the service characteristics of the modes (such as the speed of automobile traffic) can result in changes in the external burden on public services. The method of measuring these impacts depends to a large extent on the particular fiscal mechanisms that are in place in a community, which vary considerably. For example, in some jurisdictions, ambulance costs are billed to the affected parties in an accident; elsewhere the costs, like those for most police and fire services, are covered by general revenues. When services are paid for from general revenues and handle both transportation and non-transportation needs, it can be difficult to separate the transportation-related expenses from other cost elements.

Impacts on Land Use, Location, and Urban Form

Changes in the relative price of travel will affect the relative attractiveness of different locations and hence will affect land use and urban form. Households and businesses select their locations partly on the basis of accessibility, and if travel times and costs change, the desirability of the various locations will be altered, reducing demand for some sites and increasing it for others. Generally speaking, higher transportation costs (time and dollars) would favor shorter trips, and lower costs would support longer ones; location close to an activity center would be favored in the former case and dispersed locations in the latter. However, demand for a particular location reflects the relative value of conducting activity in that location compared to others, so location choices will shift only if it is net beneficial to do so, taking into consideration the characteristics of alternative locations as well as any costs that changing the location of activities may entail. As noted earlier, certain location shifts (e.g., shopping destinations) can be changed more readily and faster than others (housing locations, workplace locations.)

The net effect of various transportation pricing strategies on location, land use and urban form is not easily generalized. For example, to the extent that agglomeration economies operate in activity centers, they would tend to dampen the effect of price increases to or within those centers due to congestion pricing or parking pricing. Resulting improvements in travel time due to lessened congestion and enhancements to alternative modes of transportation also would offset the impact. Conversely, transportation policies which remove subsidies currently prevalent in low density areas could reduce the attractiveness of those locations. The overall impact would be highly context-specific.

Current transportation models for the most part handle location and land use changes crudely, and often treat housing and activity locations as exogenously determined. More advanced models treat destination choice and location choice in greater detail and thus represent the full effects of transportation times and costs.

Putting it All Together: Benefit - Cost Analysis

The most rigorous way to assess the economic implications of transportation pricing strategies would be to carry out a formal benefit-cost analysis. The purpose of benefit-cost analysis is to inventory all of the net gains or losses in social welfare that arise, over time, as a result of the implementation of a project or policy. Broadly speaking, gross social welfare or societal *benefits* are increased (everything else being equal) when a project or policy has at least one of the following effects:

- The total resources committed to an activity decrease as a result of the project;
- The project permits consumers to acquire a good or service for less than what they would have been willing to pay for it. (This effect is referred to as creation of consumer surplus.)

Conversely, social welfare is decreased when either of these effects is reversed, i.e. when there is an increase in resource commitment or a reduction in consumer surplus as a result of the policy. Benefit-cost analysis inventories these gross changes in social welfare, and measures the net change for every period of the planning horizon over which the policy or project will have influence in the economy.

The accurate measurement of changes in consumer surplus and changes in resource use (production cost) is crucial to the accurate rendering of a benefit-cost analysis. Furthermore, benefit-cost analysis requires explicit treatment of the timing of economic impacts; since the effects of a particular project or policy may be composed of a stream of impacts that play out over a long period, care must be taken to properly time-weight these impacts in rendering the overall estimate of net benefits.

As the previous discussion of impacts should have made perfectly clear, however, it is not always possible to carry out a full-blown benefit-cost analysis. Data on a number of important phenomena may be limited or lacking; travel models address only some of the key impacts and behaviors; there is disagreement about the nature and magnitude of certain costs and benefits.. Under these circumstances, a middle course is to apply benefit-cost concepts and methods, but to use them in conjunction with other indicators and evaluation data. This is the approach adopted for this study (see later chapters); we review key issues in benefit-cost analysis here largely in order to put the analyses and evaluations in later chapters into proper perspective.

Measuring Changes in Consumer Surplus

The measurement of changes in consumer surplus is central to benefit-cost assessment and, in many respects, is the most difficult part of benefit-cost assessments in practice. Consumer surplus requires measurement in changes in excess willingness to pay; since the demand curve is the aggregation of consumers' willingness to pay, the measurement of consumer surplus requires some understanding of the nature of demand relationships.

The measurement process is made somewhat easier by the fact that only changes in excess willingness to pay need be inventoried to measure the change in consumer surplus. Suppose a policy or project decreases the price paid by some group of consumers. It is easy to calculate the change in consumer surplus for those who originally were consuming at the higher price; their increase in consumer surplus is exactly equal to the reduction in price times the amount they were consuming previously. For those consumers who are induced to consume by the now-lower price, the calculation is a bit trickier, but we know that for individual consumers, the smallest increase in consumer surplus will be is zero, and the most is the total reduction in price. As a practical matter, aggregate changes in consumer surplus resulting from induced consumption can be approximated reasonably accurately by taking one-half of the change in price times the amount of induced consumption. This is tantamount to linearization of the demand curve over the range between the old price and the new price.

