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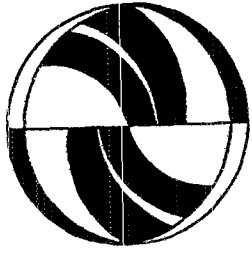
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**Transportation Pricing Strategies for
California: An Assessment of Congestion,
Emissions, Energy, and Equity Impacts**

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Transportation Pricing Strategies for California:

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

Final Report

by

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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.

Acknowledgments

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Disclaimer

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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:

- o **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.
- o **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 riding a bicycle 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 miles¹ 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 = 0.62 miles, 1 kilogram = 2.2 pounds, 1 liter = 1.06 quarts = 0.23 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.

- o 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?

- o 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?

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

- o **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.

- o **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

- 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 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.

- o **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.

- o **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

- o **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
- o **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
- o **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.

- o **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:

- o congestion pricing
- o parking charges
- o fuel tax increases
- o VMT fees
- o 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 - 0.5 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 - 1.5, 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 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 \$5,000 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 (or 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 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 Fees²

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

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

- o exemption of a portion of the VMT (e g , first 5000 miles) from fees to provide for a "lifeline" level of travel
- o different rates for private and business travel
- o fees levied, in part or in whole, on a household basis rather than a vehicle basis
- o 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

- o a new car fee or rebate according to the vehicle's specific emissions characteristics
- o a fee that depends on emissions levels but not mileage, e g , a super-emitter fee or clean car rebate
- o 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
- o means-tested ("lifeline") fees
- o 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 Pricing¹

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.

- o **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.

- o **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).

- o **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).

- o **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.
- o **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.
- o **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.
- o **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 house-

holds. Congestion relief (lower time costs) or declining fuel prices (lower dollar costs) might induce the opposite effect, especially among higher income households

- o **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

- o **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 (-0.5 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 50 percent. 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., -0.5 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, public 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

- o 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,
- o The average value of waiting and walking time is two to three times that of in-vehicle time,
- o There is ambiguity in the data as to whether business-related trips and recreational trips display the same or different implicit time valuations,
- o 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:

- o The total resources committed to an activity decrease as a result of the project,
- o 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 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:

- o Net Benefits = $PV_b - PV_c$
- o 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

- o the income distribution of affected travelers,
- o the price base (including parking, tolls, and other out-of-pocket expenses),
- o the pattern of delay in the transportation system,
- o the network configuration for the affected mode, particularly the presence or absence of competitive routes,
- o the availability of competitive alternate modes,
- o 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 Evidence¹

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, an 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 Malmö. 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.

5. Framework for Policy Analysis

5.1 Overview

As previous chapters have documented, transportation pricing strategies are based on well-established concepts of economic efficiency and travel behavior, and numerous studies have found that they would be effective in reducing congestion, improving air quality, increasing energy efficiency, and lowering greenhouse gas emissions. However, until recently, few outside of academia have shown much interest in reforming transportation pricing. U.S. highway programs have been based on an average cost approach that supports extensive cross-subsidies and does not account for externalities such as congestion or emissions. Air quality planners and energy conservation program analysts have emphasized technology mandates and other "command and control" regulatory programs.

Several factors appear to motivate the new interest in transportation pricing. Probably the most significant reason for the current willingness to investigate transportation pricing strategies is the shortfall of funding that is beginning to threaten transportation programs and projects across the country. Transportation pricing strategies are seen as possible ways to generate revenues which then could be used to supplement existing sources of financing for transportation, replace existing revenue sources, or pay for new transportation programs. A second reason for interest in transportation pricing is that the current levels of technology mandates and regulatory requirements fall short of meeting Clean Air Act requirements and greenhouse gas reduction commitments, but more stringent mandates and requirements are increasingly costly and difficult to implement. Transportation pricing strategies are on the table as potentially more effective ways to meet legal obligations and political commitments. Finally, there is some interest in transportation pricing as a more efficient and fairer way to pay for transportation and its impacts, particularly as the vehicle fleet becomes more diverse. Urban and suburban traffic congestion and associated impacts are increasingly recognized to involve significant economic losses, and although a variety of

approaches are being applied to deal with these problems, many observers have come to believe that relief can be only partial unless market pricing principles are applied

However, as the examples in the previous chapter illustrated, far more transportation pricing measures have been studied than have been implemented. Many policy-makers, including those who are interested in transportation pricing measures, are concerned that the measures may not work as billed or could have unacceptable side effects and be disastrously unpopular. Policy-makers considering changes in transportation pricing want reliable information on the potential limitations as well as the potential contributions of the various pricing approaches.

In designing the analyses of transportation pricing measures carried out for this study, we turned to leading policy experts for help in identifying issues that need to be taken into consideration.¹ These experts, in turn, recommended additional persons and organizations to contact for each of the case study regions. We carried out interviews and participated in several discussions and meetings on transportation pricing measures and re-interviewed a sample of the respondents a second time near the end of the study.² In this manner we obtained input from a variety of policy makers and interest groups, including planners and

¹ The technical advisory committee established for the study provided suggestions on policy issues to be evaluated and helped identify interests whose views needed to be taken into account. Additional recommendations on issues and interviewees came from team members.

² Interviews and discussions with faculty at the University of California at Berkeley, UCLA, UC Irvine, UC Davis, MIT, Harvard, City College of New York, and the University of Minnesota, and with experts at the U.S. Department of Transportation, the U.S. Environmental Protection Agency, the Volpe National Transportation Systems Center, and the Lawrence Berkeley Laboratory were conducted. The authors also discussed their work and received comments from the White House Conference on Global Climate Change, the President's Council on Sustainability, the President's Council on Greenhouse Gas Reduction (CarTalk), the Transportation Research Board, and National Association of Motor Vehicle Emissions Control. In California, the authors participated in discussions of transportation pricing policies at a series of meetings of the Metropolitan Transportation Commission's Congestion Pricing Demonstration Project and the Environmental Defense Fund's study of transportation pricing and equity in Southern California. Additional discussions with local agency staff and consultants were held as part of a series of symposia organized by the UC Institute of Transportation Studies and held in Sacramento, Los Angeles, San Diego, and the Bay Area. Important feedback on transportation pricing options also was received at the 1995 California Senate Fiscal Retreat. Finally, the authors discussed transportation pricing policies with representatives of MPOs across the country, including Seattle, Portland, Houston, Dallas, New York, Chicago, and Washington, as well as with state officials in Maine and Oregon.

engineers from local governments, metropolitan planning organizations, transportation operating agencies, and state and federal regulatory agencies, representatives of businesses, environmental groups, and social equity advocacy organizations, and local elected officials and members of the California State Legislature. We also discussed transportation pricing policy issues and analysis needs with technical experts from academia and the private sector. A small number of additional discussions were held with representatives of federal agencies and national transportation organizations in Washington, D C , as well as with key informants from other states and metropolitan areas.

The key issues thus identified are

- o How to set transportation prices
- o Effectiveness
 - transportation impacts
 - environmental impacts
 - energy impacts
 - land use and locational impacts
 - revenue generation
- o Unintended consequences
- o Fairness/distribution of impacts
- o Use of revenues
- o Political acceptability
- o Legal barriers
- o Implementation and administration
 - assignment of responsibility for implementation
 - monitoring and enforcement
 - dependence on new technologies

The nature of these issues, as indicated by the discussions and interviews, is considered in the next section. In the final section we consider how these issues can be addressed in our case studies.

5.2 Key Issues

How to Set Transportation Prices

Several concerns are raised about how to set transportation prices. While, as discussed in Chapter 3, economists point out that efficiency would dictate setting the price at the short run marginal cost, practitioners and policy makers worry that such price setting would be too complex to be practical. For example, they worry that the price would have to change frequently to remain efficient, but frequent price changes could be difficult to communicate or explain to the public and might necessitate an extensive new system of communications (dial-up information on travel conditions and prices, e.g.) to make the variable prices acceptable.

Probably the most important concern is how high the prices might have to be to internalize costs and make a difference in congestion levels, emissions burdens, or energy use. If very high prices were needed, many would have doubts about political acceptability. Some of those we interviewed thought such prices would indeed be needed. Concerning congestion pricing, for example, doubters have suggested that noticeable congestion relief might not occur until prices were so high that travelers would not be tolerate them on publicly financed roads.

Effectiveness

Proponents look to transportation pricing to reduce travel times and produce operating cost savings for auto and transit users, increase transit productivity and reliability, reduce emissions and energy consumption, and generate economic benefits from more efficient organization and cost reductions for activities. Planners and policy-makers need explicit information about each of these effects so that they can compare pricing strategies to other transportation strategies which could be used to accomplish similar ends, such as new investments, operations improvements, demand management, and technology substitution.

-- Transportation Impacts

Key questions raised by planners and policy-makers are

- o How would transportation pricing affect the transportation system, in terms of travel time, travel cost, mode shares, and overall travel patterns?
- o Would congestion be reduced, or would it simply shift to other facilities, locations, and times? Would the reduction be long lasting?

The magnitude and longevity of congestion reduction is of particular concern to many policy-makers. Congestion pricing in particular raises fears that massive numbers of travelers would be forced to take other routes or modes or forego travel altogether, disrupting alternate routes, overcrowding transit, and harming economic activity. Transportation analysts may know that only a small change in volume can produce congestion relief, but this would need to be demonstrated for specific facilities before policy-makers' concerns would be alleviated.

--Environmental Impacts

Air quality is without a doubt the environmental issue of greatest concern to policy makers in most large cities today, and Clean Air Act requirements have helped to draw attention to transportation pricing. Studies of ambitious programs of transportation demand management, operations improvements, transit investments, and the like, find that such measures will only reduce emissions by 5-10 percent at most (see, e.g., Harvey and Deakin, 1991). Since emissions reductions of several times that amount often are needed, other options must be pursued. Consequently planners and policy-makers in a number of urban areas are taking a look at transportation pricing as an option for improving urban air quality.

Both the magnitude of emissions reductions and their timing are of concern. Timing matters not only because certain strategies might take a long time to implement but also because the characteristics of the vehicle fleet in the future could be considerably different from those of today's fleet, so that comparative effectiveness could change. The question of timing also is particularly important for strategies that might be dependent on new technologies being implemented, e.g., on-board vehicle emissions monitoring equipment or remote sensing devices.

-- Energy Impacts

Concern about petroleum dependence has waned among most policy-makers, even though U.S. oil imports are at record highs. However, there is considerable concern in some (though far from all) quarters about greenhouse gas emissions, of which about 25 percent are from transportation sources. Since greenhouse gas emissions from transportation are proportional to fuel use, strategies which save energy also reduce greenhouse gases, and the effectiveness of transportation pricing strategies in this regard is of interest.

-- Land Use and Locational Impacts

Some planners, policy-makers, and business leaders voice concerns that pricing strategies could significantly change the attractiveness of certain locations, disrupting local economies, altering land markets for both housing and commercial development, and inducing movement to less costly locations. In particular, concerns are expressed that congestion pricing would disadvantage the central city and inner suburbs, and many forms of parking pricing would disadvantage outer suburban locations. Other planners and analysts are convinced that there would be no significant land use impacts from pricing changes of the magnitude being considered. Analyses which can demonstrate the pattern of price changes and elucidate the locational impacts are needed.

-- Revenue Generation

An attractive feature of transportation pricing measures is that they can pay for themselves and generate additional revenues, whereas most other transportation management strategies are costly to implement. Many also produce cost savings for the public sector, the business community, and individuals.

The magnitude of the revenues likely to result from various measures is a key interest of both planners and policy-makers. However, there may be significant limitations on these expenditures, including anti-tax sentiment and the inherent difficulty government has in managing certain activities.

Unintended Consequences

Several planners and policy-makers expressed concern that certain transportation pricing strategies could have unintended consequences that would lower the strategies' effectiveness or increase the costs and complexity of implementation. They observed, for example, that parking pricing has sometimes simply pushed parkers into unregulated spaces on neighborhood streets or in nearby shopping centers, and that tolls have sometimes caused traffic diversion to parallel routes. Such spillovers would either have to be minimized through detailed design of the strategy, or their effects would likely reduce the benefits of the transportation pricing policy.

Others raised the possibility that such measures as VMT fees or vehicle registration fees based on mileage could lead to some motorists tampering with their odometers, bribing inspectors, skipping required vehicle inspections, registering vehicles outside of the areas where the policies apply, or simply not registering their vehicles at all. Along similar lines, the concern was expressed that higher fuel taxes could lead to more tax avoidance and to extra-territorial fuel purchases.

Fairness / Distribution of Impacts

While some of those we interviewed argued that using prices to signal the costs of transportation and its impacts would be more efficient, cheaper, and ultimately fairer than command-and-control regulation, others expressed concern that pricing strategies would further exacerbate income differences and hit hardest on lower and middle income groups. Key questions raised include:

- o Who will benefit and who will not?
- o To what extent is the success of pricing dependent on differences in income and constraint, rather than differences in taste and choice?

- o What are the social implications of various pricing schemes - how might lifestyles, activity participation, and travel behavior be affected?
- o Should losers from the application of pricing strategies be compensated, and if so, what would be efficient ways of doing so? In particular, if low and moderate income people are harmed by various transportation pricing strategies, what might be done to compensate them for their losses?
- o What would be the consequences of a shift to market pricing for those who have made location decisions based on the previous prices and conditions?
- o Would gradual implementation be more equitable and understandable to the public?

Transportation pricing clearly will have differential impacts depending on users' circumstances. For example, congestion pricing will benefit those drivers, HOV users, and transit users continuing to use the facility who place a high value on the travel time savings they receive. Others will shift the time they travel, their route, or their mode, and many in this group are likely to find the tradeoff they made acceptable or even advantageous. However, travelers who place a low value on the travel time savings on the newly priced facility but for some reason must continue to use it may consider themselves worse off, as may motorists who now drive at time of day they find less convenient because the tolls are lower, or who choose not to make the trip at all because of the new cost. Travelers who are "priced off" to competing, slower facilities and services also may feel that the pricing policy has made things worse for them, as may other travelers on those other facilities and services, if those facilities are unpriced and congestion increases on them. Travelers who switch from driving to HOV or bus services on the tolled road may benefit or lose depending on circumstances: some of those who switch may benefit if bus or HOV speeds are greatly improved, but others may lose if speed improvements are modest or these modes were fairly inconvenient to begin with.

Although the specifics would differ, other pricing strategies also would have differential impacts on households and individuals depending on their income, the location of their homes and workplaces, their household responsibilities and personal preferences, and even the kinds of cars they own. In each case the pricing strategy would produce social benefits -

congestion relief, cleaner air, lower fuel use, lower emissions of greenhouse gases - and revenues could be used to expand or improve transportation facilities and services or reduce other transportation taxes and fees. On a personal level, however, some would find themselves better off after pricing strategies are implemented, but others would not, in the latter group are some who would prefer to continue their current behavior but are unable to afford to do so.

Recognizing the potential for differential impacts, the persons we interviewed put forward a number of arguments challenging the basic fairness of transportation pricing policies. Congestion pricing, they worried, was likely to hit low and moderate income users of highways in order to advantage the affluent. Emissions fees were seen as falling predominantly on lower income households dependent on older cars. Policies favoring parking pricing, some argued, would be inconsistent and unfair so long as local governments continue to require plentiful parking as a condition of development, and at best would be only indirectly related to congestion, emissions, or energy impacts caused by parking users. Emissions fees were viewed as difficult to set fairly, given the importance from a pollution perspective of time and place of travel. VMT fees were thought to be too indirectly related to congestion, emissions, or energy use to be justified as impact fees and hence were characterized as unreasonable constraints on mobility. Finally, some took the position that highways already have been paid for through gas taxes and other fees, and that tolls amount to "paying twice."

Others argued that pricing policies are fair and ethical, alerting individuals to the costs of their choices and thereby encouraging them to choose economical and socially responsible modes of travel. They asserted that many of the new pricing proposals being considered would be fairer than the current reliance on fuel taxes and other imposts, which result in cross-subsidies between users of rural and urban roads, peak and off-peak users, and users of more and less congested facilities, new pricing strategies would be particularly desirable, they suggested, if they replace highly regressive taxes. Revenues from pricing, some argued, would enable the government to provide programs that benefit a wide spectrum of the population, and to offset any hardships among low and moderate income

groups. Finally, it was pointed out that if in the future, a variety of fuels are in use, alternative pricing policies may be a necessity - it would be neither fair nor practical to rely on at-the-pump charges if a substantial percentage of the vehicle fleet is electric and fuels up at a home recharging station, for example.

All of these contentions would have to be taken into account in assessing transportation pricing options and designing specific implementation programs, including mitigation plans as needed.

Use of Revenues from Transportation Pricing

What are appropriate uses of the revenues from transportation pricing strategies? For most forms of pricing directed toward the automobile and its use, an efficient use of revenues would be to direct them to the best available means of reducing the impacts that are being targeted. For example, economic principles would direct that congestion pricing revenues be used primarily for highway improvements, as long as the revenues are sufficient to cover the short run marginal cost of the investments. The proceeds could cover the costs of original outlays for the roadways and any subsequent maintenance costs, and for expanding capacity to respond to demand. In the case of emissions fees, revenues would best be directed to the most efficient means of reducing the emissions burden. In each case the benefits produced by efficient expenditures might make it possible, over time, to reduce the prices charged or fees imposed.

Comments from our interviews and meetings make it clear that revenue use is unlikely to be dealt with as a simple matter of economics, however. For one thing, in many places expanding highway capacity is currently seen as politically impossible. Paradoxically, this seems to be the case in built-up areas where levels of congestion are very high and hence congestion pricing revenues (or parking impact fees, as a second-best approach) also would be high. An inability to return revenues to motorists via improved transportation facilities might reduce the likelihood that pricing measures would be adopted, or could lead

to a decision to set prices at a level reflecting revenue needs rather than at a marginal cost basis, since the latter might seem excessive if the funds were not at least in part returned by means of improvements benefitting those who paid them

In addition, many of those interviewed expressed strong preferences to use transportation pricing revenues for a variety of projects and programs, including general tax relief, replacement of sales tax earmarks for transportation, income tax credits for commute costs for low and moderate income households, and compensatory programs such as transit improvements, ridesharing subsidies, and high-emitting vehicle repair or retirement programs. For example, many thought that to implement congestion pricing it would be necessary to commit funds to public transportation, construction of HOV lanes, park and ride lots, etc., to implement emissions fees it would be necessary to help low income owners of dirty cars clean up or replace their vehicles. It is conceivable that the revenues from efficient pricing levels would not be sufficient to cover the costs of such programs, and there is no direct assurance that politically popular means of "compensating" those harmed by the price increases will in fact do so, or will be efficient overall.