Measuring Changes in Resource Use (Producer Cost)

Policy changes also will change the use of resources. For example, if the policy change reduces the use of roadways, the total cost of wear-and-tear (or the maintenance resources expended to avoid it) will be reduced. The appropriate measure of the change in resource costs thus is the change in total producer costs that result from the policy.

Aggregating Consumer Surplus Across Different Consumers

Benefit-cost analysis requires aggregating impacts across individuals. However, it is the rare project or policy that has precisely the same impact on all consumers. Moreover the consumers themselves may be dissimilar in important ways (for example, in the value they place on time). Individual consumers have somewhat different demand curves, and experience different changes in the consumer surplus they enjoy as the result of an increase or decrease in price.

In the case in which the policy change results in all consumers being better off, the fact that different consumers are affected differently is irrelevant; everyone is made better off (i.e., the policy is pareto efficient.). In the case in which some consumers are made better off and some are made worse off, however, the question arises as to whether a given dollar change means the same thing to all individuals (in terms of their perception of their social welfare). This concern challenges the validity of simply adding up all consumer surplus changes (positive and negative) and treating the dollar measures the same for all individuals.

One response is to tally the nominal changes in consumer surplus experienced by major classes of people (individuals of different income backgrounds, for example) in addition to the aggregate estimates of consumer surplus. Other approaches, including those applied in later chapters, disaggregate specific impacts of interest for perusal by interested parties.

Accounting for the Timing of Benefits and Costs

Typically, project or program benefits and costs accrue over a period of time. In general, we discount the benefits and costs that occur in the future, yielding a present value for benefits and costs. The discounting process is straightforward arithmetically, but there is considerable debate over the discount rate that should be used in evaluating projects or policies, particularly public policies.

The vigor of the debate is fueled by the fact that many projects require sizable up-front expenditures (building a fixed-rail transit system, for example) with the benefits accruing only much later. Since the higher the discount rate, the less future benefits figure into the present value calculation, a project that offers net benefits at a low discount rate could fail to do so at a higher rate.

Economists argue that the appropriate discount rate is the private borrowing and lending rate for activities of like risk, since the funds are diverted to the project at hand at the expense or opportunity cost of private sector activities and from a net social welfare perspective funds should not be diverted to low-yielding public activities if high-yielding private activities exist.

Nominal interest rates are composed of three underlying elements, the real interest rate, a risk premium, and a premium to compensate for expected inflation over the expected investment horizon. The rate chosen to represent the time-value opportunities of the funds involved in a public project or policy should reflect the risk circumstances that face the public in pursuing the project, and a time-horizon consistent with the project's planning horizon.

Public projects often have been justified on the basis of too-low a discount rate. A frequent mistake in selecting discount rates for the analysis of public transportation projects is the use of the rate paid by the public agency on its bonds. Generally speaking, it is not appropriate to use either U.S. or state borrowing rates in such calculations, although it is frequently done. Most public agencies enjoy lower financing rates than private entities because of implicit (or explicit) guarantees of agency bonds, and because the coupons of such bonds are exempt from local, state or federal income taxation. When analyzing a public project's feasibility, however, the appropriate universe of alternative projects is not simply the alternatives facing the public agency, but rather the alternatives facing the taxpayers who must give up those opportunities in order to finance the bond guarantees and the tax-exempt status of the bonds. Hence, the appropriate discount rate is the private, non tax-exempt borrowing rate.

Most public as well private ventures involve risk, and this also should be recognized in the discount rate used. Transportation projects, for example, involve risk in patronage and cost estimates. This suggests that corporate bond rates for comparable activities with like time horizons would be an appropriate nominal discount rate to choose. The rates paid by private transportation companies, such as bus, airline and railroad companies, are available either singly, or in transportation bond-rate indices.

Fluctuating interest rates do not require additional calculations; use of the current rate is appropriate, for two reasons. First, the current rate (bond rates, for example) should be used in comparing the policy or project in question to the other alternative uses to which society might put its resources at the time of the analysis or decision. Second, much of the movement in interest rates (particularly long-term rates) relates to changes in inflation expectations, which are highly volatile. However, since the expected rate of inflation incorporated in nominal discount rates is probably the rate of inflation that should be assumed in estimating future benefits and costs, it generally would not change the benefit-cost calculation. Only changes in real interest rates have an effect, and while these rates do fluctuate, the long-term real rate is actually quite steady and can be manipulated by central bank policy for only short periods of time.

Project Ranking and Selection

After inventorying the streams of benefits and costs that a policy or project engenders, the gross benefit and cost streams can be discounted to obtain the present value of benefits (PV_b) and the present value of all resource costs (PV_c) including externalities. To maximize social welfare, the project(s) chosen should be those that maximize the net of benefits over costs, in present value terms.

Two simple calculations are helpful in the ranking and selection of projects:

- Net Benefits = PV_b - PV_c
- Benefit-Cost Ratio = PV_b / PV_c

If the only decision is to proceed with the given project or not, then the appropriate criterion is simply whether net benefits are greater than zero. All other like opportunities already have been implicitly assessed by using the appropriate discount rate. If there are many mutually-exclusive projects, then economic principles dictate that the project with the greatest positive net benefits should be selected. Finally, if there is limited access to funding, then the projects with the highest benefit-cost ratios should be built first, and additional projects added until funds are exhausted. This rule simply guarantees that the chosen projects will maximize net benefits.

Integrating Benefit-Cost Analysis with Other Performance Measures

A full benefit-cost analysis would produce a dollar value for each cost and benefit, and input these values into the analysis. We have noted earlier, however, that sometimes there is no way to assign a reasonable value, or range of values, to a particular resource, or the range of estimates is so wide as to render the resulting benefit-cost estimates useless from an evaluation standpoint. In such cases, the resource in question should be removed from the benefit-cost calculation, and project evaluation should proceed using other performance measures along with benefit-cost data. One such approach, called multicriterion analysis, uses the net (measurable) benefits as one criterion and a tally of the "unpriceable" impacts as a second criterion. See, as an example of such analysis, T. Saaty (1980.)

Matrix displays of impacts are another approach that is commonly used in evaluation. Entries in the matrix, often produced by models, may be monetized and discounted, or they may simply be reported as gallons of fuel, tons of emissions, etc. Dollar costs are often provided for a specified analysis year; if so they should be presented in current dollars or discounted as appropriate.

3.6 Implications for the Analysis

This chapter has reviewed how transportation prices affect travel demand, considering the types of changes in travel behavior and location choice that could be expected to result from changes in transportation prices. Travelers have numerous options available for responding to transportation prices, and their behavior responds to a combination of individual and household characteristics, workplace constraints, neighborhood factors, and transportation system conditions. Adjustments to changes in transportation prices could include simple shifts in route or time of travel, shifts in mode, destination choice, or frequency of travel, and even shifts in the location of workplace and home.

Transportation price elasticities reflect these opportunities and constraints. For a particular location and time, the aggregate price elasticity will depend on:

- the income distribution of affected travelers;
- the price base (including parking, tolls, and other out-of-pocket expenses);
- the pattern of delay in the transportation system;
- the network configuration for the affected mode, particularly the presence or absence of competitive routes;
- the availability of competitive alternate modes;
- the flexibility of travelers to change the timing of their activities (e.g., non-work trips often are more 'discretionary' than work trips).

The evidence on price elasticities suggests that the magnitude of travel changes that might be expected are small, but nevertheless they are significant. Also, differences in context make it necessary to use extreme caution in applying the elasticities derived from one study or case to another situation. Simple elasticity measures reflect the broader context from which they are derived, including important economic, spatial, technological, and demographic factors. They cannot be assumed to apply to substantially different circumstances, nor will they necessarily work if the policy under consideration extends far beyond existing experience. In short, while elasticities are adequate indicators of the general direction and magnitude of change under pricing, they will rarely provide sufficient detail to respond to more exacting questions of magnitude, net benefit, and distributional consequences.

How should transportation prices be set? In general, economists advocate setting prices to cover short run marginal costs. For transportation, these costs usually include both a facilities and an operations component, as well as a component to reflect the costs of externalities such as congestion (which can be thought of as creating excess time costs), air pollution and noise. Given these complexities, the evaluation of transportation pricing measures is often fraught with uncertainties. While economists strongly prefer to evaluate projects using a formal cost-benefit analysis framework, many others prefer a combination of methods - especially when there is no agreement on how to evaluate certain costs, when data are missing or of dubious quality, or when the aggregation of impacts may hide socially and politically important distributive issues.

Despite all of these caveats, the fact remains that well-crafted travel demand models have provided reliable estimates of price effects in realistic settings (such as for transit price increases). This suggests that while the phenomena may be complex, travel demand forecasting can provide a good approximation of the first-order effects.

4. The Effects of Transportation Pricing: A Review of the Evidence[1]

4.1 Overview

Just as a review of the theory of travel behavior and transportation economics is helpful in understanding what transportation pricing might accomplish and how sound policies should be formulated and evaluated, a review of available evidence on transportation pricing is helpful in characterizing the state-of-the-art, sizing up likely impacts, and developing an initial assessment of key implementation issues including institutional feasibility and political acceptability. In this chapter, we present a brief review of the evidence on the effects of transportation pricing, considering both direct experience and "what-if" analyses and assessments conducted over the last 25 years. We also report briefly on ongoing studies and proposals which we identified through interviews we conducted with agencies and researchers known to have an interest in transportation pricing strategies. The agencies contacted for this effort include state agencies and metropolitan transportation organizations (MPOs); federal transportation, environmental, and energy agencies; academic research institutes, key interest groups with a research orientation; and key academics.

A substantial body of evidence has accumulated on effects of price changes on transportation system performance and traveler behavior. While most of this evidence derives from prices set to generate revenues rather than to manage congestion, reduce emissions, or moderate petroleum use in a direct fashion, it is nevertheless useful as an indicator of the kinds of transportation impacts price changes might have.

On the other hand, only a few urban areas in the U.S., such as Boston, Chicago, New York, and the San Francisco Bay Area, have enough transit use, paid parking, and tolled highway facilities that they have systematically monitored travelers' real-world responses to price.