Parking pricing strategies raised perhaps the greatest level of concern about the use of revenues, particularly in the cases where the strategy would induce private operators to charge for parking. Many objected that it would be inappropriate for government to intervene in private operators' pricing decisions on economic grounds alone, and pointed out that there would be no assurance that revenues from private parking pricing would mitigate broader social impacts in any but the most general and clumsy ways.

The numerous concerns raised about the use of revenues from transportation pricing would have to be addressed in designing pricing programs and evaluating their net benefits. It may be difficult to design a compensation scheme that is as concrete or credible as the losses the losing groups anticipate. In addition, not every individual will be compensated, and at least some of the individuals who pay the new price or are priced out of the system are still likely to lose despite overall compensation.

Finally, it was noted that there often are legal restrictions on both the amounts that can be charged and the use of revenues from transportation. For example, levels and permitted uses of fuel taxes and vehicle registration fees are specified in law in most states. Moreover, restrictions on the expenditure of fuel taxes are frequently located in the state constitution. Such legal restrictions would have to be dealt with before an effective transportation pricing program could proceed.

Political Acceptability

Transportation pricing strategies have been accepted for years among academics and a few others, but for many, the use of pricing as a policy tool is a new idea. And many in this latter group are ambivalent. They are willing to consider pricing, but that doesn't mean that they want it or would implement it if any other options seemed viable.

Most of those we interviewed believed that resistance to tax increases and opposition to having to pay for a good or service formerly considered to be "free" can be expected when transportation pricing mechanisms are proposed. On the other hand, they believed that support may be forthcoming if the new pricing mechanism replaces a less direct or more onerous tax (e.g., if pricing replaces a portion of a sales tax earmarked for transportation), or if it pays for a highly desired expenditure program (such as transit improvements or general fund deficit reductions).

Historically, transportation pricing strategies have had no significant support from elected officials, policy-makers did not see congestion, environmental problems, energy concerns, or revenue shortfalls as being severe enough to justify an intervention strategy which could disrupt many people's established travel habits. While these attitudes may be softening, there still is considerable concern that pricing strategies could cause more harm than good. Moreover, transportation price increases are widely thought to be likely to generate negative reaction and even resistance from the general public, in particular, the idea of using pricing to regulate demand or mitigate impacts is thought to be poorly understood and little accept-

ed, though proposals to raise fees to pay for transportation improvements can sometimes be acceptable

Parking controls of all sorts, including pricing, are viewed by many as primarily a local issue. In this view, public officials can be relied upon to price publicly owned parking at levels appropriate to local conditions. Prices charged for privately owned parking are often considered none of government's business.

Other forms of transportation pricing, e.g., fuel tax increases, would be considered with some reluctance because of past concerns voiced about them by voters and by elected officials. In addition, numerous comments stressed the need to tie any tax increase to a specific expenditure plan which makes it palatable.

Despite the considerable concern about the political acceptability of pricing strategies, political leaders expressed a conviction that we cannot afford to build our way out of congestion, either financially or environmentally. As a result they are willing to consider (though not necessarily persuaded to implement) congestion pricing and other forms of transportation price increases. In addition, some groups are beginning to see pricing as less onerous than direct regulatory requirements for environmental protection.

The political acceptability of a transportation pricing measure will depend in large part on who supports it, who opposes it, and how strongly the respective groups feel about it. Here congestion pricing may face special difficulties. As one public agency official stated, the implementation of congestion pricing is discussed by academics as creating winners and losers, but for public officials it is extremely difficult to even acknowledge that there might be losers, despite concerns raised about the efficiency of compensatory programs, it was felt that public support would depend on potential losers being compensated by using the revenues raised for a package of measures probably including transit and HOV service expansion, in-lieu or direct compensation to those for whom alternatives are not feasible, and assurances that possible spillover of traffic or parking to local streets will be managed.

Even with compensatory measures, it may be difficult to gain political support for transportation pricing, for several reasons. The beneficiaries of pricing often will be harder to mobilize politically than the losers, for example, those who would share the benefits of toll revenues may be a large group but individual benefits may be fairly small. Travelers who place a high value on time may benefit greatly, but these benefits are, at least in advance of tolling, somewhat speculative. Many of the losers, by contrast, will see that they have an obvious and significant stake in opposing tolling, and their numbers may be large in some situations. This is especially likely to be true of motorists who believe that they have no reasonable alternative to driving during peak periods.

Transit agencies and ridesharing agencies are likely supporters of transportation pricing strategies as potential revenue recipients. However, in areas where the funds would be used primarily for highway improvements, the support of these agencies may not be as readily forthcoming. Some observers noted that many plans and policies on transit, ridesharing, and HOVs are based on the assumption of worsening congestion, and argued that as a result, some interest groups may have a stake in congestion continuing.

Particular interest groups may have special clout and may strongly influence the design of the transportation pricing proposal. Among the groups mentioned by our informants are business interests, environmentalists, truckers and delivery businesses, labor groups, and advocates for the poor.

-- Business Groups

The acceptability of transportation pricing strategies to business interests varies with the particular policy and its affect on businesses themselves, their employees and customers, and the regional economy. Furthermore, business interests are diverse, they do not speak with one voice. In the San Francisco Bay Area, for example, big businesses' interest in congestion pricing was substantially motivated by a desire to avoid employer-based trip reduction programs focused on large employers. However, smaller businesses which would

have been exempt from the regulation did not necessarily agree that pricing strategies are a more desirable way to go. Similarly, many business interests reacted favorably toward gas tax increases and emissions fees, but these were strongly opposed by the auto and oil industries.

Of all the policies considered in this study, parking pricing appears to generate the least support among businesses - employee parking pricing is greeted with little enthusiasm even when revenues go to the employer, and the notion of charging for parking for customers and clients generates considerable hostility.

Some researchers argue that proposals to impose parking pricing might be acceptable to employers if they in turn got some relief from other regulatory impositions, and if local governments' parking requirements were re-evaluated. However, a number of employers made it clear to us that they had no desire whatsoever to take away a subsidized parking benefit from their employees.

-- Freight Carriers

Congestion is undoubtedly deleterious to high value goods movements, and so trucking interests would be expected to strongly benefit from congestion pricing. In at least one instance, however, delivery firms have asked to be exempt from congestion pricing proposals on the grounds that the direct costs would be excessive. Such exemptions would be likely to result in windfall benefits.

Increases in fuel tax and registration fees are more understandably costs that truckers might oppose. Some transportation specialists argue that truckers might be less opposed to any of these pricing strategies if it were a substitute for other fees and charges such as sales and excise taxes.

-- Environmental Groups

Environmental groups increasingly have been expressing interest in full cost pricing of transportation and several groups have published studies advocating the removal of parking subsidies, increases in fuel taxes, price incentives for fuel efficient and low emissions vehicles, and so on. Several environmental groups have expressed a special interest in pricing strategies as a way of meeting air quality requirements as well as reducing congestion, and have advocated congestion pricing. However, the linkage between air quality and congestion may be of greatest relevance in areas where congestion occurs over large areas and at many times of day, where congestion is less pervasive, the air quality/congestion pricing linkage is less clear. Since in most urban areas more than half of vehicle emissions are typically due to non-work, non-peak travel, air quality strategies may need to look further than congestion. Thus after considering all the issues, gas tax increases, emissions fees, and/or parking pricing may be the preferred alternatives.

Not all environmental groups support pricing, however. Several expressed a desire not to be associated with tax increases or policies that they view as favoring the elite.

-- Social Justice Groups

Some advocates for the poor and for working class groups are willing to consider transportation pricing strategies in part because the current system of transportation finance is seen as highly inequitable (particularly the portion financed via property taxes and fees, sales taxes, and development exactions). These groups note that other forms of transportation pricing could be used to provide relief from the more regressive taxes, and that revenues could be used to make the system fairer. On the other hand, some social justice groups are dubious that a new pricing system would be more equitable than the current system, or that revenues would be directed toward the disadvantaged. As a result, some of these groups will do their utmost to prevent implementation of such measures as congestion pricing or emissions-based vehicle registration fees.

Legal Barriers

In the interviews and discussions, the need to change state and federal laws in order to implement many transportation pricing strategies was considered a major to their application. In particular, the prohibition on tolls on many federal-aid facilities was considered problematic, while even piecemeal tolling may work effectively if the key bottle-necks in a metropolitan highway system can be tolled, in most metropolitan areas the federal restriction would probably prevent tolling of many key congested facilities.

State restrictions on the use of fuel taxes and vehicle registration fees also might have to be removed before certain program elements could proceed. Finally, in a number of states, and in particular in California, home to our four case study metropolitan areas, provisions restricting government's ability to increase taxes or impose new taxes and fees must be carefully accounted for.

Implementation and Administration

A final issue raised in the interviews and discussion groups had to do with how transportation pricing strategies might be implemented and administered. In practically every case, there would be considerable work to do to design the specifics of the measure, establish a legal and institutional framework for its implementation, put it into effect, monitor its results, and follow up on its effectiveness. Specific concerns raised in this study were:

- o assignment of responsibility for implementation
- o monitoring and enforcement
- o dependence on new technologies

-- Assignment of Responsibility for Implementation

Two key questions raised in interviews and discussion groups are

- o What characteristics should an organization have in order to successfully implement and manage transportation pricing programs?
- o Are transportation pricing policies consistent with current institutional arrangements and assignments of responsibility, and if not, what would it take to set up appropriate organizations?

Many observers argued that institutional capacity to develop pricing policies and to oversee revenue collection, monitoring, enforcement and revenue distribution would have to be developed, since the tasks and skills are quite different from those carried out by most transportation agencies, motor vehicle bureaus, or environmental divisions today. In addition to providing the legal authority and the budgetary wherewithal to act, institutional change would probably need to extend to personnel recruitment and training, for at present the personnel in key agencies would likely view the management of transportation pricing strategies as a major departure from agency missions. Specific requirements would include an ability to receive and process revenues and the capability to handle accounting, audits, monitoring and enforcement.

Several of those we interviewed cautioned that adequate time would need to be allotted to devise an appropriate institutional and administrative framework for transportation pricing. On the other hand, many thought that a variety of approaches might be workable. For example, depending on the transportation pricing measure and its design, a single state or regional agency might be given the responsibility for implementation and administration, or a cooperative arrangement, voluntary or otherwise, might be needed among many existing agencies. The state department of transportation or toll authorities for different facilities, counties, etc., might handle congestion pricing, a peak period parking surcharge might be implemented regionally or by each local government acting pursuant to a memorandum of understanding or even acting independently. In addition, various elements of a measure

might be assigned to different agencies, for example toll collection to one organization and audits and accounting to another

-- Monitoring and Enforcement

Many transportation pricing strategies would require regular monitoring and enforcement to prevent noncompliance, evasion or fraud, and for some of the measures our respondents felt that this could be a costly and complicated task. In particular, many believed that vehicle registration fees and VMT fees would present considerable opportunity and temptation for evasion or fraud. A monitoring and enforcement program would need legal authority and assignments of responsibility to appropriately staffed, equipped, and funded agencies, as well as procedures for revising the pricing program to reflect lessons learned about its design and implementation.

-- Dependence on New Technologies

While new technologies are not strictly necessary to implement transportation pricing measures, their application would in many instances lower implementation costs, increase public acceptance, and allow a better matching of costs and benefits. For example, toll tags or other means of electronic toll collection would greatly ease the implementation of congestion pricing and could be used, as well, to collect certain parking fees. Tamper-resistant electronic odometers and on-board emissions monitoring and recording devices could greatly aid the implementation of VMT fees or emissions-based vehicle registration fees. The problem is that the deployment of the new technologies may take considerable time, at least if large scale applications are contemplated. This is particularly true of technologies that are practical primarily as equipment on new cars rather than as add-ons to the existing fleet.

In some cases new technologies may remove a barrier to implementation. For example, it has been alleged that toll booths create delay and increase accidents. From a practical viewpoint, the success of congestion pricing may depend on the ability to collect charges without greatly slowing down traffic. The success of automated toll collection systems in several applications in the U.S. removes an argument against tolls and congestion pricing.

At the same time, some of those we interviewed cautioned that technologies also could be invented to aid the circumvention of transportation pricing strategies (much as radar detectors lower the speeding motorist's chance of getting a ticket.)

Great advances have been made in AVI, but AVI technology will probably need further refinements for congestion pricing in large-scale applications. It must be able not only to correctly identify and bill (charge) users, but to detect violations (unlicensed vehicles, tampered or vandalized equipment, non-payment) and trigger enforcement against them. The workability of the technology should a large number of road users attempt to subvert the system also remains to be tested. More work also may be in order on automated ticketing-by-mail of violators through camera radar or other devices, a method which also might require some changes in law (e.g., if owners rather than drivers are to be held responsible for moving violations).

5.3 Implications for the Study Design

As the preceding section indicates, policymakers and other key actors can be expected to raise numerous questions about the feasibility, effectiveness, fairness, and political acceptability of new transportation pricing strategies. How can studies be structured to help answer these questions?

First, some of the issues identified can be addressed, in whole or in part, through empirical studies - data analyses and modeling. Issues which can be addressed in this fashion include

- o How to set transportation prices -magnitude needed to achieve certain policy goals
- o Effectiveness of particular policies
 - transportation impacts
 - environmental impacts
 - energy impacts
 - certain land use and locational impacts
 - amount of revenue generated
 - economic impact of various uses of the revenues
- o Fairness/distribution of impacts who benefits and who pays, by income or other socioeconomic grouping

Other issues are dependent on the specifics of the proposals being considered, and the analysis required is more qualitative, depending on legal, political, and institutional knowledge. Falling into this category are assessments of

- o likely public reaction to various measures
- o the nature and likelihood of unintended consequences, considering program design and traveler behavior
- o impact on public acceptability of various uses of the revenues
- o legal considerations
- o Implementation and administration program needs

In the chapters that follow, we present a series of quantitative and qualitative analyses to address these issues using data gathered from our four case study regions

6. Analysis Methods and Analysis Approach

6.1 Overview

This chapter discusses the analysis methods and the analysis approach used in the evaluation of transportation pricing measures for four California metropolitan areas: the San Francisco Bay Area, Los Angeles, San Diego, and Sacramento. We begin with an overview of the basic analysis tool we selected for use in this study - a travel demand analysis modeling package called STEP.

STEP was designed for planning applications and policy analyses and encompasses a wide range of household and individual choices that affect travel behavior, including (among other things) such choices as where to live, how many autos to own, how often to travel, work location, destinations for shopping and other trip purposes, what mode to use, what route to take, and what time of day to travel. We discuss how STEP works and how we used it to examine the potential impacts of pricing strategies on travel behavior, traffic volumes, and environmental impacts in the analyses.

We also briefly describe other methods used to supplement the STEP analyses. In particular, we applied estimates of the elasticity of vehicle fuel economy with respect to fuel price in order to account for changes in the efficiency of the auto fleet that might result from fuel price increases, we also used detailed network models in conjunction with STEP to study the effects of congestion pricing and to estimate link-level prices in two specific corridors.

Additional documentation of the STEP model is presented in Appendix A. Specific results from the model applications are presented in Chapter 7.

6.2 Overview of the STEP Package

STEP is a travel demand analysis package composed of an integrated set of travel demand and activity analysis models, supplemented by a variety of impact analysis capabilities and a simple model of transportation supply. STEP is based on microsimulation - a modeling technique which uses the individual or household as the basic unit of analysis rather than dealing with population averages (cf. Orcutt, 1976). STEP results are aggregated only after the individual or household analyses are completed, allowing the user great flexibility in specifying output categories.

STEP has been applied in a number of Bay Area studies over the years, and has been adapted for use in studies in Los Angeles, Sacramento, Chicago, and the Puget Sound region (Seattle). Applications can proceed with model reestimation specifically for the region - essentially, by creating a completely new set of models for STEP - but to date nearly all applications outside the Bay Area have relied on extensive recalibration of the default (Bay Area) models plus a limited amount of re-estimation as needed to match local conditions.

Several features of STEP supported its choice as the basic modeling tool for the analyses presented here. STEP's regional, subarea, and corridor-level analysis capabilities fit well with the scope and scale of the policies under consideration. Its model formulations can represent a comprehensive set of possible price effects, and its models display linkages consistent with travel behavior and pricing theory. Its use of microsimulation makes it possible to address many of the questions about equity and the distribution of impacts that frequently arise in debates about pricing. Finally, it is far faster to calibrate STEP for a region than to upgrade the regional models to include pricing variables, and far faster and less expensive to run STEP than to apply regional models.

STEP's data analysis capability is another important asset in pricing studies. STEP's microsimulation formulation permits the package to be used as a survey tabulation technique employing sophisticated data transforms and linkages. For example, many travel surveys contain detailed information about the vehicles each household owns and indicate

which vehicle was used for each trip made on the survey day(s). Using STEP, these vehicle data can be tabulated so that exact usage patterns by model year or vehicle type can be determined. They also can be related to personal and household characteristics to yield useful information about, e.g., low-income households' dependence on old vehicles and their contributions to vehicular emissions.

STEP itself was originally developed for sketch planning analyses in the San Francisco Bay Area (Harvey, 1978). Since that time, all of the models in STEP have been completely reestimated and additional models addressing location choice, time-of-day of travel choice, and congestion effects have been added. The most recent formulations are nested logit. A number of versions of STEP are currently available, including options that permit the analysis of activity data as well as travel data, and versions that use either MOBILE or California EMFAC emissions data.