1. This chapter draws upon material prepared for the project by KT Analytics, Inc., Faye Wachs, Elizabeth Deakin, and Greig Harvey

Thus, for most areas (including three of the four examined in this study - Los Angeles, Sacramento, and San Diego), pricing strategies must be evaluated by drawing inferences from other areas' experiences, by building upon models developed elsewhere, or by surveying local residents to elicit stated responses to hypothetical price increases.

Many of the cases in which price effects have been documented concern changes in gasoline or other fuel prices due to market perturbations and tax increases. Studies of parking price changes, transit fare changes, and toll changes also have been reported fairly frequently. In comparison, there is relatively little experience with congestion pricing and even less with VMT fees or emissions fees. For these latter measures we must rely, for the most part, on studies done to explore their potential rather than direct implementation experience. The quality and detail of these studies vary considerably, so they must be used with caution; still, considerable amounts of information can be gleaned from them.

The amount of evidence on the different impacts of transportation measures also varies widely. Much can be said about changes in traffic levels and parking accumulations; considerably less direct evidence is available concerning other important aspects of transportation pricing, such as its emissions and fuel use consequences. In part this is because we can count the number of vehicles on a facility or the number of cars parked in an area much more easily than we can measure the emissions generated by those cars or the changes in fuel use that result from specific projects or policies (though new monitoring technologies may soon make the latter tasks easy as well.) Because direct measurement currently is difficult or impossible we instead rely on calculations or models to estimate emissions and fuel use. Hence we often must rely on modeling studies as a source of information on certain impacts even when implementation has occurred.

4.2 Experience and Studies in the U.S.

Only a few programs have been implemented in the U.S. with the explicit objective of using pricing to reduce traffic congestion, air pollution, or energy consumption. However, a much larger number of studies have evaluated pricing options as possible ways to manage traffic or as transportation control measures for possible inclusion in transportation-air quality plans.

An early body of U.S. evidence came from studies carried out in the 1970s with funding from the Urban Mass Transportation Administration (UMTA - now the Federal Transit Administration - FTA.) UMTA encouraged local experimentation with transportation pricing through its demonstration program, and a few cities showed interest. Preliminary assessments for those cities (including Berkeley, California and Madison, Wisconsin) suggested that downtown entry charges on the order of $2.00 a day (at that time) would have reduced peak period trips by 20-25 percent (Cheslow, 1978; Spielberg, 1978). Although the cities were interested in traffic relief, they withdrew from the pricing program when local objections to the strategies began to surface.

Somewhat more acceptance has been found for parking pricing, which both UMTA/FTA and the U.S. Environmental Protection Agency (EPA) have encouraged as a traffic management and air quality strategy. Local circumstances (for instance, a tight parking supply coupled with community resistance or cost barriers to parking construction) have sometimes provided the conditions needed to proceed with implementation. Berkeley, for example, was able to implement increases for all-day parking in its downtown facilities as part of a larger program to manage traffic and improve air quality. Implementation has been unsuccessful, however, when the only reasons for parking pricing are federal mandates or regional concerns. The San Francisco Bay Area's air quality planning efforts of the 1970s, '80s, and '90s all looked at parking pricing strategies and found them to be potentially among the most effective measures available (Harvey and Deakin, 1991). However, the acknowledged potential of the measures was not enough to overcome the distinct lack of enthusiasm with which most local governments and businesses greeted parking pricing proposals, and very few instances of implementation occurred.

Until quite recently gas taxes and vehicle registration fees have been treated almost entirely as means of cost recovery and revenue generation rather than as ways to manage demand.

However, important evidence on fuel price impacts was produced by the fuel price shocks resulting from the Arab oil embargo in 1974 and the Iranian crisis in 1979. While the findings from that period are not entirely straightforward, because both price and occasional shortages were at issue, there is little disagreement that fuel price increases resulted in short term reductions in travel - recreational travel was particularly hard hit. In addition, higher fuel prices resulted in increased trip linking, moderately increased ridesharing and, in some markets, transit use, and substantially increased interest in fuel-efficient vehicles. More recent data indicate that the historically low fuel prices of the last few years are having the opposite effect (Schipper, Deakin and Sperling, 1994).

In recent years both the federal government and a few state legislatures have considered substantially higher gas taxes as a way of to reduce fuel use and meet pledges to reduce greenhouse gases, but so far the proposals have remained items for discussion only. A few legislatures also have considered using vehicle registration fees as a means of controlling air pollution or other environmental harm, but for the most part, the studies have been kept out of sight of the general public, and in some cases no formal reports on the findings have been produced to date. General anti-tax sentiment and concerns about impacts on auto-dependent and low income populations are clearly part of the reason for reluctance to act on these measures.

Road pricing is another option that until quite recently was used almost exclusively for revenue generation. Indeed, after a spate of toll road construction in the 1950s, few additional toll facilities were built; and in some cases tolls were removed once construction bonds had been paid off. In the last few years, however, toll roads have again become an option, largely where demands for road building could not be met from gas tax revenues. New toll facilities, some with peak-hour or HOV pricing strategies, are in various stages of development and implementation in California, Texas, Virginia, and other states.

In a few cases innovative pricing strategies are being considered as part of the toll road package. Specific transportation pricing strategies that have been proposed and studied include peak / off-peak pricing of particular roads, bridges, or tunnels, pricing of new roads or lanes on otherwise free facilities, differential pricing of high-occupancy vehicle lanes, area entry pricing, and parking pricing. A handful of these studies is moving forward toward implementation, though to date the only actual implementation is State Route 91 in southern California (discussed later in this chapter.)

Clean air requirements also have stimulated a number of studies of transportation pricing. Extensive proposals have been made for the Los Angeles (South Coast) region and the San Francisco Bay Area in response to state air quality laws; these proposals include congestion pricing based on automatic vehicle identification (AVI), vehicle registration emissions fees based on tailpipe measurements and odometer readings, employee parking fees, and gasoline taxes set at levels approaching Organization for Economic Cooperation and Development (OECD) member country norms. In the San Francisco Bay Area, the proposals have garnered at least nominal support from the business and environmental communities and have been formally adopted as the long-range element of the regional air quality plan, though little progress has been made toward implementation and the political road remains rough. Los Angeles' studies of pricing strategies for the region's freeway and arterial system are still underway, but leaders there expect that implementation could face many roadblocks.

A few examples of past and ongoing studies and experiences are presented here for illustrative purposes.

Examples

Los Angeles

A study for the Southern California Association of Governments (SCAG) assessed the impacts of area pricing for the Los Angeles Region, using price elasticities derived from national experience along with local evidence from parking price changes (Urban Institute and K.T. Analytics, Inc., 1991). The assessment suggested that an entrance charge of $3.00 (1991), aimed at Los Angeles' two square mile central business district (CBD) during a six hour morning period on weekdays, would reduce the number of vehicle trips downtown by 10 percent or so. However, this would represent less than one-half percent reduction in total regional VMT. In order to achieve significant reduction in regional freeway congestion and emissions, the authors concluded that area pricing would need to be applied to 20-25 principal activity centers within the region, covering a significant proportion of the region's employment and travel.

More detailed studies exploring the effects of transportation pricing measures and comparing their equity to other transportation policies and financing mechanisms were carried out by the Environmental Defense Fund (EDF) using Los Angeles as a case in point (Cameron, 1991; Cameron, 1993). The studies, which were based on versions of the STEP models developed by Harvey (also described in this report), found that congestion could be reduced to attain LOS D/E or better on a system-wide basis by applying congestion pricing averaging 10 cents a mile during the peak periods. Furthermore, the studies found that either congestion pricing or VMT fees would have a lesser effect on low income households than fuel tax or sales tax financing of transportation.

San Francisco Bay Area

Studies of parking pricing, toll increases, fuel tax increases, and congestion pricing for the San Francisco Bay Area date back to the mid-1970s, with the Metropolitan Transportation Commission (MTC), local entities, university researchers and private groups all making major contributions. Several of these studies modeled the impacts of various pricing measures in some detail and compared the pricing results to those of other traffic management and control strategies. For example, the analyses supporting the development of the region's transportation-air quality plan found that a package of parking pricing, congestion pricing, fuel tax increases, and emissions fees could reduce hydrocarbon emissions by about 30 percent, whereas the best package of conventional transportation control measures including major transit and HOV lane investments and a variety of other programs would produce only 5-7 percent reductions (Harvey and Deakin, 1990).

The most recent and focused effort is the Bay Bridge Congestion Pricing Study. That study, which builds upon earlier work done by the Bay Area Economic Forum, Small, Winston, Pozdena, and Harvey, among others, has made extensive use of modeling, survey analysis, focus group interviews, and small group meetings to explore the potential impacts and effectiveness of a peak period toll increase to $3.00 from the current $1.00. Such a toll, collected one way only, would save Bay Bridge travelers about eight minutes a day and would generate sufficient revenues to support major new transit and ridesharing services in the affected areas. The study is still underway, although implementation, which requires legislative action, is not assured.

Berkeley

The City of Berkeley, a older streetcar suburb just north of Oakland and across the Bay from San Francisco, has a long history of managing traffic problems in dense core area through a combination of traffic restraints transit promotion, and pricing policies. A 1978 study, using off-the-shelf mode share models, estimated that areawide pricing of $1.00 per trip (1978) applied to all vehicles traveling to and within Berkeley city limits could reduce trips by 22 percent, or by 35 percent if packaged with significant improvement in transit service. (Cheslow, 1978). If the charges were imposed only during three hour morning and three hour afternoon peak periods, trip reductions would drop by half these amounts. A proposed program was forwarded to the City Council for their consideration, but also was discussed with the press before city officials had had an opportunity to evaluate the proposal. Press reviews were unfavorable, and faced with skeptical questioning and potential opposition from constituents, Council members disavowed the program.