STEP's models are applied using actual or forecast data on household socioeconomic characteristics, the spatial distribution of population and employment ("land use"), and transportation system characteristics for the selected analysis year(s). The socioeconomic characteristics of a sample of households and its members are usually taken from a regional travel survey or from the U.S. Census Public Use Microdata Sample (PUMS). Population, number of households, and employment by category (type) are taken from the regional "land use" data base. Transportation level-of-service data (times and costs) are derived from the region's travel model system. The land use data are provided to STEP for subareas (which could be zones, districts, or corridors) and for the region as a whole; the level-of-service data are provided in the form of large matrices of interzonal times and costs. STEP then reads through the household sample, attaching level-of-service and land use data to each household record as necessary. For each household, STEP uses its models to predict a daily travel and activity pattern for each individual in the household. Finally, household travel is summed up and household totals are expanded to represent the population as a whole.

STEP can analyze any change in the population or in the transportation system that 1) can be represented in terms of the variables in its models and 2) can be associated with a specific geographic area or grouping of households. Testing the effect of a change in conditions or policies is a simple matter of re-analyzing the household sample using the new data values, and comparing the results with previous outputs. For example, a new highway or new transit service can be represented by changed travel times and costs for the areas served, a parking price increase can be represented by an increase in out-of-pocket costs, an increase in income in a particular area or for a particular population subgroup can be represented by editing the household file to incorporate the revised incomes. Along similar lines, future years can be represented through proportional factoring and reweighting of survey observations to reflect expected regional trends, or can be based upon a more sophisticated microsimulation of household changes based on cohort survival and other methods of demographic forecasting.

The sampling framework preserves the richness of the underlying distribution of population characteristics and permits tabulation by any subgroup with sufficient observations to be statistically significant. For example, the results can be disaggregated by income level and age, which would allow an assessment of effects for, say, various income quintiles among the retired population. This is a significant advantage over an aggregate model, which uses zonal averages for most socio-economic data.

STEP maintains its quick response capability while achieving great detail in representing behavior in part by reducing its detail in representing transportation networks. STEP does not have an internal transportation network representation and traffic assignment model, so changes in level of service resulting from changes in demand must be calculated in another way. Both an approximate method and a more detailed and conventional network modeling approach have been developed for this purpose.

To approximate the effects of changes in demand on network performance and vice versa, a simple routine for estimating level-of-service was incorporated into STEP in the early 1980s (Harvey, 1993). The simplified level of service model uses peak and off-peak travel

times and base case demand estimates to calibrate a supply function for appropriate spatial groupings of trips (i.e., trips in broadly-defined "corridors") The basic form of this equation is $t = a \cdot (1 + [V/C]^b)$, where t is the travel time in minutes per mile, V is the volume in vehicles per hour, C is the "capacity" in vehicles per hour, and a and b are coefficients fit to each corridor For each change in demand, the calibrated function can be used to compute a new "equilibrium" in the corridor

While the simplified level of service model is useful for many analyses, it is intended only as an approximation of changes in network performance and is likely to be inadequate in cases where large network perturbations could occur or where specific route choice changes are at issue When network questions are critical, STEP must be used in conjunction with a more detailed network model

In the typical application, STEP is "interfaced" with the region's detailed highway network STEP's modal trip outputs are summarized on a district-to-district basis (A district is defined as an aggregate of the zones for which land use data are reported, for example, in the Los Angeles region there are 1555 zones and 55 districts defined by the regional agency) If the policy under analysis results in any significant differences from the base-case district-to-district trip tables, the differences are used to factor the zone-to-zone trip tables in the aggregate model system The network models are then run using these new trip tables, and the results are fed back into STEP as a revised set of level of service inputs Iterations continue much as is done in a conventional travel model system until an acceptable level of convergence is achieved Transit networks also may need to be run in conjunction with STEP in cases producing significant differences in highway travel times of a sort likely to affect bus operations

For certain transportation pricing measures, such as proposals to toll specific links or facilities in a network, use of the detailed network models together with STEP is of particular importance For the analyses presented here, we used the network models for Los Angeles and the Bay Area to test the route choice effects of congestion pricing, interfacing in the manner described above with the versions of STEP developed for each region

The major variants of the STEP model system are described in Appendix B, Figure B 1 shows the version used in our pricing studies. The basic data requirements of the STEP model are summarized in Figure B 2. A typical sequence of activities for a STEP application is shown in Figure B 3. Sources of the specific data we used are summarized in Table 6 1.

Transferring STEP Models to Other Regions

Although each application of STEP could utilize models estimated specifically for the region being studied, a less costly approach is to transfer models estimated in one region to another. In the analyses presented here, STEP models originally estimated for the Bay Area were transferred to Los Angeles, Sacramento, and San Diego, with detailed calibrations and a moderate amount of model re-estimation in each case.

Procedures for transferring models and evaluating their performance are well established - in fact, many regions routinely use one or more transferred models in their regional model systems. The procedure for transferring STEP to a new region follows much the same general sequence of actions and so will be discussed only briefly here.

To transfer STEP to a new region, the required data first must be set up. The region's most recent household travel survey is obtained and checked (incomplete observations are excluded), and network data and land use data for the year of the survey are extracted from the regional modeling data bases. The data are then linked and a trial simulation is carried out to determine how closely the models to be transferred match the actual travel patterns in the survey data. Invariably, a sequence of adjustments to model constants (and sometimes to a small number of coefficients) is necessary to achieve an acceptable replication of the base travel pattern. These adjustments serve both to capture actual differences in behavior and to compensate for variation in the way regional planning agencies define certain variables such as transit wait times, income ranges, and specific categories of land use.

Once an acceptable simulation of the survey year (the "base case") has been obtained in this fashion, STEP should closely reflect travel conditions and behaviors in the region to which it is being transferred, and consequently can be used with local data and forecasts for the full range of modeling applications

6.3 Applying STEP to Pricing Measures

Overview

The application of travel forecasting models to specific pricing policies is rarely a straightforward matter. In nearly every case, both the models themselves and the available data bases impose some limits on the policies that can be tested. For example, the regional transportation data bases (and models based on the data bases) typically lack information about the variation of parking price in each zone, and may have only approximate information about the vehicle used for a specific trip. In cases where such details would play a large role in determining the impact of a policy being studied, only an approximate estimate of the policy's effects can be formally estimated through modeling. The analyst must devise a means of representing the policy as well as possible given the models and data, and must be prepared to make off-line calculations and adjustments to improve the realism of the analysis, or to do further analyses after gathering additional information.

Some discussion of implementation scenarios is necessary simply to determine how a proposed pricing concept should be analyzed, clearly, however, much more attention to specifics would be needed in an actual implementation. In our analyses, for example, we implicitly assume that evasion or outright fraud would be insignificant, hence the measures would be fully effective as proposed. For most transportation pricing measures, monitoring, enforcement, and audits would be needed to assure that

In our analyses we found that it generally was possible to define transportation pricing strategies in ways that were tractable from an analysis perspective and also yielded information which is helpful in thinking about policies as they might actually be implemented. The use of advanced modeling capabilities, along with the availability of good data, made it possible to explore behaviors that often would be omitted from a more conventional analysis. Nevertheless, the analyses did require a number of assumptions, and they have certain limitations that must be acknowledged and taken into consideration in policy evaluations.

The following sections detail how the pricing concepts analyzed in our analyses were specified and analyzed. In each case, the underlying rationale for the pricing concept is stated, a specific pricing measure is defined, modeling assumptions to represent the pricing measure are outlined, and key implications of the assumptions are noted.

6.3.1 Congestion Pricing

Congestion occurs in the highway system when more vehicles attempt to traverse a segment of road per unit of time than that segment can accommodate. Such a location is called a bottleneck. Congestion pricing builds on the simple realization that travelers are sensitive to the cost of travel; a fee levied at a bottleneck will divert some vehicles from the traffic stream, reducing congestion. The diversion of a specific vehicle might be to a different route, time-of-travel, mode, or destination; it could reflect a trip foregone, or, over the long run, it might follow from a change in residence or workplace location.

Two major design issues arise in thinking about how to use pricing to manage congestion at a bottleneck:

- o **Price level** - Price can be varied over a wide range to achieve different levels of traffic improvement. Economic theory tells us that price should be set to reflect the

social cost caused by the marginal user at a bottleneck, less the average variable cost already paid by users. While this should be the clear goal of any congestion pricing application, considerations of implementation and management ease may point toward a simpler price criterion based, for example, on achieving and maintaining a conventional level of service measure from the literature of traffic engineering. We know that the "optimal" level of congestion reduction will be unique at each bottleneck, but it is much easier to explain a generally applicable congestion reduction goal in the policy-making process, and easier to implement and manage facilities based on observed performance. Hence, the actual criterion for setting the congestion price may well be framed in terms of standard traffic level-of-service metrics (e.g., B,C,D,E). For similar reasons of simplicity and clarity, specific prices might be chosen to reduce the amount of change-making required (rounded to the nearest 25 cents or to the nearest dollar, for instance), although with modern road pricing technologies this would not be strictly necessary. Periodic adjustments in price are likely to be needed to maintain effectiveness, and they too would likely be done in simple, rounded increments of 25 cents or a dollar, unless electronic toll collection were in place.

o **Period of application** - Some economists have argued forcefully that congestion prices should change dynamically in response to traffic conditions, perhaps varying from minute to minute to achieve the optimal reduction in congestion. However, few seriously believe that such a dynamic scheme would be implemented any time soon, for several reasons: 1) the practical difficulties of creating, testing, and maintaining the hardware and software required for such a system, 2) the unresolved theoretical question of whether a truly dynamic system would produce a stable set of prices, 3) the strong revealed preference of travelers for predictable conditions, even if the price of predictability is a somewhat higher average time or cost, and 4) the question of how to treat incident-related delay in a dynamic pricing environment. An initial congestion pricing scheme more likely would involve prices that can be explained through relatively simple signage and do not vary from day-to-day (though weekend-weekday and seasonal variations might be both desirable and feasible). Hour-to-hour variation might, however, be used to avoid large price increases and decreases at the peak / off-peak.

boundaries, and might be designed as a pyramid of prices centered on each peak hour in order to be relatively easy for the driver to remember

In addition to these basic design issues for pricing at a bottleneck, there is a question about how widely congestion pricing would be applied in the highway network. While pricing would be easiest to implement on limited access facilities, spillover from priced freeways to unpriced arterials and collectors could be a problem in some locations¹. Local communities seem unlikely to tolerate significant traffic diversion to the facilities under their jurisdiction, and could be expected to oppose freeway pricing schemes if they created or worsened congestion on local roads. The localities might, however, accept a broader-based pricing plan which manages traffic on a systemwide basis, especially if part of the revenues were returned to affected jurisdictions. Widespread implementation of congestion pricing hence could mean pricing both freeways and parallel routes where significant delay appears.

The congestion pricing measures tested in our analyses were designed to reflect these observations about the policy environment. We assumed that some form of electronic payment system would be used rather than toll booths, so that there would be no stopping to pay tolls. Prices were applied everywhere delay appeared in the highway network (as represented in each region's model system - freeways and arterials plus some major collectors). Price levels were set to reduce congestion to meet to specific levels of service, we investigated a range of level-of-service targets and eventually chose LOS D/E for use in all four metropolitan areas². Our analyses allowed prices to vary by corridor, determined

1 The first US congestion pricing project opened in December 1995 on State Route 91 in Orange County, California, the San Francisco-Oakland Bay Bridge is currently being studied as a second possible application. Because of the special characteristics of these two applications, spillover to arterials is not likely to be a major issue. SR 91 pricing will apply only to the new lanes added in each direction, with the original lanes left unpriced, in the Bay Bridge case there are essentially no realistic alternative highway routes. The extension of pricing to other facilities such as I-10 in the Los Angeles area or I-80 in the Bay Area would, however, have to confront the possibility of spillovers to parallel routes.

2 The choice of LOS D/E was based on analyses of benefit measures from the STEP model which indicated that stable, near-capacity flows (about 10 percent below actual capacities) were the most economically efficient traffic regime. Specifically, we used delay reduction per marginal unit of price as the measure of benefit.

peak definitions by the extent of congestion in each corridor, and permitted different prices to be charged in each corridor for each hour of the AM and PM peak periods, but we stopped short of dynamic pricing. Rather, we assumed that travelers would face a fairly simple schedule of prices by time of day, readily comprehensible to travelers and influencing their travel behavior and location choices.³

It is important to note that under this pricing approach, users of the facilities in greatest demand still would perceive traffic as heavy and somewhat constrained, with speeds below posted limits. (At least for the cases considered here, higher speeds would not be as efficient from an economic point of view.) Note also that we assume that prices would be maintained in constant dollars, meaning that from time to time price adjustments might be necessary.

The STEP analyses were carried out by focusing on highway performance at the corridor level, as follows. In the STEP calibration phase each of the metropolitan areas was divided into major corridors based on topography and highway function. Each district-to-district trip interchange was assigned to a corridor, and approximate volume-delay relationships (i.e., expressing travel time per mile as a function of volume and capacity) were developed for the corridors.⁴ This was carried out for both the AM and the PM peak in each region.

3 We assumed congestion prices would be in effect on non-holiday weekdays only - 250 days a year.

4 The shape of the volume/delay curve is a critical determinant of the outcome of the analysis, because it indicates how much traffic would have to be removed from the peak in order to achieve a given LOS. To represent volume/delay relationships, STEP uses an equation initially developed in a study for the California Energy Commission and later re-estimated in studies for the Metropolitan Transportation Commission, the Southern California Association of Governments, and the Puget Sound Council of Governments (Seattle region). The equation expresses the relationship between the ratio of average peak to average off-peak travel times in each "corridor" - basically a trip exchange - and the aggregate capacity serving that corridor. Separate estimations were done using data from the detailed highway networks of the three regions, because the coefficients of all three models were nearly identical, a single equation was implemented in STEP. The specific functional form is $t/t_0 = 1 + (V/C)^2$.

This corridor function, derived from regional network models, shows travel time climbing rather gradually as congestion builds. We know from highway operations research that the buildup of congestion for specific facilities is more abrupt and steeper in the region of capacity flows than this equation indicates. However, because the corridor function represents an aggregation of facilities of different types, it reflects the "family" of volume-delay relationships for the freeways, arterials, and

The level of service target was defined in terms of the volume delay function. For the generic functional form used in this version of STEP, level-of-service D/E corresponds to a travel time that is about 85 percent longer than the time under free-flow conditions. In other words, the target level-of-service was represented by a 1.85 ratio of peak to uncongested travel time in a corridor.

In the Los Angeles region, about 300 aggregate "corridors" were defined in this manner, and about 220 of them - 73 percent - were sufficiently congested in the AM peak to justify congestion pricing. For the San Francisco Bay Area 150 corridors were defined, with 90 (60 percent) meeting the criteria for pricing in the AM peak. San Diego and Sacramento were both considerably less congested, only 15 percent of the 80 corridors analyzed in San Diego and 8 percent of the corridors analyzed in Sacramento were candidates for pricing.

To estimate the price needed to achieve the target level of service, STEP was applied to each sample of households and the average price per mile was adjusted on a corridor-by-corridor basis until all corridors were at or below the 1.85 peak/off-peak travel time ratio, and no corridor had a higher congestion price than necessary. This took approximately five iterations (model runs) for each region and each analysis year.

major collectors embedded in the network models and producing their travel time estimates.

The steepness of the buildup of congestion is important in determining what the congestion price would have to be. If the slope is steeper than our equation indicates, as it would be in a corridor with a single facility, congestion prices could be lower for a given level-of-service improvement than we report here. This is because a steeper slope implies that fewer vehicles would have to be priced off each corridor's facilities to achieve a given LOS. We tested a number of functional forms in STEP, and the different forms did indeed produce some variation in optimal prices. For example, letting the slope parameter rise to 4, the value used in the standard Bureau of Public Roads (BPR) equation, would lower the "optimal" congestion price by about 40 percent (regional average). Since the BPR curve is for a single freeway facility, it is much steeper than any corridor curve could be (unless the corridor consisted of a single freeway). Therefore the BPR value should be viewed as an outer limit.

For each region, a specific congestion price was estimated for each corridor and time period ⁵ For 1991 conditions, the congestion prices would vary from zero (for the uncongested exchanges) to as much as \$1.00 per mile for a very few corridors, such as the I-80 corridor and the Bay Bridge corridor in the San Francisco Bay Area and the I-405 and I-10 corridors in the West Los Angeles - Santa Monica area. In San Diego, the highest corridor level prices would reach about 40 cents per mile, whereas in Sacramento the highest corridor prices would be about 20 cents per mile. By the year 2010, congestion is expected to worsen considerably in all four regions, many more corridors would be candidates for pricing, and prices would have to be higher to maintain the LOS D/E target ⁶

Estimated reductions in travel time, VMT, trips, emissions, and fuel use resulting from the resulting congestion prices, as well as estimates of the total revenues generated, were calculated by summing up the analysis results for each corridor. To simplify the presentation of price levels and provide an indicator of overall price impact, a corridor-weighted average

⁵ In the four case study regions, PM peak conditions are less sharply congested but last longer than AM peak conditions. Hence evening congestion prices, at least initially, could be somewhat lower but would be in effect for a somewhat longer period of time than those in the morning peak. However, congestion pricing would flatten and spread out the AM peak somewhat, diminishing AM-PM differences in prices and hours of application.