A later study of parking pricing was more successful. The Berkeley TRIP project, a joint effort of the City of Berkeley and the University of California, Berkeley, was carried out with funding from the U.S. EPA. The researchers estimated that removing the discount for all day parking in city-owned garages and lots and raising rates to market rates (about $3.20 per day in 1982 dollars) would reduce auto trips into the central part of the city by about 5 percent (Deakin et al., 1982). As part of larger program to promote ridesharing and transit use, the city implemented the parking increases, offering a significant discount to carpools of three or more and vanpools. The University also began a series of price hikes that raised its central campus parking charge to market rates, though the University was motivated more by a need to cover the costs of its transportation programs, free up surface parking lots for building sites, and raise revenues to pay for earthquake retrofit of parking structures than by concerns over traffic or environmental impact. The price increases had the forecasted effects in cutting parking demand, though spillover parking in residential neighborhoods was a problem, especially around the campus, until the city implemented programs limiting on-street parking to residents who purchased permits. Prices have not kept pace with inflation, however, so the impact has eroded over time.

State Route 91 - Orange County, CA

The first example of congestion pricing on U.S. roads is currently being implemented on S.R. 91 in Orange County, California. A high-occupancy vehicle (HOV) lane in the median of the facility between Orange and Riverside Counties is designed to allow use by single-occupant vehicles in numbers regulated through a dynamically-set toll This facility is currently the only highway in the country with formal congestion pricing.

Puget Sound (Seattle Metropolitan Area)

Based on a study of the efficacy of a bundle of pricing measures including congestion pricing, fuel fees, and parking pricing, The Puget Sound Regional Council has formally adopted pricing strategies as an integral element of the region's long range plan.

Oregon

The Oregon State Legislature, the Oregon Department of Transportation, and the Oregon Department of Environmental Quality have sponsored studies of a variety of pricing measures over the past several years. Among the measures that have been evaluated are several vehicle emissions fee concepts, bridge tolls, parking charges for suburban Portland, and congestion pricing on Portland area freeways.

While none of the measures has been implemented as formal policy and political difficulties are recognized, staff training and public information programs on pricing strategies have been undertaken as a first step toward more serious consideration of these proposals in the future. In addition, federal funding has been obtained for additional studies of congestion pricing in Portland.

Maryland

The State of Maryland has conducted detailed studies of emission-based vehicle registration fees, and the State Legislature actually adopted such fees in 1994, only to have the fees overturned by the courts on grounds that they were inconsistent with the state constitution.

Manhattan

A 1986 study (Cambridge Systematics, Inc., 1986) investigated entry pricing for the entire area of Manhattan south of 64th Street. Vehicles entering this area between six a.m. and noon would be required to exhibit a supplementary license priced at $5.00 per day (1986 $). It was estimated that trips entering the area would be reduced by 20 percent (equivalent to a 3.7 percent reduction in total daily trips to the entire island of Manhattan), and that average speeds in the area would increase from under 8 mph to over 12 mph.

4.3 Experience and Studies Abroad

Transportation pricing policies in other developed countries vary significantly from those in the U.S. The gap reflects differences in price, as well as in the patterns and timing of urban and regional development, in the structure of national and regional economies, and in general taxation and finance policies. Views on the appropriate role of government also differ. Comparisons of travel behavior and transportation system operations under different countries' policies offer insights into consumer responses which may be instructive for the U.S. But economic, social and cultural differences suggest caution is well advised in interpreting the findings.

In general terms, the Europeans and Japanese collect fuel taxes several times higher than those in the U.S. and impose significantly higher taxes and fees on vehicle purchase and registration. On a per capita basis their governments spend more on transit and less on highways than the U.S. Both public authorities and the private sector provide less parking in commercial centers, and offer less of it free of charge, though parking on public streets is often heavier and less regulated or enforced than in the U.S. (Japan stands alone in requiring the availability of an off-street parking space as a condition of car purchase.) Again with the exception of Japan, the other developed countries have been somewhat slower than the U.S. to adopt vehicle emissions controls, and for the most part they have imposed lower levels of control.

These differences (among others) are reflected in significant country-to-country variations in travel mode shares, VMT per capita, and fuel consumption and emissions per capita, with the U.S. considerably higher on every metric than its overseas counterparts. The differences are too large to be explained solely by differences in income and demographics, though these influences do of course have to be taken into account.

Though many find the differences in policies and performance instructive, it would be wrong to conclude that the U.S. could simply adopt European or Japanese policies and mimic European or Japanese investments and expect thereby to replicate their results. Historic development patterns, economic structure, and cultural and political perspectives are an important part of the story and would surely lead to differences in policy suitability and effectiveness. Moreover the growth rates in automobile ownership and use in Europe and Japan suggest that they may be mimicking us rather than vice versa. Between 1970 and 1987, for example, the number of cars multiplied by 1.6 in North America but by a factor of two in Western Europe and by 3.4 in Japan (Button and Barde, 1990).

Despite these caveats, the European experience and studies would seem to offer evidence of relevance to U.S. conditions. Even the experiences of Singapore and Hong Kong, places politically and culturally very different from the U.S., can provide valuable insights into implementation issues.