⁶ One might ask whether the prices arrived at in this manner are the optimal prices. The issue is not simple to resolve, in the first place it is well understood that user-optimal may not be identical to system-optimal (Wardrop, 1952). User optimality is examined here, although we note in passing that pricing also could be used to achieve system rather than user optimality. The analysis of user-optimal prices is particularly complex, because travelers can respond to pricing in a number of ways, shifting trips among corridors and altering their frequency and times of travel. It is necessary to account for the possibility that travelers could switch to another route, travel at a different time of day, change modes, choose different destinations for some trips, increase or reduce the number of trips made, move to a different residence, or change their place of work. STEP accounts for these phenomena, but because STEP is a hybrid mix of non-linear demand functions of various types, it is not possible to mathematically prove the existence of a unique set of congestion prices for a given level-of-service criterion. Simulation offers an alternative approach for assessing whether model results represent a stable and unique equilibrium, and we used it to investigate the optimality of our corridor prices. We applied a number of procedures designed to determine whether STEP would produce different sets of "optimal" congestion prices. These included adopting different search algorithms in the program code, and starting the searches from different initial corridor prices. All search strategies that produced stable outcomes were in agreement with the initial "optimal" prices, which lends some support to the notion of a unique equilibrium.

price per mile is shown in the tables, and can be thought of as the average price peak period drivers would face overall. It is not necessarily the price any individual traveler would experience. For example, the price necessary to obtain LOS D/E on the San Francisco Bay Bridge in 1991 would have been about \$6, or 75 cents a mile for that corridor, in contrast to the average Bay Area AM peak price of about 9 cents a mile.⁷

Corridor-level results are useful for preliminary planning purposes, but for implementation planning it is important to translate the results into specific facility charges. Within the resources of this study, we were not able to test congestion pricing in a full network context for each of the four case study areas. Instead, we ran STEP for the four areas, then selected two corridors for more detailed analysis: I-80 from the Carquinez Bridge to the Oakland-San Francisco Bay Bridge, and I-10 from Santa Monica to Downtown Los Angeles - two of the most congested locations of all those we studied. We ran regional network models for the Bay Area and Los Angeles to see how prices would need to vary among facilities in the selected corridors, given the corridor prices and demand levels produced by STEP. The Tranplan network analysis program was used, with an equilibrium traffic assignment for the AM peak hour and price incorporated into the route choice criterion.⁸

Tranplan corridor analyses produce results comparable to STEP if the per-mile price is applied equally across all facilities in the corridor. With the same price per mile on all alternate routes, the main effect will be a reduction of overall corridor demand rather than a rearrangement of traffic among corridor facilities. (Absent differential prices, traffic in a congested corridor will distribute itself such that all routes will have about the same travel times.) However, Tranplan analysis made it possible to test link-by-link pricing to more precisely target bottlenecks in the system. We went through five iterations in which we

⁷ The Bay Bridge congestion pricing studies underway at the time of this writing are discussing considerably smaller prices, e.g., a \$3.00 peak period toll. A \$3.00 toll in 1996-1997 dollars would be the equivalent of a \$2.50 toll in 1991 dollars. Such a price increase would be sufficient to cut the queue at the toll plaza by about a third, but would not achieve LOS D/E.

⁸ It was possible to use the network provided by the Southern California Association of Governments for this part of the analysis, but for the Bay Area a new Tranplan network was created as part of the study. (MTC uses UTPS networks and the study team did not have access to this software.)

manually adjusted link prices in the two test corridors, each time increasing the price on links that remained congested and decreasing the price on links with better than D/E level-of-service and then running Tranplan to evaluate link-level impacts. Overall corridor delay reduction tended to improve from iteration to iteration, while overall price levies tended to fall. After the five iterations, we judged that the effectiveness of congestion pricing, in terms of reduced delay per dollar, might be 10-15 percent higher in these corridors than the approximate results of the STEP analyses would suggest. This should be considered when reviewing the average prices and/or time savings presented in the tables.

What if prices varied by location, but were set at modest prices initially and were increased only gradually to the levels necessary to avoid stop-and-go driving? This approach would give people a chance to adjust their travel and location behavior under prices that accurately signal the ultimate spatial distribution of impacts. Dynamic models would be necessary to fully explore the changes that such a pricing approach would produce over time, STEP does not currently include such dynamic models. However, STEP is able to evaluate lower-than-"optimal" congestion prices as would occur in a pricing phase-in (and perhaps in many cases where prices are set on political as well as technical grounds). We tested the impacts of lower prices by taking the final corridor congestion prices for the Bay Area and Los Angeles and applying them in 10 percent increments (i.e., prices at 10 percent of optimal corridor prices, 20 percent of optimal prices, etc.) The STEP results indicate that the shape of the aggregate demand curve is moderately convex, with slightly decreasing effects for each price increment. For each of the two case analyses, the first price increment of 10 percent produced almost twice the impact of the final increment of 10 percent. This suggests that implementing a constrained price can still be reasonably effective.

The STEP analyses are for scenarios in which pricing is used to manage congestion wherever it occurs on the network of highways and arterials, how congestion pricing would work if implemented on a few facilities is a different question. Even if the ultimate objective is system-wide implementation, it is likely that initial applications would be "spot pricing" - pricing applied to just a few facilities or corridors. As we discussed earlier, however,

closely-parallel routes could receive significant amounts of diverted traffic if a single congested facility is priced, such traffic diversion could lead to significant congestion on the parallel routes, and opposition from affected jurisdictions might well be enough to halt implementation, unless the parallel routes can be priced as well

Even where diversion to parallel routes is infeasible for most travelers, as is the case for the San Francisco-Oakland Bay Bridge, or where each facility in a corridor can be differentially priced, as our analyses of the I-80, I-405, and I-10 corridors considered, a number of concerns about "spot pricing" remain. For example, our analyses indicate that implementation at a single highly-congested location or in a single corridor will alter regional patterns of trip distribution, residential location, and workplace location, with specific effects varying with household income level. The result of spot pricing could lead to a distortion of the spatial structure of the region, because the spot pricing leads to exaggerated locational impacts. Thus single facility pricing may produce a misleading view of the eventual areawide effects of congestion pricing.

6.3.2 Employee Parking Charges

In most metropolitan areas, parking is commonly provided to its users free of charge, although providing such parking can be quite expensive and presumably is recouped in other ways (e.g., through the prices charged for goods and services, for private parking, or through public tax subsidies, for public parking). Charging for parking, whether done through private initiative or in response to government incentives or mandates, would make the costs of parking more apparent to travelers and would likely reduce auto use somewhat.

Parking could be priced for all users, and sometimes is (at many commercial garages, e.g., or by local governments who install on-street meters). However, proposals for the implementation of parking pricing often focus on daytime employee parking, since the associated employee travel typically occurs during the costly peak periods. If employees

had to pay for parking, it is reasoned, they would be more likely to use alternative commute modes such as transit, carpooling, or walking. In the analyses we present here we analyze only employee parking charges.

In comparison with congestion pricing, parking pricing is a relatively simple measure to analyze using STEP. The average zonal parking price (daily, for work trips, and hourly, for non-work trips) is a variable in each of the STEP mode choice models, and zone-level parking price data are available for each of the four metropolitan areas studied here. Thus, any parking scenario that can be expressed as a change in an average zonal price can be analyzed using STEP.

Proposed parking price changes do not always target the average zonal parking price, however. Consider a city in which a substantial amount (varying by zone) of the all-day parking is provided by a private operator, who charges a daily fee for use. The operator, perhaps given an incentive by local or state tax policy, decides to raise the fee by \$1.00 per day. To analyze the impact of this increase, it is necessary to have an estimate of the percent of all-day parking in each zone that is provided by this operator and hence will be affected by the increase. A number of cities maintain a parking inventory which could provide this information, although many other cities would have to conduct a special survey to produce this estimate.

Other parking pricing proposals can be far more complicated to analyze. Consider a \$3.00/day parking surcharge which applies only at employment sites with 100 or more employees. In order to translate this surcharge into zonal average price estimates, we would need information about the fraction of workers in each zone who work at sites with 100 or more employees. We would need to account for the possibility that some of those employees do not provide any parking now, in order to figure out what share of each zone's employees would be subject to the fee. The possibility that some employees could avoid a fee at their workplace by parking elsewhere should already be reflected in the calculation of zonal average parking cost, but we also must consider the possibility that employers will simply pay the fee themselves rather than passing it on to the employee, again reducing the

number of affected workers (Note that certain implementation strategies, such as treating parking as a taxable benefit or requiring the surcharge to be collected from the employee as a payroll deduction, would reduce the likelihood and the impact of this latter concern) Very few cities have an employer and parking data base organized to support such an analysis, and we have found none that has information on likely alternative parking sites or on employer responses to such policies Hence, calculating the actual increase in zonal average parking charges that our surcharge would produce could require either a great deal of data collection Nevertheless, for preliminary planning purposes it usually will suffice to make some simple assumptions in developing the data inputs or in interpreting the results For example, we could analyze the parking surcharge as if it applied to all employees and then factor the results downward to account for its more restricted reach if regional employment data indicate that only 40 percent of the region's jobs are provided by employers with 100 or more workers, then our impact estimates should be reduced by about 60 percent

For our four analyses, we utilized parking cost data files developed by the regional transportation agencies These files present only the estimated average employee parking price (nominal price) by zone Given the data we had available, we chose to model two general policy options a flat daily charge on all employees who drive alone and do not currently pay for parking, as well as a daily surcharge on all employee parking, paid or not The first option could be thought of as a rough approximation of what prices might be like if free parking were no longer provided to employees, or it might be thought of as the result of a policy that imposes an impact fee or tax on free employee parking but waives the fee on parking that is already priced at or above some threshold level The second option would be a flat impact fee (or tax, depending on how it is structured and applied)

Using STEP, a range of daily employee parking charges from \$1 00 to \$10 00 was examined for each of the four metropolitan areas To model the minimum price threshold option, drive-alone parking fees for all workers in each sample were set to the specified minimum or to current levels, whichever was higher - fees in zones where existing zonal average parking fees exceeded the threshold charge were held constant The second

option we evaluated, a flat fee or surcharge on all employee parking, was even easier to represent than the minimum price option, the fee was simply added to the employee parking price in effect in each zone. In both analyses, we assumed that the employees would personally pay the parking charges (hence we treated the charges as out-of-pocket expenses). We also assumed that carpool and vanpools would be permitted to park for free at their destinations, and that no charges would be imposed for park-and-ride parking. These latter assumptions are generally consistent with the current treatment of HOVs and park-and-ride in the four case study regions.

STEP accounts for the full set of travel effects we would expect parking pricing to have, including impacts on highway performance, but to verify that STEP's simplified level-of-service functions provide an adequate representation of the latter, the peak period trip tables from STEP were assigned using Tranplan to the relevant networks for Los Angeles and the Bay Area, and the resulting travel times were cycled back through the STEP model. No significant changes from STEP aggregate performance measures were identified.

Results for \$1.00 and \$3.00 parking price increases are reported here. Given the ubiquitousness of free parking in each of the four regions, the differences between the two policy options were minimal. The estimated impacts of the parking fees varied by 10 percent or less (i.e., a reduction of 1 percent in VMT for the minimum price option, a 1.1 percent VMT reduction for the surcharge).

Our assumptions that prices would apply to all drive-alone vehicles⁹ and that HOV parking would be exempt from charges maximize the impact of the employee parking fees. In actual implementation, a number of factors could reduce these impacts. For example, as our earlier discussion pointed out, exemptions of certain employers would reduce the number of employees in each zone who actually would pay a parking fee, with the impact varying widely among zones.

⁹ To calculate impacts on an annual basis, we assumed employee parking charges would apply 250 days a year.

In addition, in situations where parking is differentially available to or subsidized for different income or occupation groups, the impacts of price changes may vary from those we have shown. Our results assume that a parking fee would be paid by all who drive alone. But under some conditions the fee might actually be absorbed by the employer, for example, some blue collar workers have negotiated for free parking as part of their labor agreements, and a parking surcharge would have to be paid for by the employer or compensated through offsetting salary increases. In cases such as these, the fee on parking could vary systematically with income group, and hence be disproportionate to the number of workers affected.

Finally, the impact of free parking for high-occupancy vehicles deserves special attention. Free HOV parking is a common measure in our case study regions and might well be permitted under a policy to charge for parking, but it is not a necessary feature of the analysis. If the parking fees apply equally to HOVs, HOV users still experience an advantage over solo drivers because they can split the cost among all passengers, but the price differential between drive-alone and HOV decreases - by about 40 percent on average. Based on STEP runs for all four metropolitan regions, this diminished advantage would cut the impact of the parking fee by about 15 percent, because fewer current drivers would switch to HOV and some of those who currently are HOV users would decide to drive to work.

6.3.3 Fuel Tax Increases

A fuel tax increase would be a direct approach for reducing fuel consumption and also for reducing greenhouse gas emissions (because CO₂ emissions are proportional to fuel consumed). Its effects on other emissions and travel are muted, though still significant, because auto purchase decisions and usage patterns can lead to a more efficient vehicle fleet and reduced per-mile operating costs.

The fuel tax increases analyzed here are expressed as straightforward additions to the at-the-pump price of gasoline and diesel fuel. For our base case, vehicle fleet fuel economy is about 22 miles per gallon (0.364 gallons per mile). Base-case fuel cost is about \$1.20 per gallon, or 5.45 cents per mile at average fuel economy. With no increase in fleet fuel economy, a 50-cent-per-gallon fuel tax increase would add about 2.3 cents and a \$2.00-per-gallon tax (or other form of price increase) would add about 9.1 cents to the average per-mile cost of driving. However, empirical evidence and common sense suggest that the in-use vehicle fleet would become more efficient under a significant fuel price increase. In the many households with more than one car, household members could quickly arrange to make more use of their fuel-efficient vehicles and less use of their "gas guzzlers", cutting fuel consumption considerably. Over time, both single-vehicle households and multi-vehicle households could be expected to increase vehicle fuel efficiency as they replace some vehicles and retire others.

How fast and to what degree such vehicle substitutions, replacements, and retirements might occur in response to fuel price increases has been a matter of considerable dispute. The issue is important to our analysis because it could significantly affect the impact of a fuel tax. Travel and location choices are undoubtedly affected by the costs of vehicle ownership and operation, i.e., by both the number of vehicles a household chooses to own and the type and age of its vehicle(s). Faced with higher fuel costs, a household which for whatever reason does not reduce its per-mile fuel consumption (by changing its vehicle holdings or changing which vehicles it uses most) will have to devote more of its income to fuel purchases, or take steps to reduce its vehicular travel (or some combination of the two). If on the other hand the household finds it possible to reduce the price effect through vehicle substitution and replacement, fuel efficiency improvements will have a smaller effect on travel.¹⁰

¹⁰ A household's ability to change vehicle holdings is related to its current and expected income, its current vehicle holdings, ownership and operating costs of the alternatives, etc. The household's willingness to change its vehicle holdings depends on many additional factors, such as vehicle seating capacity, comfort, handling, and safety. Fuel economy, an element of operating cost, is but one influence.

STEP includes a model of the number of vehicles a household chooses to own, so we were able to capture the effects of fuel price increases on auto ownership in our analyses. However, STEP currently does not address the type or age of the vehicles owned, information which is needed to estimate the cost per mile under different fuel price scenarios. We did not have direct access to a model of household vehicle purchase decisions for this study, so to account for the broader range of impacts, we turned to outside sources for evidence on the elasticity of fleet fuel economy with respect to fuel price.

The literature from the U.S. and abroad suggests that fleet fuel economy (miles per gallon) is quite sensitive to the price of fuel. Pickrell's recent research (Pickrell, 1993) and his syntheses for the Presidential Commission on Greenhouse Gas Reduction (a group known popularly as "Car Talk") (Pickrell, 1995) examine the impact of fuel prices and report findings from a wide range of reputable U.S. and international studies in advanced economies. He cites numerous estimates of long-run average elasticity of fleet fuel economy with respect to fuel price in the .5 - .6 range, with estimates as low as .2 to .3 and some higher than 1.0. An elasticity of 0.5 means that a 25 percent increase in real fuel price (e.g., from \$1.20 to \$1.50) would increase long run average fleet fuel economy from 22 miles per gallon (mpg) to almost 25 mpg, a 16.7 percent increase in real fuel price (e.g., from \$1.20 to \$3.20) would increase long run average fleet fuel economy from 22 mpg to about 40 mpg (82 percent). A 40 mpg fleet average sounds high for U.S. conditions, but it cannot be dismissed out-of-hand, especially for a longer-term scenario (2010 or later) and/or one in which the price increase was implemented nationwide or in a majority of urban states (so that manufacturers would have sufficient time and incentive to offer more fuel-efficient vehicles).

Substantial fuel economy improvements could, in fact, be obtained through shifts in consumer choices among the vehicles currently available for purchase. For example, by purchasing the four cylinder rather than the six cylinder version of a midsize sedan, a consumer could obtain a 10-15 percent improvement in mpg. This percent increase in fuel economy is about what a 25-50 cents per gallon price increase would require, at a .5 elasticity. However, for large fuel price increases, an elasticity of .5 would imply that at least

some consumers also would have to change the type of vehicles they own and use, i.e., greater numbers would have to purchase and use highly efficient vehicles and restrain their purchase and use of the least efficient ones. Currently over a dozen vehicles are sold in the U.S. which obtain over 40 mpg, so this seems technically feasible, and may become more so if gradual improvements in technical efficiency, averaging perhaps 1-2 percent a year, are forthcoming over the next decade or so, as many analysts expect (Pickrell, 1995). Whether buying habits in fact would change in the necessary fashion could be debated.

For further evidence of how fuel prices might affect fleet composition and use, we turned to models of the vehicle fleet. Since our case study regions were all in California, we were particularly interested in an analysis tool known as the Personal Vehicle Model (PVM), which the California Energy Commission has used to estimate the composition of the state's vehicle fleet by size and age, as a function of the price of fuel and other factors.¹¹ We asked the CEC to provide some indication of the PVM elasticity of fuel economy with respect to fuel price, as evidence for California fleet conditions. A run of the PVM made for this study by the CEC in January 1995 indicated that a \$2.00 fuel surcharge would lead to a 2 mpg increase in fuel consumption (from 22 to 24 mpg), for an average elasticity of .05.

The PVM-estimated elasticity is much lower than the elasticities reported by Pickrell. A partial reason for the difference is that most national and international long-term elasticity estimates allow for changes in the products manufacturers offer in response to fuel price increases. In contrast, the PVM analysis assumed that the price increase would only apply in California, and that manufacturers would not increase the fuel economies of the cars they offer in response to a change in only one state, even a state as large as California. The PVM analysis does allow consumers to purchase more efficient vehicles from those otherwise available. It does not consider increased relative use of the more fuel efficient vehicles within each household's existing vehicle holdings.

¹¹ The PVM was developed more than a decade ago, and at the time of our study the CEC was engaged in a multi-million dollar project to replace it with an updated package based on new data and state-of-the-art modeling concepts. Hence we chose to treat the PVM as one source of evidence rather than to rely solely on it.