Apart from fuel tax differences and a few examples of vehicle registration and licensing policies, many of the transportation pricing policies best documented in other countries involve cordon or area pricing, in which tolls are charged at each entry point to an area or special licenses must be purchased in order to bring a vehicle into the area. In a few cases the fees differ by time of day, though in many a flat fee is charged. The interest in such schemes is understandable given the severe conflicts that arise when heavy auto traffic is introduced into the narrow streets and high densities of the central areas of many older cities. In such situations the imposition of pricing serves a traffic-calming function (much as do other auto restricted zones) in addition to whatever revenue or access road congestion relief it might provide. To date, area pricing has been implemented in several Norwegian cities, and is being considered as well in Stockholm and Milan.

The Europeans also have shown considerable interest in more explicitly pricing roads for congestion relief in recent years, though to date congestion pricing has been implemented only on one facility in Normandy and in a minor way in Trondheim. Studies in London and Cambridge (UK) and in the multi-city Randstad region of the Netherlands have considered the use of peak period pricing on a larger scale, but at the time of this writing the studies appear to have stalled.

Examples

Singapore

Singapore has operated a form of road pricing in its core area since 1975. Motorists wishing to enter the core during peak periods must display a windshield license which currently costs about U.S. $2.00 per day. The licenses can be bought at roadside stands and at selected post offices, either on a daily basis or in advance. Monthly licenses are also available. Enforcement is carried out at about 30 access points, with violators cited by mail. The fine for traveling without the license is about U.S. $23 for a first offense, with sharp increases for repeat offenses. Transit services to the core have been increased and park-and-ride lots have been established along approach roads to provide alternatives to driving downtown (Behbehani et al. ,1984; Watson and Holland,1978; May,1983; Bhatt and Beesley,1976).

The program initially reduced peak period traffic volume entering the priced area by over 40 percent, eliminating the severe congestion experienced before the program was implemented. Carpool and bus use both increased substantially. However, diverted traffic produced severe congestion on the ring road, a problem that has been alleviated by expansion of this facility. Over time, traffic to the central area has grown, but it remains some 20-25 percent below 1975 levels despite substantial growth in population, employment and incomes.

Hong Kong

Hong Kong experimented with electronic licenses in a pilot program carried out 1983-1985. This was planned to be the first step of a large scale scheme to alleviate traffic congestion, using road pricing which was to vary by location and time of day. Some 2,500 cars were fitted with the electronic licenses, which were read by interrogator loops embedded in the pavement and connected to a central computer. The pilot project demonstrated the feasibility and accuracy of the electronic technology, and modeling studies projected that a full scale road pricing program, varying the price by location and time of day, could reduce peak period traffic by 20 percent. However the government was unable to implement the full program due to strong opposition from the neighborhood councils, who were permitted to vote on the program and overwhelmingly rejected it. The opposition has been attributed by various authors to a perceived invasion of privacy, a perception of the prices as yet another tax, bad timing (the voting occurred just as Britain agreed to return Hong Kong to China), and a failure by the government to present a clear case for the program or to develop measures to mitigate potential adverse effects (Harrison,1986; Catlin and Harbord, 1985; Dawson and Brown,1985; Borins, 1988; Government of Hong Kong, 1985.)

Norway

The Norwegian cities of Bergen, Oslo, and Trondheim have implemented road pricing schemes as a means of financing road improvements and transit. In Bergen, a central area pricing program has been in operation since 1986. In Oslo, 18 toll points around the city center were established in 1990. Trondheim installed its toll ring in 1991. A combination of collection methods is used, including monthly billing based on detection of subscribers' electronic windshield tags and manual toll collection with booths or machines.

The tolls, which were implemented despite substantial motorist opposition, are modest, about U.S. $.70 - $1.75 with substantial discounts for regular subscribers. Only Trondheim charges a peak period premium (about 30 cents). The tolls have been set primarily to raise revenues, not to reduce traffic impacts; but studies estimate that traffic has been reduced somewhat, about five percent in Oslo and about 6 -7 percent in Bergen (Jones,1989; Larsen, 1988; Traffic Eng. & Control, 1986).

France

Congestion pricing has been implemented on the A -1 toll road between Paris and Normandy to reduce congestion that occurs as urban dwellers return from weekends in the countryside. On Sunday afternoons, an evening toll surcharge of 25-50 percent depending on trip length has been imposed during the peak travel period, 4:30 - 8:30 p.m.. A discount of equal amount applies on both shoulders of the peak, 2:30 - 4:30 p.m. and 8:30-11:30 p.m. A standard flat toll applies at all other times. The toll and discount have changed travel behavior enough to smooth traffic flow on the facility.

Sweden

The Swedish government has evaluated road pricing options to address congestion and air quality problems in several cities including Stockholm and Malmo. The proposal for Stockholm initially called for the area entry licenses (pre-paid, automatically monitored electronic "debit cards"), but implementation was postponed because of opposition both to the entry fees and to a proposed ring road, whose purpose was questioned. It was estimated (Ramjerdi,1989) that a charge of U.S. $4.50 per round trip for crossing the cordon around the Stockholm inner city area would reduce congestion significantly, cutting auto trips by 28 percent and emissions of key air pollutants by about 18 percent. Furthermore, the net revenues from the program were projected to be sufficient to permit transit fares to be cut in half. (The program was expected to generate over $135 million in new revenues annually versus an annual operating cost of about $6 million.) Use of the net revenues for transit fare reduction was estimated to further reduce trips and emissions, resulting in a trip reduction of 35 percent and emissions reductions of 25 percent. (Jones, 1989; Peterson,1989; Ramjerdi, 1989; Stoelhorst and Zandbergen, 1990).

Britain

In the mid-1970s, several cities in England investigated various area license plans as ways of reducing high levels of congestion in their central areas. London and Bristol developed detailed program designs and carried out in-depth assessments, but neither area went ahead with implementation. Now London is once again considering road pricing options in a multi-year, multi-million dollar study.

The earlier London plan would have required daily or monthly supplementary licenses for auto travel in the ten square mile core between the hours of 8:00 a.m. and 6:00 p.m. Because congestion is severe in this area all day long, the license requirement would have been in effect all day. Licenses were to be sold, at commission, through automats, newspaper kiosks, post offices, service stations, banks and other retail outlets. Detailed information programs and administrative, monitoring and enforcement procedures were developed for the program, and penalty structures for various offenses were set up. Modeling analyses indicated that a daily price of $2.50 (1975) would have decreased automobile traffic by 37 percent. Annual cost of running the pricing program was projected to be less than 10 percent of the estimated $70 million in annual revenues, leaving substantial sums to finance the planned collateral expansion of transit service as well as other improvements.

Opposition to the plan from both elected officials and other groups led to its demise. The major objections centered around adverse impacts on the poor and those with special needs, such as visitors. Objections also were raised about restrictions on mobility and freedom to travel, which the promised expansion in transit did not appear to counteract. Concerns that might have been addressed more easily included administrative and enforcement feasibility issues and the threat of spillover traffic (Greater London Council, 1975; Bhatt and Beesley, 1976; May,1983).

The current study of road pricing for London began in 1991. The study was motivated by continuing traffic and environmental problems and growing financial constraints. The study is examining a wide range of pricing strategies and is evaluating their potential impacts on travel, business, and property market values. One such option would establish multiple pricing zones, e.g. with higher charges for travel in the core and lower charges at the periphery. Public and political acceptability of the various measures and mitigation options are also being assessed (Richards,1992).

Cambridge, England also is investigating a pricing strategy in which the fees for entry and movement would vary by distance and speed. An areawide system of detectors would be installed and on-vehicle "smart cards" would be debited when traffic movement is slow, or stop and go. Occasional visitors to the city would pick up passes from vending machines at city entrances. Revenues would be earmarked for public transit (Richards,1992).

Denmark

Denmark has the highest fees and taxes on auto ownership in Western Europe, and while these fees and taxes were not established solely to manage congestion and emissions, it is instructive to consider their impacts. High auto ownership and first-time registration costs have probably restrained ownership levels somewhat, but a more telling point is that the Danes keep their cars longer than other Europeans do. One result is lower fleet efficiency and higher pollution levels than might otherwise occur (Schipper, Deakin, and Sperling, 1994).

Japan

Japan has a registration fee system which, while not based directly on emissions, has the net effect of encouraging new vehicle purchase. Basically, the Japanese registration system includes mandatory inspections on all vehicles except those less than three years old. These inspections are biennial for private vehicles through ten years of age, following which they become an annual requirement. For commercial vehicles, the inspections are an annual requirement after the initial three year exemption. The fees are sufficiently steep that a considerable portion of vehicle owners purchase a new vehicle at the end of the three year exemption period, thus avoiding inspection fees altogether. An equally well defined portion of vehicle owners purchase newer vehicles near the end of the ten year biennial inspection period, apparently to avoid the onset of annual inspections.

The Japanese inspection fee includes a weight fee that ranges from $290-$415 (at 1994 exchange rates of 120 yen to a dollar), a liability insurance fee of $260, an average repair fee of $385, and a tax based on engine size that can range from $277 to $854. Accordingly, total inspection fees range from $1200-$1900. If the fees are not paid, the subject vehicle must be scrapped.

The net result of the Japanese system is a younger fleet. In the United States, nationwide, nearly a third of registered vehicles are older than ten years. Similarly-aged vehicles in Japan constitute less than ten percent of the registered vehicle fleet.

4.4 Commentary

A number of lessons can be gleaned from this review of experiences with transportation pricing. Perhaps the most important point is that while there has been considerable interest in transportation pricing strategies, as evidenced by the large number of studies carried out over the past two decades, implementation is far less common than analysis. Pricing strategies can be shown to have potential, but their ability to garner sufficient support for implementation is considerably less clear.

The implementation experience that is available is consistent with the findings from modeling studies. Both models and field evidence indicate that price elasticity does exist, though it is fairly small, often on the order of -.1 to -.2. Such elasticities are sufficient, however, to significantly reduce congestion, lower energy use, and cut down on pollution and greenhouse gas emissions.