We discussed the fuel economy - fuel price elasticity issue with a number of researchers and ultimately settled on testing a range of assumptions about the fleet response to fuel price, expressed in terms of the elasticity of fuel economy (miles per gallon) with respect to price. Results for three elasticity levels are reported here: 0.5, 0.16, and 0.05. The researchers we contacted felt (and we agreed) that the 0.05 PVM elasticity should be used as a lower boundary, and that a 0.5 elasticity, i.e., the lower end of the 5-6 estimates from the national studies, was a reasonable upper boundary for a California-only policy.¹²

The fuel economy elasticities can be used to compute average mpg and out-of-pocket vehicle operating costs per mile resulting from a fuel price increase. For example, consider a two dollar per gallon increase, i.e., a fuel price of \$3.20 per gallon. In comparison to the current \$1.20 per gallon, for which average out-of-pocket expenditure is about 5.5 cents per mile, the estimated mpg and cents-per-mile costs would be

Elasticity	MPG	Cents per Mile
0.00	22	14.6
0.05	24	13.3
0.16	28	11.4
0.50	40	8.0

¹² A California-only gas tax increase seems more plausible for small to moderate tax increases (25 cents or less) than for higher ones, especially those of a dollar or more. Of course, it is not necessary to assume that a fuel tax or other fuel price increase would be implemented in California only; the analyses could equally well represent the impacts of scenarios involving federal fuel tax increases or state tax increases implemented in many states. Also, for the analyses presented here, at-the-pump price increases implemented by sellers would have the same effects as a fuel tax increase. A California-only interpretation of our analyses does not necessarily require new, highly efficient vehicles to be produced for the state market (though it might make California an attractive test bed for such vehicles, including ones currently sold overseas but not now marketed in the U.S.) It does however presume that, of the vehicles produced for the U.S. market, manufacturers would sell a higher share of the most efficient vehicles in California. Also, the used car market would be affected; demand for low mpg cars would decline in the state, and such cars would likely be retired earlier or perhaps shipped to other states or countries for sale there.

It is clear from this table why fleet response to fuel price is such an important issue. At a 0.5 fuel economy elasticity, the average fuel cost per mile increases by more than 140 percent, this would result in large reductions in travel. By comparison, at an elasticity of 5, the average fuel cost per mile increases by about 45 percent. In the first case, trip and VMT reductions account for most of the drop in fuel use, while in the second case, improved fleet fuel economy accounts for most of the drop in fuel use. Since both the incidence and the economic implications of the fuel price increase differ markedly between these two cases, forming a more precise understanding of fleet fuel economy sensitivity to fuel price is of some importance.

Using our three elasticities, we studied a range of fuel price increases from \$0.10 to \$3.00 in 10 cent increments. The results for the \$2.00 fuel price increase under different elasticity assumptions are presented here, along with some results for a \$0.50 price increase. Results for these two price levels are sufficient to support generalization about price effects over the full range.¹³

It is worth noting that for some policy objectives, the fuel price (fuel tax) might be adjusted periodically to maintain the per-mile cost, i.e., to reduce the impact of improved fuel economy. Such tax adjustments would make sense in terms of paying for road maintenance, since maintenance costs do not decline proportional to fuel use. Similarly, if pay-at-the-pump insurance policies were implemented, it would be necessary for the component of the fuel "tax" designated for insurance to be de-coupled from fleet efficiency. If for either reason the fuel tax were adjusted to compensate for revenue losses due to fleet efficiency improvements, its effects on VMT, trip rates, delay, and emissions would be greater than we have estimated here. Essentially, such adjustments would make the fuel tax very much like the VMT fee discussed below.

¹³ We calculated impacts on the basis of 250 times the average weekday rate plus 115 weekend and holiday days at 95 percent of the weekday rate.

6.3.4 VMT Fees

A fee on vehicle-miles of travel (VMT) would directly charge users for the amount of vehicular travel consumed. A VMT fee therefore could be used to reduce VMT-related impacts.¹⁴ Such a fee also would be a better targeted road user payment mechanism than the fuel taxes we now use, because drivers could not reduce their exposure to the fee by purchasing more fuel efficient vehicles.¹⁵

Currently, the easiest way of collecting a VMT fee would be through a charge determined at the time of vehicle registration or vehicle inspection, based on owner-reported or inspector-recorded odometer readings. However, if one goal of a VMT fee is to reduce vehicular travel and its negative externalities, the fee should be linked as closely as possible to day-to-day use of the vehicle. Collecting the VMT fee as part of an annual payment for vehicle registration would probably be less effective in reducing VMT than more frequent charges. An annual fee is remote from individual drivers' thinking about their day-to-day driving behavior, and may be less effective in influencing it. Also, drivers would "discount" annual payments compared to more frequent levies.

There is no reason, of course, that a VMT fee tied to registration or I/M programs would have to be paid annually. One can imagine a variety of alternative arrangements, including ones in which the registration or I/M fee itself is paid in monthly or quarterly installments. One approach might mimic the billing method used by public utilities, in which monthly or

¹⁴ VMT is roughly related to congestion, though a VMT fee would have a bigger effect on non-work travel than on work trips, which make up the majority of VMT during the congested peak periods. VMT is also roughly related to fuel use and to hydrocarbon, NO_x, and carbon monoxide emissions. In contrast, PM₁₀ emissions from on-road transportation are closely related to VMT.

¹⁵ Used as a road user payment mechanism, the VMT fee would have to be adjusted periodically or indexed to reflect costs of road construction, operations, and maintenance, or if such road costs increase, the fee's percent cost coverage would decline. Nevertheless, costs to each user would remain proportional to use. Per-gallon fuel taxes also suffer from declining cost coverage unless adjusted or indexed, but are far less directly related to use of the roads because of divergent vehicle fuel efficiencies.

quarterly bills are based on estimated usage, and a periodic reading (or report) is used to calculate the additional increment due or credit earned ¹⁶

Recent technological developments offer other ways to frequently measure and collect a VMT fee. It is currently feasible to put in place a VMT monitoring system using automatic vehicle identification (AVI) technologies and covering all major facilities including freeways and major arterials. Systems such as these are currently being deployed on tollways in many parts of the U.S. as well as abroad, and offer timely and accurate fee collection. In one design motorists purchase debit cards which are displayed on their vehicles, fees are deducted from the cards electronically as the vehicles pass AVI readers. In another design the readers record each passing vehicle's identification code and transmit the data to a computerized system which accumulates the charges and periodically bills the vehicle owner.

An alternative concept currently in prototype stage would base the VMT fee on an at-the-pump reading of an electronic odometer or a special VMT-accumulating "smart card", the corresponding fee would be calculated electronically and could be collected as part of the payment for fuel, or perhaps recorded and billed separately. In one approach, scanner or microwave technologies would automatically read the odometer or another on-board electronic device designed to monitor VMT. In another approach, the motorist would insert the vehicle's "smart card" into a special reader, following a sequence of actions much like those used with the automatic credit card debiting devices now present in many fuel pumps.

The availability of approaches, high tech or low, for collecting a VMT fee at or close to the time of road use is important, because such immediate and visible prices are likely to be treated by travelers essentially as out-of-pocket costs similar to current fuel costs. Here we treat the VMT fee as a pure increase in the per-mile cost of driving, with no possibility of

¹⁶ Income and payroll tax collection methods are another possible model: frequent payments are made based on estimated amounts due and reconciliation of the amounts due is done via an annual report, subject to audit.

avoidance and no "discounting" by drivers for delayed payment. In essence, the fee defined in this way would be the equivalent of a fuel tax increase that is indexed to vehicle fleet efficiency.

VMT fees ranging from 1 to 10 cents per mile were analyzed for each metropolitan area (at the base case fleet fuel economy, this is equivalent to fuel price increases ranging from \$0.22 to \$2.20 per gallon). Results for the 2 cents per mile fee are reported here.¹⁷ In keeping with the methodology described earlier, all elements of the STEP model were employed, from residential location through supply response. For Los Angeles and the Bay Area, we further checked the results by assigning STEP-based peak trip patterns to the highway networks. No differences were found that would significantly alter the findings from STEP.

Note that because the results were produced at a regional level, they are for within-region VMT only. They do not include VMT generated outside each region being analyzed. A VMT fee designed for revenue generation might, of course, be implemented on a statewide basis and could be analyzed in that fashion.

A regional VMT fee based on AVI monitoring of road use would be simple enough to implement. A regional fee based on odometer readings, on the other hand, would charge the motorist for interregional, interstate, and international travel (Mexico, Canada) unless some mechanism for excluding such travel were devised. One can easily imagine ways to credit motorists for interstate and international travel, for example, motorists who want a credit for out-of-state travel could have their odometers read at stations along major entry and exit routes to the state, or a procedure might be established allowing a tax credit for documented out-of-state travel, much like the one now used for fuel tax credits for exempt off-road vehicle use. It would be much more difficult to devise a low-tech way to credit within-state interregional travel without creating a major paperwork burden for all involved. Since Caltrans periodically does statewide travel surveys which include both within-region

¹⁷ We calculated impacts on the basis of 250 times the average weekday rate plus 115 weekend and holiday days at 95 percent of the weekday rate.

and interregional travel, one approach might be to use the survey data to create a system of adjustments for each region to account for the average out-of-region component of VMT, perhaps by vehicle age

If the VMT fee were collected infrequently, e.g., once a year based on an odometer reading or report, its impacts might be somewhat less than we estimate here due to discounting of future lump-sum payments in comparison to equivalent "out-of-pocket" payments. Hence the results reported here should be viewed as the high end of likely effectiveness.

6.3.5 Emissions Fees

Emissions fees represent a means of reducing tailpipe emissions that could give the consumer somewhat more flexibility than the current system of mandated performance backed by vehicle inspection and maintenance. The basic concept is that the total pool of annual vehicular emissions in a region would be assigned a cost (presumably pollutant-by-pollutant), and each vehicle would be charged a fee set to reflect its contribution to the total emissions burden. Levying such a fee on vehicular emissions arguably would be the most direct way to instill a sense of personal responsibility for mobile source air pollution.

While the concept may be simple to state, emissions-based vehicle fees are the most difficult of the pricing policies to define and analyze. Reasons for this are

- o the literature offers widely varying perspectives on the social costs of air pollution, so an agreement on a monetary basis for the emissions fee is not easy to reach,
 - o estimates of cumulative emissions from individual vehicles are imprecise and are likely to remain so unless and until vehicles are equipped with accurate, tamper-proof on-board emissions monitoring devices,
 - o because knowledge about how consumers would trade off emissions fees, repair costs, insurance, and other auto-related expenditures is not well developed, the change in fleet composition resulting from a targeted emissions fee is difficult to estimate

We carried out analyses of two prototypical emissions fee strategies, each using a different type of information about emissions. Following the same line of argument as for the VMT fee, we assume that emissions fees can be collected on a "pay as you go" basis, so that they are perceived by drivers as an out-of-pocket expense. This could be done with a technologically advanced system such as an on-board monitor, read and billed, e.g., at the time of fuel purchase, or by combining some other method of fee calculation with a monthly billing system. If the emissions fee is determined as part of vehicle registration or inspection/maintenance and is billed annually or biennially as part of those programs, the fee may well have less influence on day-to-day travel behavior than we show. (On the other hand, a large, infrequent fee might have a big influence on vehicle ownership levels, vehicle age and type, and vehicle maintenance.)

All non-arbitrary emissions fee concepts rely on some assumption about the social costs of air pollution. Accordingly, we searched through the literature for evidence that would support a specific emissions fee in each region, and sought the advice of experts in university research groups and air pollution control agencies. We found that the costs of air pollution had not been researched consistently for all the case study regions, and that the sources that do exist show a wide disparity in their damage estimates. Credible cost estimates for mobile source pollutants range from about 25 cents per vehicle mile to about 8 cents per vehicle mile (using regional damage estimates, reduced by the portion of emissions not attributable to mobile sources, divided by annual regional VMT). The range reflects differences in the severity of the pollution problems of the various regions and in the types of damage considered, as well as disagreements over specific costs in a given region (controversy is especially acute concerning the interpretation of epidemiological studies.)

Lacking more specific estimates of the social costs of emissions in each of the California regions, we chose to set our emissions fee to average one cent per vehicle mile. This represents a plausible, perhaps somewhat conservative estimate of current social costs of mobile source air pollution in these urban areas. Evidence suggests a much higher pollution cost in the Los Angeles region and perhaps a lower pollution cost in the Bay Area.

The one cent per vehicle mile average fee would total about \$1.15 million per day in the Bay Area and about \$2.9 million per day in the Los Angeles Region, under base year (1991) VMT conditions. While the amounts sound high, annual receipts from such a fee would amount to about 0.3 percent of the gross domestic product of each region.¹⁸

Clearly, it would be inaccurate to simply charge each vehicle the regional average per-mile emissions fee, since vehicles' emissions characteristics vary widely. We therefore analyzed two possible methods for assigning a per-mile emissions fee to different vehicles. Under the first method, the per-mile emissions fee would vary by model year and would be based on data on each model year's average emissions characteristics (i.e., using EMFAC in California). Under the second method, the per-mile emissions fee would vary with the actual emissions performance of each vehicle, which might be determined through emissions testing, remote sensing, or on-board emissions monitoring. The latter approach would account for the differences in emissions among vehicles of the same model year.

For each household in the four regional travel survey samples,¹⁹ we knew the make, model, and age (year) of the vehicle holdings for the base year, and we knew how each vehicle actually was used on a representative weekday. Thus, we were able to provide a well-grounded assessment of how vehicles of different ages and types are used and who would be impacted by emissions fees.²⁰ However, we did not have access to a model of how household vehicle holdings or vehicle usage patterns would change as a result of differential changes in the per-mile cost of vehicle operations, so we had to address these issues in terms of plausible scenarios rather than modeled estimates.

18 We used the same one cent per vehicle mile average fee for the year 2010 analyses, lacking more specific cost data.

19 The most recent regional survey for Los Angeles did not record vehicle make and model data. However, the Caltrans statewide survey of the same vintage included these data and had enough observations in the Los Angeles region to support the analyses described here. For this policy only, then, we extracted the Los Angeles data from the Caltrans survey and used it for our analyses.

20 We calculated impacts on the basis of 250 times the average weekday rate plus 115 weekend and holiday days at 95 percent of the weekday rate.

Fees Based on Average Emissions by Model Year:

For the average emissions by model year approach, we began by determining, for each region, the average daily within-region VMT and emissions for every vehicle in the regional travel survey. We extracted from the survey data the vehicle trip sequences and their characteristics, and inferred whether the trip was a cold start, etc., based on the time between trips in the trip sequence. We also determined the average trip speed and distance, deriving these data from the applicable highway networks. We then used EMFAC7F data specific to each vehicle model year to compute the emissions for each vehicle trip.

From the resulting samples of vehicle trips and their associated emissions, average weekday emissions and VMT were calculated for each model year on a region-by-region basis. Annual emissions and VMT for each region were then estimated. The annual VMT estimates were used to calculate total emissions costs for each region at the postulated one cent per mile average.

For the year 2010 forecasts, it was necessary to describe the likely vehicle age distribution and patterns of use for that future year. We made the simple assumption that the 2010 fleet would have the same general characteristics (age distribution, usage profiles) as the current fleet does. We then applied EMFAC7F 2010 emissions factors to this hypothesized future fleet's trips to determine the future base case (total VMT and emissions, emissions by model year, etc.).

For both 1991 and 2010, we used our calculations of emissions by vehicle model year to apportion the regional emissions cost estimates among model years. The annual VMT calculations by model year then were used to determine an average emissions cost per mile for each model year. For example, from the 1991 data for Los Angeles, the average emissions fee per mile for a 1 year old vehicle would be about 0.4 cents, while the average emissions fee for a 17 year old vehicle (from the pre-catalyst era) would be about 7.0 cents.

Note that the method we describe here should apply only to miles driven within each urban area, since emissions costs are calculated and apportioned on a regional basis. If the collection scheme used odometer readings as the basis for the VMT portion of the fee, some vehicle owners would be charged for miles driven in other regions or in other states. To avoid this potential inequity, methods could be developed to estimate in-region and out-of-region vehicle use and apportion the fee(s) accordingly, and credits could be given for documented out-of-state travel.

We analyzed the effects of our per-mile emissions fees varying by vehicle age, assuming that households would not alter their vehicle holdings or pattern of use in response to the fees. This assumption is not entirely realistic, since households could lower their fees by replacing their older cars with newer ones, and if AVI measurements or odometer readings are the basis for the VMT component of the fee, by using their newer cars in place of their older ones for some trips.²¹ Nevertheless, the analysis results provide an indication of the maximum travel impact and the minimum emissions impact that a such an emissions fee could be expected to have, without fleet changes the full impact of the fee would be passed through as an out-of-pocket cost to the driver, and the emissions reductions would come from reductions in travel rather than from the use of newer, presumably cleaner, cars.

A more robust analysis would consider how vehicle holdings and usage patterns might change in response to an emissions fee. The analysis would account for the determinants of household vehicle ownership and use and would estimate the effects of an emissions fee on the number of vehicles owned, the vehicle makes and model years, and VMT per vehicle. Such a comprehensive model was not available to us, but we did have STEP's internal auto ownership model, which estimates whether a household will have 0, 1, or 2+ vehicles as a function of household characteristics, travel conditions, and vehicle ownership and operating costs.

²¹ Alternatively, VMT could be estimated based on averages by model year taken from survey data. This might be simpler to implement than an approach requiring odometer readings, but would remove much of the incentive for multi-car households to reduce "older car" use by substituting their newer, presumably cleaner vehicles for certain trips.

We used the STEP auto ownership model to partially account for the effects on the vehicle fleet as follows. For each region and analysis year, the base case household fleet was used to estimate the average annual cost of auto ownership for each household. Then, revised annual ownership costs were computed to reflect the addition of emissions fees for each vehicle (based on model year and the actual daily VMT revealed in the survey). New auto ownership probabilities then were calculated using STEP²²

While this method is an improvement over simply representing the emissions fee as an increase in out-of-pocket costs, we feel that on balance it still is likely to overstate travel effects and understate emissions effects. For implementation scenarios involving AVI or odometer readings, households with more than one vehicle could shift use among household vehicles to reduce their emissions fees without cutting back on travel. Both the revenues from emissions fees and their impact on households are therefore likely to be lower than what we have estimated here.

²² Since STEP does not predict which autos might be disposed of or what model years added when auto ownership levels change, we imposed a series of assumptions. We assumed that, since the per-mile emissions fee is higher for older vehicles, households that reduce their auto ownership levels would get rid of their oldest car(s). We assumed that households maintaining their current auto ownership levels would also maintain the age distribution of the vehicles they own. Households that added vehicles were assumed to add car(s) of the average age and fuel efficiency for that ownership level. These assumptions allowed us to estimate the effects on emissions, fuel use, etc.

Fees Based on Measured Emissions:

To analyze an emissions fee based on measured emissions, we first needed an estimate of how emissions vary within each vehicle model year. One possible source of such information would be the data from vehicle inspection and maintenance tests, but we did not have access to these data. Therefore we used an alternative source, a database from Professor Donald Stedman of the University of Denver, containing in-use measurements obtained passively with his remote sensing device at a location on Rosemead Blvd. in Southern California.²³ Stedman expressed these data as frequency distributions of emissions by model year.

We used the Stedman data to develop a frequency distribution of emissions fees per mile for each model year in each region. Taking the fleet age distribution and the VMT by model year estimated from the regional survey data, we used the Stedman emissions distributions both to estimate the aggregate emissions by model year and to apportion emissions responsibility within model years. This approach allowed us to assess a higher fee for high-emitting vehicles, and a lower fee for relatively clean vehicles, within each model year.²⁴

To estimate the effects of a measurement-based emissions fee, we first made a special STEP run to create a base case with emissions derived from the high-emitter distributions rather than from the pure EMFAC data. Since we did not have actual emissions measurements for the vehicles in our samples, during this run we simulated the presence of

23 There is some reason for concern that emissions distributions recorded for a single location and operating environment may not reflect the full spectrum of operating conditions, and thus cannot be assumed to represent the "high-emitter" distribution for all regimes of urban travel. A similar criticism would apply, however, to vehicle inspection/maintenance test measurements, which are based on a single measurement and a specified operations sequence, or to any other data set based on single measurements and conditions.

24 An alternative approach would be to use the EMFAC data as the estimate of the average emissions by model year, and to use the Stedman data (or another source) to represent the underlying distribution of emissions for that model year. Note that the overall approach does not produce different results if a higher or lower total emissions burden is assumed.

high emitters in the fleet. Each vehicle in the sample was randomly assigned an emissions level from the distribution for its model year (and tagged with that emissions level for use in the "after" analysis). Then, the fee policy was tested using the same method as for the fee based on model year averages, except that in this case the proposed fees were based on the emissions level assigned during the "before" run.

A fee based on measured emissions would probably require new technology of one sort or another. Tamper-resistant on-board monitoring and recording equipment would be the preferred approach, fees based on multiple measurements using remote sensing equipment would be a second option. A third approach would be to use the emissions measurements from I/M testing, though this would raise a number of issues including whether the fee should be prospective or retrospective and whether it should be based on before-repair or after-repair measurements.

With an emissions fee targeting super-emitters, households could be expected to adroitly manipulate their vehicle holdings and use to minimize the impact of the fee. This would tend to produce lower travel impacts and higher emissions reductions than shown here.

Table 6.1: Main Data Sources for Case Study Analyses

	Bay Area	Los Angeles	Sacramento	San Diego
Household Survey Data	<ul style="list-style-type: none"> 1981 MTC Travel Survey 1990 MTC Travel Survey (DHS Corrected Versions) 1991 Caltrans Travel Survey 	<ul style="list-style-type: none"> 1991 SCAG Travel Survey (DHS Corrected Version) 1991 Caltrans Travel Survey 	<ul style="list-style-type: none"> 1991 SACOG Travel Survey w/ Caltrans Travel Survey (DHS Corrected Version) 	<ul style="list-style-type: none"> 1985 SANDAG Travel Survey 1991 Caltrans Travel Survey
US Census Data	<ul style="list-style-type: none"> 1990 Public Use Microdata Sample 	<ul style="list-style-type: none"> 1990 Public Use Microdata Sample 	<ul style="list-style-type: none"> 1990 Public Use Microdata Sample 	<ul style="list-style-type: none"> 1990 Public Use Microdata Sample
Base Year (1990/91) Zonal Demographic Data	<ul style="list-style-type: none"> Current ABAG/MTC Zonal Data File for 1990 as of 2/95 	<ul style="list-style-type: none"> Current SCAG Zonal and Tract Data File for 1990 as of 10/94 	<ul style="list-style-type: none"> Current SACOG Zonal Data File for 1990 as of 6/94 	<ul style="list-style-type: none"> Current SANDAG Zonal Data File for 1990 as of 10/93
Transportation Networks, Travel Time and Cost Data	<ul style="list-style-type: none"> MTC 1990 Network (zones, superdistricts) 	<ul style="list-style-type: none"> SCAG 1990 network - final runs using DHS corrected version March 95 	<ul style="list-style-type: none"> SACOG network (zones, superdistricts) 	<ul style="list-style-type: none"> SANDAG network provided by Cambridge Systematics, Inc
Parking costs	<ul style="list-style-type: none"> MTC 1990 	<ul style="list-style-type: none"> SCAG 1990 	<ul style="list-style-type: none"> SACOG 1990 	<ul style="list-style-type: none"> SANDAG 1991
Vehicle fuel efficiency	<ul style="list-style-type: none"> modeled based on vehicle type (known from 1990 survey) 	<ul style="list-style-type: none"> modeled based on vehicle type (using 1991 Caltrans data) 	<ul style="list-style-type: none"> modeled based on vehicle type (known from 1991 survey) 	<ul style="list-style-type: none"> modeled based on vehicle type (using 1991 Caltrans data)
Emissions data	<ul style="list-style-type: none"> EMFAC 7F 	<ul style="list-style-type: none"> EMFAC 7F 	<ul style="list-style-type: none"> EMFAC 7F 	<ul style="list-style-type: none"> EMFAC 7F

7. Impacts of Transportation Pricing Strategies

7.1 Overview

This chapter presents analysis results for a set of transportation pricing measures for the San Francisco Bay Area and the Sacramento, San Diego, and South Coast (Los Angeles) metropolitan regions. The results were produced through the application of modeling and data analyses for five strategies - congestion pricing, employee parking fees, fuel tax increases, vehicle-miles traveled (VMT) fees, and emissions fees - as described in some detail in Chapter 6. This chapter presents analysis results for the set of transportation pricing measures we analyzed for our four case study regions. We present a series of 18 tables summarizing the basic findings of our analyses, both by measure and by region. For each pricing measure, we present the predicted percentage changes in VMT, trips made, travel time, delay time, fuel consumed, CO₂, ROG, CO and NO_x emissions, and annual gross revenues¹, for the years 1991 (the base year²) and 2010.

7.2 Detailed Results

Tables 7.1 - 7.5 present the results organized by pricing measure for the year 1991. Tables 7.11 - 7.14 present a subset of the year 1991 results, reorganized by region. Each regional table includes analyses of the synergistic effects of groups of pricing measures, under two scenarios.

¹ Net revenues depend on the specific implementation strategy selected (public vs private sector implementation and administration, technologies used, scope of implementation, timing of implementation, etc.) In general, implementation designs costing a small fraction (5-15%) of gross revenues are feasible. For further discussion of costs, net revenues, and cost-effectiveness, see Chapter 12.

² The base year (here, 1991) refers to the demographic, economic, land use, and travel conditions and the transportation system performance levels which, according to the MPO for each region, were in place in 1991. Future year base cases (here, 2010) are derived from MPO data and forecasts for the applicable year.

1 "Modest Pricing" - A relatively low set of prices from each category (e.g., \$1.00 per day parking price increase, \$0.50 per gallon fuel tax increase), coupled with only enough investment in transit to maintain existing levels of service

2 "Full Pricing" - A relatively high set of prices from each category (e.g., \$3.00 per day parking increase, \$2.00 per gallon fuel tax increase), coupled with investment in transit corresponding to build-out of each region's long-range transit plan (as expressed in future network files made available by each MPO). Note that such a transit expansion would absorb a significant fraction of the pricing revenues

Tables 7.6 - 7.10 and 7.15 - 7.18 present the same ensemble of results for the year 2010. The percent changes shown are from a year 2010 base case, created by using STEP as a forecasting tool. The regions' forecasts of households, household income, and household size (or population) were used to "factor" the 1991 household file to create a year 2010 household file for each region. The STEP models then were run to create a year 2010 "base case", using the 2010 household file plus the MPO network data for the year 2010.³ Finally, policy analyses were carried out to predict changes from the future base case.

The tables are dense with information, reflecting the detailed results that can be obtained from advanced travel models such as this. To help the reader interpret the data, we shall work through the columns of one table in some detail: Table 7.1 (congestion pricing).

The first column in Table 7.1, labeled Description, contains an overview of the measure being analyzed. The description in this table and the ones that follow are fairly detailed, in recognition that each page may be used separately from the report.

³ In the Los Angeles region, some adjustments were made to SCAG's highway travel times after analyses indicated that the SCAG models then in use showed far more trips and VMT than STEP's more complex models would predict. Otherwise, MPO level-of-service projections were broadly consistent with STEP internal calculations and were used as provided to form the basis of the 2010 base case.

The second column, labeled Region, indicates the region of application

The third column, labeled Average Price, indicates the average peak-period fee that would be charged in each region under this strategy. The actual peak charges specified in STEP vary significantly among corridors and among facilities within a corridor, from 0 to perhaps \$2.00 per mile in a typical situation. The average is calculated by summing all of the congestion fees collected during the peak periods (defined by the presence of at least one priced location - between 4 and 9 hours per day, depending on the region), and dividing by the total regional vehicle-miles traveled during that time. The average price thus is not a direct indicator of how the congestion pricing policy would impact the road user, but serves as a comparative measure of how intensely the roads must be priced in order to achieve the level-of-service standard (here, D/E)

The next eight columns present changes from 1991 base year conditions. An example of such base year conditions, taken from EMFAC 7F, is shown in Table D.1, however, the percentages would equally apply to amended base year data as long as the underlying fundamental relationships, such as the general ratio of startup emissions to running emissions, do not change too much.⁴

Column four, labeled VMT/VKT/PM, shows how a primary measure of highway travel consumption - vehicle-miles - would be affected by the congestion fee. For example, according to Table 7.1, a congestion fee averaging 9 cents per mile in the Bay Area would reduce VMT by about 1.8 percent. This refers to daily VMT (24-hour, average weekday) for personal travel based in the region, it excludes commercial VMT and VMT due to trips that neither originate nor terminate in the region.

⁴ Major changes to the underlying processes for, e.g., emissions calculations would call for a review of the impacts, just as they might call for a revision to emissions inventories, SIPs, etc.

Vehicle-kilometers traveled and particulate emissions are referenced in the same column as VMT because both are proportional to VMT and thus experience the same percent changes ⁵

The fifth column, labeled Trips, shows the number of vehicle trips that would be suppressed by the congestion fee. Again, the basis is personal weekday vehicular travel within the region.

The sixth column, labeled Time, refers to the vehicle hours of travel, indicating change in the aggregate of all weekday vehicular travel within the region. This measure of travel time change, which is a standard measure used in transportation planning, is composed partly of a reduction in delay and partly of a reduction in travel - both fewer and shorter trips.

The seventh column, labeled Delay, addresses the reduction in delay resulting from the congestion pricing strategy. STEP measures the delay in terms of the difference between "actual" travel time and "free-flow" travel time for every trip, so a 100 percent reduction in delay would mean that every trip moves at free-flow speeds.

The eighth column, labeled Fuel/CO₂, presents the change in fuel consumption for personal travel. CO₂ is included here because for practical purposes its emissions can be considered proportional to fuel consumption.

Columns 9-11 show changes in emissions of three major urban pollutants: reactive organics (ROG), carbon monoxide (CO), and oxides of nitrogen (NO_x). Again, the data refer to emissions resulting from personal weekday travel only.

Column 12, Annual Revenues, show the gross estimated receipts from congestion prices, in millions of dollars.

⁵ A kilometer is .625 miles. Particulate emissions are calculated from VMT using per-mile rates provided in EMFAC7F.

Detailed discussions of how the models work and how the pricing strategies were analyzed are presented in Chapter 6 and Appendices B and C

We have focused our reporting on percent changes (except for revenue), because there is some uncertainty about total travel and the total emissions burden in each metropolitan area, and because a model such as STEP can produce estimates of policy-driven change that remain consistent across a range of assumptions even though aggregate estimates may vary. Our preference is for each reader of this document to think about the policy effects in Tables 7.1 - 7.18 in terms of current estimates for each metropolitan area.

We have included in Appendix D estimates of the California Air Resources Board's baseline data for each region (current as of 1/94) to provide readers who are used to working in VMT totals, tons of emissions, etc., with a point of reference. By applying the percent changes to the baseline data, it is a simple matter to calculate absolute changes. For example, Table D.1 shows that baseline 1991 ROG in the Bay Area was about 251 tons per weekday. Table 7.1 indicates that ROG would be reduced by 4.5 percent under a congestion fee. Thus, the absolute reduction in ROG would be 11.29 tons per weekday, or about 2824 tons per year (at 250 days per year). Going one step further, the amount of congestion pricing revenue collected per ton of ROG reduced is $(1143000000/2824) = \$404,781/\text{ton}$.

7.3 Interpretation

The results for each analysis year represent stable, long-term, effects of the pricing measures, i.e., the impacts shown are all those that would occur over a period of several months to several years following full implementation of the pricing measures. Note that certain impacts of pricing, e.g., changes in route choice, mode choice, time of travel, and non-work, non-school destination choices, would likely occur very quickly, over a period of days, weeks, or months. Other impacts would typically take longer - auto ownership decisions, work location choice, and housing location choice, for example, are likely to change over a longer period of time.

Percent changes are widely used to communicate transportation analyses and increasingly are used in other planning arenas. For example, several federal Clean Air Act provisions are expressed as required percent changes from a baseline, greenhouse gas reduction targets similarly are expressed as desired percent changes. What exactly do such changes mean? While a specific interpretation of each metric should be based on a review of the context in which it occurs, some examples, taken from an analysis of the San Francisco Bay Area's TCM plan (Harvey and Deakin, 1991) allows broad comparisons to be drawn

- o Omitting an employer program comprised mainly of parking charges, the Bay Area's package of State TCMs for Phase 1 (reasonably available measures, target year 1994), was estimated to produce a total ROG reduction of 2.8 percent. The congestion pricing strategy shown in Table 7.1 is in contrast estimated to produce a ROG reduction of 4.5 percent - 61 percent more effective than the entire package of conventional commute alternatives.
- o Region-wide implementation of traffic operations improvements and coordinated signal timing were estimated to reduce ROG by 1.63 percent. Congestion pricing would be 175 percent times as effective.
- o An extensive program of HOV lanes for the Bay Area, proposed as part of Phase 2 of the Air Plan, was estimated to produce 4.1 percent reduction in ROG. Congestion pricing would be almost 10 times more effective than the HOV lane program.

Obviously many other factors affect the implementation feasibility of various transportation measures, including the amount of public support each measure can garner, its legal status, and its match with agency missions and objectives (among many other things). Nevertheless, it should be clear that from this example, and the tables in general, that pricing strategies would be far more effective than many conventional transportation control strategies. This itself may be a reason to give pricing strategies a careful look.

Overall, the results presented in this chapter show that carefully crafted and targeted transportation pricing strategies could do much to reduce travel times (hence congestion), cut energy use, and reduce emissions, at the same producing large gross revenues. Nevertheless, it also is clear that auto use and its impacts are quite inelastic with respect to most aspects of price. This has two important implications: first, sizable increases in revenue can be obtained with relatively little effect on travel; conversely, large price increases are necessary to obtain sizable reductions in travel and its externalities.

The results also provide an empirical dimension to the notion that the most efficient way to use price as a mechanism for reducing transportation externalities is to price each externality in a direct way. Thus, as the tables here and in Chapter 12 detail, the most effective pricing strategy for emissions control (in the sense of emissions reductions per dollar charged) is to target high-emitting vehicles as precisely as possible; the most effective strategy for achieving large reductions in fuel consumption (and CO₂ production) is to raise the price of fuel; the most effective way to reduce congestion is to impose a toll at congested locations, and so on. Note that we refer to efficiency and effectiveness here in a purely technical sense. Other factors - ethical, institutional, political, and social - contribute to a broader assessment that may lead to different conclusions about policy effectiveness.

The results reported in Tables 7.1 - 7.18 are referenced and discussed in some detail in the chapters that follow.

**Table 7.1
Analysis Results for Congestion Pricing - 1991**

Description	Region	Average Price	Change From 1991 Base						Annual Revenue		
			VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG		CO	NOx
<p>The congestion pricing strategy analyzed here assumes that prices would be assessed on a per mile basis everywhere that congestion appears in the highway network, including on arterials and collector streets as necessary. A technology for electronic toll collection would be required. Roadway message signs or in-vehicle readouts would provide information about tolls on upcoming segments, likely as part of a broader highway information system. Prices would not vary minute-by-minute, but would be set to reflect average conditions on each highway link during each period of the day, perhaps with seasonal adjustments. The results shown here are based on a reduction of congestion to level-of-service D/E, defined as a volume-to-capacity ratio of 9. Note that travelers would continue to experience some delay under this criterion, but that greater reductions in volume might not be justifiable in economic terms.</p>	Bay Area	\$0.09	-1.8%	-1.7%	-5.7%	-19.5%	-5.8%	-4.5%	-4.7%	-2.1%	1143
	Sacramento	\$0.04	-0.6%	-0.5%	-1.8%	-6.0%	-1.8%	-1.5%	-1.6%	-0.7%	143
	San Diego	\$0.06	-1.0%	-0.9%	-3.1%	-10.5%	-2.9%	-2.6%	-2.7%	-1.1%	401
	South Coast	\$0.10	-2.3%	-2.2%	-6.8%	-22.5%	-6.7%	-5.5%	-5.5%	-2.5%	3187

Notes: Revenue expressed in millions of dollars per year. VMT denotes weekday vehicle-miles traveled, VKT is weekday vehicle-kilometers traveled, PM10 is particulate emissions of 10 microns or less, trips are weekday vehicle-trips, time is weekday vehicle-hours of travel, delay is weekday vehicle-hours of delay, fuel is daily gallons of gasoline/diesel; CO2 is daily tons of carbon dioxide, ROG is daily tons of reactive organic hydrocarbons, CO is daily tons of carbon monoxide, and NOx is daily tons of oxides of nitrogen

**Table 7.2
Analysis Results for Employee Parking Pricing - 1991**

Description	Region	Minimum		Change From 1991 Base										Annual Revenue
		Price		VMT/VKT/PM	Trips	Time	Delay	Fuel/CO ₂	ROG	CO	NOx			
The parking pricing strategy analyzed here applies only to spaces used by workers in each region. The intent is to make parking cost explicit by requiring each worker to pay at least some threshold cost to park all day at or near the workplace. Only drive-alone vehicles would be charged under this scheme. The analysis was carried out through adjustments in the average zonal parking price. Basically, if an average zonal price in the base data was less than the minimum price to be tested, it was raised to match the minimum. This is tantamount to saying that no worker would face an average area price less than the stated minimum. However, basing an analysis on such an average implies that some individual workers still might experience prices lower than the minimum	Bay Area	\$1 00 \$3 00		-0.8% -2.3%	-1.0% -2.6%	-1.3% -3.7%	-2.3% -7.0%	-1.1% -2.6%	-0.9% -2.5%	-0.9% -2.4%		405 1196		
	Sacramento	\$1 00 \$3 00		-1.1% -2.9%	-1.2% -3.1%	-1.6% -4.1%	-2.5% -6.0%	-1.2% -3.0%	-1.2% -3.1%	-1.0% -2.8%		99 290		
	San Diego	\$1 00 \$3 00		-1.0% -2.6%	-1.1% -2.9%	-1.5% -3.8%	-2.5% -6.0%	-1.1% -2.7%	-1.0% -2.7%	-0.9% -2.5%		190 558		
	South Coast	\$1 00 \$3.00		-1.0% -2.7%	-1.1% -3.0%	-1.5% -4.2%	-2.5% -7.5%	-1.2% -2.9%	-1.1% -2.8%	-1.1% -2.7%		948 2788		

Notes: Revenue expressed in millions of dollars per year, VMT denotes weekday vehicle-miles traveled, VKT is weekday vehicle-kilometers traveled, PM10 is particulate emissions of 10 microns or less, trips are weekday vehicle-trips, time is weekday vehicle-hours of travel, delay is weekday vehicle-hours of delay, fuel is daily gallons of gasoline/diesel, CO₂ is daily tons of carbon dioxide, ROG is daily tons of reactive organic hydrocarbons, CO is daily tons of carbon monoxide, and NOx is daily tons of oxides of nitrogen

**Table 7.3
Analysis Results for Fuel Tax Increases - 1991**

Description	Region	Tax Increment	Fuel Elasticity	Change From 1991 Base					Annual Revenue			
				VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx	Revenue
<p>The fuel tax analyzed here is a straightforward addition to the pump price of gasoline and diesel fuel. Base fleet fuel efficiency is about 22 miles per gallon (0.364 gallons per mile). Base fuel cost is about \$1.20 per gallon, or 5.46 cents per mile. With no increase in fleet fuel economy, a \$2.00 per gallon fee would add about 9.1 cents to the per-mile cost of driving. However, both empirical evidence and common sense suggest that the vehicle fleet would become more efficient under a significant price increase, both from substitution of more efficient vehicles within each household and from replacement through vehicle purchase. We tested a range of assumptions about increased fuel efficiency, expressed in terms of the elasticity of fuel consumption (gallons per mile) with respect to fuel price. Three versions are reported here: -0.22, which implies an increase in fuel efficiency from 22 to 28 mpg for a \$2.00 fuel tax, -0.13, which implies an increase from 22 to 28 mpg for a \$2.00 fuel tax, and -0.05, which implies an increase from 22 to 24 mpg. The latter figure is consistent with estimates from the California Energy Commission Personal Vehicle Model, which shows a 2 mpg increase from a \$2.00 fuel surcharge. Studies of international experience with fuel price changes tend to point toward higher elasticity values.</p>	Bay Area	\$0.50 \$2.00 \$2.00 \$2.00	-0.13 -0.13 -0.05 -0.22	-3.9% -12.8% -16.6% -7.7%	-3.8% -12.1% -15.8% -7.1%	5.4% -17.0% -21.8% -10.1%	-7.5% -22.0% -28.0% -12.0%	-8.1% -31.3% -23.6% -42.3%	-3.7% -12.6% -16.3% -7.5%	-3.6% -12.2% -16.0% -7.3%	-3.4% -11.8% -16.6% -7.0%	954 2884 3207 2422
	Sacramento	\$0.50 \$2.00 \$2.00 \$2.00	-0.13 -0.13 -0.05 -0.22	-4.3% -13.9% -18.4% -8.5%	-4.0% -13.3% -17.6% -7.8%	-5.6% -17.6% -23.0% -10.9%	-8.5% -18.5% -23.0% -12.0%	-8.5% -32.4% -25.2% -42.8%	-4.1% -13.7% -18.2% -8.3%	-4.0% -13.6% -17.8% -8.1%	-3.7% -12.6% -17.3% -7.7%	264 790 874 668
	San Diego	\$0.50 \$2.00 \$2.00 \$2.00	-0.13 -0.13 -0.05 -0.22	-4.1% -13.2% -17.4% -8.0%	-3.8% -12.7% -16.5% -7.4%	5.5% -17.3% -22.4% -10.8%	-7.0% -20.5% -25.0% -14.0%	-8.2% -31.8% -24.3% -42.5%	-3.8% -13.0% -17.2% -7.7%	-3.8% -12.8% -16.6% -7.5%	-3.6% -12.5% -16.3% -7.2%	487 1494 1668 1289
	South Coast	\$0.50 \$2.00 \$2.00 \$2.00	-0.13 -0.13 -0.05 -0.22	-4.1% -13.3% -17.6% -8.1%	-4.0% -12.8% -16.7% -7.5%	-5.4% -17.5% -23.4% -10.6%	-6.5% -21.0% -29.0% -12.5%	-8.1% -31.8% -24.6% -42.5%	-3.8% -13.2% -17.4% -7.9%	-3.7% -13.0% -17.1% -7.8%	-3.5% -12.2% -16.4% -7.4%	2405 7219 7992 6086

Notes: Revenue expressed in millions of dollars per year. VMT denotes weekday vehicle-miles traveled, VKT is weekday vehicle-kilometers traveled, PM10 is particulate emissions of 10 microns or less, trips are weekday vehicle-trips, time is weekday vehicle-hours of travel, delay is weekday vehicle-hours of delay, fuel is daily gallons of gasoline/diesel, CO2 is daily tons of carbon dioxide, ROG is daily tons of reactive organic hydrocarbons, CO is daily tons of carbon monoxide, and NOx is daily tons of oxides of nitrogen.

**Table 7.4
Analysis Results for a VMT Fee - 1991**

Description	Region	Change From 1991 Base										Annual Revenue
		VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx			
<p>The VMT fee was analyzed as a simple increment of two cents per mile in the out-of-pocket cost of driving. No specific assumption was made about the method of collection. However, the analysis approach treats the price increment as if it were charged in the same manner as a fuel tax, i.e., as if the driver were aware of the expenditure from moment to moment. This implies a potentially complex collection scheme involving real-time reading of the odometer, perhaps each time a vehicle is fueled. The simpler alternative of billing once a year based on the odometer reading at the time of registration possibly would have less effect on travel and emissions, perhaps substantially less, although revenues would be about the same as shown here</p>	Bay Area	-4.2%	-4.0%	-5.8%	-8.0%	-4.2%	-4.1%	-4.0%	-3.9%			804
	Sacramento	-4.7%	-4.4%	-6.1%	-7.0%	-4.7%	-4.6%	-4.5%	-4.3%			223
	San Diego	-4.4%	-4.2%	-5.9%	-7.5%	-4.4%	-4.3%	-4.3%	-4.1%			419
	South Coast	-4.4%	-4.2%	-6.2%	-9.0%	-4.5%	-4.3%	-4.2%	-3.8%			2024

Notes. Revenue expressed in millions of dollars per year, VMT denotes weekday vehicle-miles traveled, VKT is weekday vehicle-kilometers traveled; PM10 is particulate emissions of 10 microns or less; trips are weekday vehicle-trips, time is weekday vehicle-hours of travel, delay is weekday vehicle-hours of delay; fuel is daily gallons of gasoline/diesel, CO2 is daily tons of carbon dioxide; ROG is daily tons of reactive organic hydrocarbons; CO is daily tons of carbon monoxide, and NOx is daily tons of oxides of nitrogen.

**Table 7.5
Analysis Results for Emissions Fees - 1991**

Description	Region	Fee Basis	Change From 1991 Base										Annual Revenue	
			VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx	Revenue	Revenue		
<p>Emissions fees are the most difficult of the pricing policies to analyze, because knowledge about how consumers would trade off emissions fees, repair costs, insurance, and other auto-related expenditures is not well developed. We looked at two broad strategies (1) the emissions fee would be calculated based on EMFAC data for average model year emissions per mile and actual VMT (so that the per mile fee would vary only by model year), and 2) the emissions fee would be based on data about actual performance of each vehicle, obtained perhaps from some type of in-use testing device. Unlike the EMFAC-based approach, strategy two would focus high prices on super-emitting vehicles. In both cases, prices were set so that the fee would average about one cent per mile over the entire personal vehicle fleet. The analysis was based on assumptions about how the distribution of vehicles by age and household income would change in the face of higher registration fees (under each strategy). These assumptions then were used to adjust auto ownership and out-of-pocket costs and applied to households in the STEP sample (see text for a full discussion)</p>	Bay Area	EMFAC In-Use	-2.0% -1.6%	-1.7% -1.4%	-2.7% -1.9%	-3.5% -1.5%	-4.1% -6.9%	-6.5% -18.2%	-6.5% -17.9%	-6.7% -16.7%	320 284	-6.7% -16.7%		
	Sacramento	EMFAC In-Use	-2.7% -2.2%	-2.3% -1.8%	-3.1% -2.5%	-2.0% -1.5%	-5.2% -7.9%	-6.1% -20.7%	-8.0% -20.4%	-7.4% -18.8%	77 66	-7.4% -18.8%		
	San Diego	EMFAC In-Use	-2.4% -2.0%	-2.1% -1.7%	-2.9% -2.3%	-2.5% -1.5%	-4.9% -7.6%	-7.5% -20.1%	-7.4% -19.7%	-6.8% -17.5%	148 131	-6.8% -17.5%		
	South Coast	EMFAC In-Use	-2.2% -1.8%	-1.9% -1.5%	-2.8% -2.1%	-3.0% -1.5%	-4.4% -7.2%	-7.0% -19.4%	-6.9% -19.0%	-6.2% -17.1%	743 688	-6.2% -17.1%		

Notes: Revenue expressed in millions of dollars per year; VMT denotes weekday vehicle-miles traveled, VKT is weekday vehicle-kilometers traveled, PM10 is particulate emissions of 10 microns or less, trips are weekday vehicle-trips, time is weekday vehicle-hours of travel, delay is weekday vehicle-hours of delay; fuel is daily gallons of gasoline/diesel, CO2 is daily tons of carbon dioxide, ROG is daily tons of reactive organic hydrocarbons, CO and NOx is daily tons of carbon monoxide, and NOx is daily tons of oxides of nitrogen.

**Table 7.6
Analysis Results for Congestion Pricing - 2010**

Description	Region	Average Price	Change From 2010 Baseline							Annual Revenue	
			VMT/VKT/PPM	Trips	Time	Delay	Fuel/CO2	ROG	CO		NOx
The congestion pricing strategy analyzed here assumes that prices would be assessed on a per mile basis everywhere that congestion appears in the highway network, including on arterials and collector streets as necessary. A technology for electronic toll collection would be required. Roadway message signs or in-vehicle readouts would provide information about tolls on upcoming segments, likely as part of a broader highway information system. Prices would not vary minute-by-minute, but would be set to reflect average conditions on each highway link during each period of the day, perhaps with seasonal adjustments. The results shown here are based on a reduction of congestion to level-of-service D/E, defined as a volume-to-capacity ratio of 9. Note that travelers would continue to experience some delay under this criterion, but that greater reductions in volume might not be justifiable in economic terms.	Bay Area	\$0.13	-2.8%	-2.7%	-9.2%	-27.0%	-8.3%	-6.9%	-6.9%	-3.2%	2274
	Sacramento	\$0.08	-1.5%	-1.4%	-4.8%	-16.5%	-4.8%	-3.7%	-3.9%	-1.7%	443
	San Diego	\$0.09	-1.7%	-1.6%	-5.4%	-18.5%	-5.4%	-4.2%	-4.3%	-2.0%	896
	South Coast	\$0.19	-3.3%	-3.1%	-9.7%	-32.0%	-9.6%	-8.1%	-7.9%	-3.6%	7343

Notes: Revenue expressed in millions of dollars per year, VMT denotes weekday vehicle-miles traveled, VKT is weekday vehicle-kilometers traveled, PM10 is particulate emissions of 10 microns or less, trips are weekday vehicle-trips, time is weekday vehicle-hours of travel, delay is weekday vehicle-hours of delay, fuel is daily gallons of gasoline/diesel, CO2 is daily tons of carbon dioxide, ROG is daily tons of reactive organic hydrocarbons, CO is daily tons of carbon monoxide, and NOx is daily tons of oxides of nitrogen.

**Table 7.7
Analysis Results for Employee Parking Pricing - 2010**

Description	Region	Minimum Price	Change From 2010 Base										Annual Revenue	
			VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx	Annual Revenue			
The parking pricing strategy analyzed here applies only to spaces used by workers in each region. The intent is to remove a hidden subsidy by requiring each worker to pay at least some threshold cost to park all day at or near the workplace. Only drive-alone vehicles would be charged under this scheme. The analysis was carried out through adjustments in the average zonal parking price. Basically, if an average zonal price in the base data was less than the minimum price to be tested, it was raised to match the minimum. This is tantamount to saying that no worker would face an average area price less than the stated minimum. However, basing an analysis on such an average implies that some individual workers still might experience prices lower than the minimum.	Bay Area	\$1 00 \$3 00	-0.8% -2.1%	-0.9% -2.4%	-1.3% -3.6%	-2.7% -7.0%	-1.0% -2.4%	-0.8% -2.3%	-0.8% -2.4%	-0.7% -2.2%	473 1399			
	Sacramento	\$1 00 \$3 00	-1.0% -2.6%	-1.1% -2.8%	-1.5% -3.9%	-2.6% -6.5%	-1.1% -2.7%	-1.1% -2.8%	-1.1% -2.8%	-0.9% -2.5%	142 419			
	San Diego	\$1 00 \$3 00	-0.9% -2.4%	-1.0% -2.6%	-1.4% -3.8%	-2.6% -7.0%	-1.0% -2.6%	-0.9% -2.5%	-0.9% -2.5%	-0.8% -2.4%	271 800			
	South Coast	\$1 00 \$3 00	-0.9% -2.6%	-1.1% -2.8%	-1.5% -4.2%	-2.9% -8.5%	-1.1% -2.7%	-1.0% -2.6%	-1.0% -2.7%	-0.9% -2.5%	1408 4151			

Notes: Revenue expressed in millions of dollars per year; VMT denotes weekday vehicle-miles traveled, VKT is weekday vehicle-kilometers traveled, PM10 is particulate emissions of 10 microns or less, trips are weekday vehicle-trips, time is weekday vehicle-hours of travel, delay is weekday vehicle-hours of delay, fuel is daily gallons of gasoline/diesel, CO2 is daily tons of carbon dioxide, ROG is daily tons of reactive organic hydrocarbons, CO is daily tons of carbon monoxide, and NOx is daily tons of oxides of nitrogen

Table 7.8
Analysis Results for Fuel Tax Increases - 2010

Description	Region	Tax Increment	Fuel Elasticity	Change From 2010 Base						Annual Revenue
				VMT/VKT/PM	Trips	Time Delay	Fuel/CO2	ROG	CO	
<p>The fuel tax analyzed here is a straightforward addition to the pump price of gasoline and diesel fuel. Base fleet fuel efficiency is about 22 miles per gallon (0.384 gallons per mile). Base fuel cost is about \$1.20 per gallon, or 54 cents per mile. With no increase in fleet fuel economy, a \$2.00 per gallon fee would add about 8.1 cents to the per-mile cost of driving. However, both empirical evidence and common sense suggest that the vehicle fleet would become more efficient under a significant price increase, both from substitution of more efficient vehicles within each household and from replacement through vehicle purchase. We tested a range of assumptions about increased fuel efficiency, expressed in terms of the elasticity of fuel consumption (gallons per mile) with respect to fuel price. Three versions are reported here: -0.22, which implies an increase in fuel efficiency from 22 to 35 mpg for a \$2.00 fuel tax, -0.13, which implies an increase from 22 to 28 mpg for a \$2.00 fuel tax, and -0.05, which implies an increase from 22 to 24 mpg. The latter figure is consistent with estimates from the California Energy Commission Personal Vehicle Model, which shows a 2 mpg increase from a \$2.00 fuel surcharge. Studies of international experience with fuel price changes tend to point toward higher elasticity values.</p>	Bay Area	\$0.50 \$2.00 \$2.00 \$2.00	-0.13 -0.13 -0.05 -0.22	3.6% -11.7% -15.5% -7.1%	-3.4% -11.3% -14.8% -6.8%	5.3% -16.8% -22.8% -10.1%	-8.6% -30.6% -22.6% -42.0%	-3.5% -11.6% -16.3% -7.0%	-3.5% -11.1% -15.2% -6.4%	1332 4853 4526 3387
	Sacramento	\$0.50 \$2.00 \$2.00 \$2.00	-0.13 0.13 -0.05 -0.22	-4.1% -13.2% -17.4% -8.0%	-3.9% -12.7% -16.7% -7.7%	-6.5% -17.6% -23.1% -11.4%	-9.3% -31.9% -24.3% -42.5%	-4.0% -13.0% -17.2% -8.0%	-3.7% -12.5% -16.3% -7.5%	414 1245 1382 1049
	San Diego	\$0.50 \$2.00 \$2.00 \$2.00	-0.13 -0.13 -0.05 -0.22	-3.9% -12.5% -16.5% -7.6%	-3.5% -12.0% -15.7% -7.3%	-5.5% -17.1% -22.6% -10.6%	-9.1% -31.3% -23.5% -42.3%	-3.8% -12.3% -16.3% -7.5%	-3.3% -11.8% -15.4% -6.8%	747 2257 2513 1895
	South Coast	\$0.50 \$2.00 \$2.00 \$2.00	-0.13 -0.13 -0.05 -0.22	-4.2% -13.0% -17.1% -8.2%	-3.9% -12.5% -16.4% -7.8%	-6.1% -18.7% -24.6% -11.7%	-9.3% -31.6% -24.0% -42.6%	-4.1% -12.8% -16.9% -8.0%	-4.0% -12.7% -16.8% -8.0%	3724 11235 12483 9428

Notes: Revenue expressed in millions of dollars per year; VMT denotes weekday vehicle-miles traveled, VKT is weekday vehicle-kilometers traveled, PM10 is particulate emissions of 10 microns or less, trips are weekday vehicle-trips, time is weekday vehicle-hours of travel, delay is weekday vehicle-hours of delay, fuel is daily gallons of gasoline/diesel, CO2 is daily tons of carbon dioxide, ROG is daily tons of reactive organic hydrocarbons, CO is daily tons of carbon monoxide, and NOx is daily tons of oxides of nitrogen

**Table 7.9
Analysis Results for a VMT Fee - 2010**

Description	Region	Change From 2010 Base								Annual Revenue
		VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx	
<p>The VMT fee was analyzed as a simple increment of two cents per mile in the out-of-pocket cost of driving. No specific assumption was made about the method of collection. However, the analysis approach treats the price increment as if it were charged in the same manner as a fuel tax, i.e., as if the driver were aware of the expenditure from moment to moment. This implies a potentially complex collection scheme involving real-time reading of the odometer, perhaps each time a vehicle is fueled. The simpler alternative of billing once a year based on the odometer reading at the time of registration possibly would have less effect on travel and emissions, perhaps substantially less, although revenues would be about the same as shown here.</p>	Bay Area	-3.9%	-3.7%	-5.7%	-9.0%	-4.1%	-3.8%	-3.7%	-3.6%	1122
	Sacramento	-4.4%	-4.1%	-5.9%	-7.5%	-4.4%	-4.3%	-4.2%	-3.9%	349
	San Diego	-4.2%	-4.0%	-5.9%	-8.5%	-4.2%	-4.1%	-4.0%	-3.8%	629
	South Coa	-4.3%	-4.1%	-6.4%	-10.5%	-5.2%	-4.2%	-4.2%	-3.9%	3144

Notes Revenue expressed in millions of dollars per year, VMT denotes weekday vehicle-miles traveled, VKT is weekday vehicle-kilometers traveled, PM10 is particulate emissions of 10 microns or less, trips are weekday vehicle-trips, time is weekday vehicle-hours of travel, delay is weekday vehicle-hours of delay, fuel is daily gallons of gasoline/diesel, CO2 is daily tons of carbon dioxide, ROG is daily tons of reactive organic hydrocarbons, CO is daily tons of carbon monoxide, and NOx is daily tons of oxides of nitrogen

Table 7.10
Analysis Results for Emissions Fees - 2010

Description	Region	Fee Basis	Change From 2010 Base							Annual Revenue	
			VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx	Revenue
<p>Emissions fees are the most difficult of the pricing policies to analyze, because knowledge about how consumers would trade off emissions fees, repair costs, insurance, and other auto-related expenditures is not well developed. We looked at two broad strategies: 1) the emissions fee would be calculated based on EMFAC data for average model year emissions per mile and average model year VMT (so that the fee would vary only by model year), and 2) the emissions fee would be based on data about actual performance of each vehicle, obtained perhaps from some type of in-use testing device. Unlike the EMFAC-based approach, strategy two would focus high prices on super-emitting vehicles. In both cases, prices were set so that the fee would average about one cent per mile over the entire personal vehicle fleet. The analysis focused on assumptions about how the distribution of vehicles by age and household income would change in the face of higher registration fees (under each strategy). These assumptions then were used to adjust auto ownership and out-of-pocket costs and applied to households in the STEP sample (see text for a full discussion)</p>	Bay Area	EMFAC In-Use	-2.2% -1.6%	-1.9% -1.4%	-2.9% -2.1%	-3.5% -2.6%	-3.9% -6.6%	-5.4% -17.7%	-5.3% -17.5%	-4.6% -14.9%	384 341
	Sacramento	EMFAC In-Use	-2.6% -2.3%	-2.3% -2.1%	-3.5% -3.3%	-4.5% -5.0%	-4.0% -7.4%	-5.7% -20.2%	-5.8% -19.7%	-4.2% -17.3%	116 102
	San Diego	EMFAC In-Use	-2.5% -1.9%	-2.2% -1.7%	-3.2% -2.6%	-3.5% -3.5%	-4.1% -7.1%	-6.6% -19.6%	-5.4% -19.2%	-4.6% -16.2%	211 186
	South Coast	EMFAC In-Use	-2.5% -2.1%	-2.3% -1.9%	-3.6% -3.3%	-5.5% -6.0%	-3.9% -7.2%	-6.5% -18.9%	-5.4% -18.6%	-4.5% -15.8%	1106 980

Notes: Revenue expressed in millions of dollars per year; VMT denotes weekday vehicle-miles traveled, VKT is weekday vehicle-kilometers traveled, PM10 is particulate emissions of 10 microns or less, trips are weekday vehicle-trips, time is weekday vehicle-hours of travel, delay is weekday vehicle-hours of delay, fuel is daily gallons of gasoline/diesel; CO2 is daily tons of carbon dioxide, ROG is daily tons of reactive organic hydrocarbons, CO is daily tons of carbon monoxide, and NOx is daily tons of oxides of nitrogen

**Table 7.11
Analysis Results for the San Francisco Bay Area - 1991**

Strategy	Description	Change From 1991 Base										Annual Revenue	
		VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx				
1	Regionwide Congestion Pricing (level-of-service D/E) - Average \$0.09 per Mile In Peak	-1.8%	-1.7%	-5.7%	-19.6%	-6.8%	-4.7%	-2.1%					1143
2a	Regionwide Employee Parking Charge of \$1.00 Per Day	-0.8%	-1.0%	-1.3%	-2.3%	-1.1%	-0.9%	-0.8%					405
2b	Regionwide Employee Parking Charge of \$3.00 Per Day	-2.3%	-2.6%	-3.7%	-7.0%	-2.6%	-2.6%	-2.4%					1196
3a	Fuel Tax Increase by \$0.50 (1991)	-3.9%	-3.6%	-6.4%	-7.5%	-9.1%	-3.6%	-3.4%					954
3b	Fuel Tax Increase by \$2.00 (1991)	-12.6%	-12.1%	-17.0%	-22.0%	-31.3%	-12.2%	-11.8%					2884
4a	Mileage- and Emissions-Based Fee (Range Approx 40-4000/yr)	-2.0%	-1.7%	-2.7%	-3.5%	-4.1%	-6.5%	-6.7%					320
4b	Mileage- and Emissions-Based Fee (Range Approx 10-10000/yr)	-1.6%	-1.4%	-1.9%	-1.5%	-6.9%	-17.9%	-15.7%					264
5	VMT Fee of \$0.02 per mile	-4.2%	-4.0%	-6.8%	-8.0%	-4.2%	-4.0%	-3.9%					804
	Example of Combined Effects: Moderate Impact	-8.1%	-7.5%	-13.9%	-28.9%	-18.3%	-14.6%	-11.3%					2589
	Example of Combined Effects: High Impact	-19.7%	-19.0%	-29.1%	-46.8%	-46.3%	-37.3%	-32.6%					4817

Notes: Revenue expressed in millions of dollars per year, VMT denotes weekday vehicle-miles traveled, VKT is weekday vehicle-kilometers traveled, PM10 is particulate emissions of 10 microns or less, trips are weekday vehicle-trips, time is weekday vehicle-hours of travel, delay is weekday vehicle-hours of delay, fuel is daily gallons of gasoline/diesel, CO2 is daily tons of carbon dioxide, ROG is daily tons of reactive organic hydrocarbons, CO is daily tons of carbon monoxide, and NOx is daily tons of oxides of nitrogen.

Table 7.12
Analysis Results for the Sacramento Region - 1991

	Strategy	Description	Change From 1991 Base							Annual Revenue			
			VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO		NOx		
1	Regionwide Congestion Pricing (level-of-service D/E) - Average \$0.04 per Mile in Peak	An Automatic Vehicle Identification (AVI) scheme would be used to price the regional freeway and arterial system to maintain level-of-service (LOS) D/E	-0.6%	-0.6%	-1.8%	-8.0%	-1.6%	-1.6%	-1.6%	-1.6%	-1.6%	-0.7%	143
2a	Regionwide Employee Parking Charge of \$1.00 Per Day	All workers driving alone in the region would experience a minimum \$1.00 (1991) per day charge for parking at the workplace	-1.1%	-1.2%	-1.6%	-2.5%	-1.2%	-1.2%	-1.2%	-1.2%	-1.2%	-1.0%	99
2b	Regionwide Employee Parking Charge of \$3.00 Per Day	All workers driving alone in the region would experience a minimum \$3.00 (1991) per day charge for parking at the workplace	-2.9%	-3.1%	-4.1%	-6.0%	-3.0%	-3.0%	-3.1%	-3.1%	-3.1%	-2.8%	280
3a	Fuel Tax Increase by \$0.50 (1991)	Fees would be paid at the pump	-4.3%	-4.0%	-6.6%	-6.6%	-9.6%	-4.1%	-4.1%	-4.1%	-4.0%	-3.7%	264
3b	Fuel Tax Increase by \$2.00 (1991)		-13.9%	-13.3%	-17.6%	-18.6%	-32.4%	-13.7%	-13.7%	-13.5%	-12.6%	-12.6%	790
4a	Mileage- and Emissions-Based Fee (Range Approx 40-400/yr)	Fees would average 1 cent per mile, and would be collected frequently, as for the VMT fee	-2.7%	-2.3%	-3.1%	-2.0%	-6.2%	-8.1%	-8.1%	-8.0%	-8.0%	-7.4%	77
4b	Mileage- and Emissions-Based Fee (Range Approx 10-1000/yr)	In alternative 4a, the fee would be based on annual mileage and average model year emissions as reflected in EMFACTF. In alternative 4b, the fee would be based on actual odometer readings and in-use tailpipe measurements	-2.2%	-1.8%	-2.6%	-1.5%	-7.9%	-20.7%	-20.7%	-20.4%	-20.4%	-18.8%	68
5	VMT Fee of \$0.02 per mile	Fees would be paid often, e.g., in the same manner as fuel taxes. This implies a potentially complex collection scheme involving real-time reading of the odometer, perhaps each time a vehicle is fueled. The simpler option of billing once a year based on the odometer reading likely would have less effect on travel and emissions	-4.7%	-4.4%	-6.1%	-7.0%	-4.7%	-4.6%	-4.6%	-4.5%	-4.5%	-4.3%	223
	Example of Combined Effects Moderate Impact	1, 2a, 3a, and 4a with maintenance of current transit service	-8.3%	-7.6%	-11.3%	-14.9%	-16.3%	-13.9%	-13.9%	-13.9%	-13.9%	-12.1%	535
	Example of Combined Effects High Impact	1, 2b, 3b, and 4b with extensive transit investment (Revenue not reduced to reflect cost of new transit.)	-21.1%	-20.0%	-27.2%	-30.2%	-45.6%	-38.9%	-38.9%	-38.7%	-38.7%	-35.6%	1136

Notes: Revenue expressed in millions of dollars per year; VMT denotes weekday vehicle-miles traveled, VKT is weekday vehicle-kilometers traveled, PM10 is particulate emissions of 10 microns or less; trips are weekday vehicle-trips; time is weekday vehicle-hours of travel, delay is weekday vehicle-hours of delay, fuel is daily gallons of gasoline/diesel; CO2 is daily tons of carbon dioxide; ROG is daily tons of reactive organic hydrocarbons, CO is daily tons of carbon monoxide, and NOx is daily tons of oxides of nitrogen

**Table 7.13
Analysis Results for the San Diego Region - 1991**

Strategy	Description	Change From 1991 Base							Annual Revenue	
		VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO		NOx
1 Regionwide Congestion Pricing (level-of-service D/E) - Average \$0.06 per Mile in Peak	An Automatic Vehicle Identification (AVI) scheme would be used to price the regional freeway and arterial system to maintain level-of-service (LOS) D/E.	-1.0%	-0.9%	-3.1%	-10.5%	-2.9%	-2.8%	-2.7%	-1.1%	401
2a Regionwide Employee Parking Charge of \$1.00 Per Day	All workers driving alone in the region would experience a minimum \$1.00 (1991) per day charge for parking at the workplace.	-1.0%	-1.1%	-1.5%	-2.5%	-1.1%	-1.0%	-1.0%	-0.9%	190
2b Regionwide Employee Parking Charge of \$3.00 Per Day	All workers driving alone in the region would experience a minimum \$3.00 (1991) per day charge for parking at the workplace.	-2.5%	-2.9%	-3.8%	-6.0%	-2.7%	-2.7%	-2.8%	-2.5%	558
3a Fuel Tax Increase by \$0.50 (1991)	Fees would be paid at the pump.	-4.1%	-3.8%	-5.5%	-7.0%	-3.2%	-3.9%	-3.8%	-3.6%	497
3b Fuel Tax Increase by \$2.00 (1991)		-13.2%	-12.7%	-17.3%	-20.5%	-31.8%	-13.0%	-12.8%	-12.5%	1494
4a Mileage- and Emissions-Based Fee (Range Approx 40-400/yr)	Fees would average 1 cent per mile, and would be collected frequently, as for the VMT fee in alternative 4a, the fee would be based on annual mileage and average model year emissions as reflected in EMFACTF. In alternative 4b, the fee would be based on actual odometer readings and in-use tailpipe measurements.	-2.4%	-2.1%	-2.9%	-2.5%	-4.9%	-7.5%	-7.4%	-8.5%	148
4b Mileage- and Emissions-Based Fee (Range Approx 10-1000/yr)		-2.0%	-1.7%	-2.3%	-1.5%	-7.6%	-20.1%	-19.7%	-17.5%	131
5 VMT Fee of \$0.02 per mile	Fees would be paid often, e.g., in the same manner as fuel taxes. This implies a potentially complex collection scheme involving real-time reading of the odometer, perhaps each time a vehicle is fueled. The simpler option of billing once a year based on the odometer reading likely would have less effect on travel and emissions.	-4.4%	-4.2%	-5.9%	-7.5%	-4.4%	-4.3%	-4.3%	-4.1%	419
Example of Combined Effects Moderate Impact	1, 2a, 3a, and 4a with maintenance of current transit service.	-8.1%	-7.5%	-12.0%	-19.7%	-16.6%	-13.9%	-13.9%	-11.7%	1134
Example of Combined Effects High Impact	1, 2b, 3b, and 4b with extensive transit investment. (Revenue not reduced to reflect cost of new transit.)	-20.3%	-19.4%	-27.5%	-35.4%	-45.4%	-38.3%	-38.1%	-34.3%	2270

Notes: Revenue expressed in millions of dollars per year. VMT denotes weekday vehicle-miles traveled, VKT is weekday vehicle-kilometers traveled, PM10 is particulate emissions of 10 microns or less; trips are weekday vehicle-trips, time is weekday vehicle-hours of travel, delay is weekday vehicle-hours of delay, fuel is daily gallons of gasoline/diesel, CO2 is daily tons of carbon dioxide, ROG is daily tons of reactive organic hydrocarbons, CO is daily tons of carbon monoxide, and NOx is daily tons of oxides of nitrogen.

**Table 7.14
Analysis Results for the Los Angeles Metropolitan Region - 1991**

	Strategy	Description	Change From 1991 Base							Annual Revenue
			VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO	
1	Regionwide Congestion Parking level-of-service (LOS) - Average \$0.10 per Mile in Peak	An Automatic Vehicle Identification (AVI) scheme would be used to price the regional freeway and arterial system to maintain level-of-service (LOS) D/E	-2.3%	-2.2%	-6.8%	-22.5%	-6.7%	-5.5%	-2.5%	3167
2a	Regionwide Employee Parking Charge of \$1.00 Per Day	All workers driving alone in the region would experience a minimum \$1 00 (1991) per day charge for parking at the workplace	-1.0%	-1.1%	-1.5%	-2.5%	-1.2%	-1.1%	-1.0%	948
2b	Regionwide Employee Parking Charge of \$3 00 Per Day	All workers driving alone in the region would experience a minimum \$3 00 (1991) per day charge for parking at the workplace	-2.7%	-3.0%	-4.2%	-7.5%	-2.9%	-2.9%	-2.7%	2788
3a	Fuel Tax Increase by \$0.50 (1991)	Fees would be paid at the pump	-4.1%	-4.0%	-5.4%	-6.5%	-9.1%	-3.7%	-3.5%	2405
3b	Fuel Tax Increase by \$2.00 (1991)		-13.3%	-12.8%	-17.5%	-21.0%	-31.8%	-13.0%	-12.2%	7219
4a	Mileage- and Emissions-Based Fee (Range Approx 40-4000/yr)	Fees would average 1 cent per mile, and would be collected frequently, as for the VMT fee in alternative 4a, the fee would be based on annual mileage and average model year emissions as reflected in EMFACTF. In alternative 4b, the fee would be based on actual odometer readings and in-use tailpipe measurements	-2.2%	-1.9%	-2.8%	-3.0%	-4.4%	-7.0%	-6.2%	743
4b	Mileage- and Emissions-Based Fee (Range Approx 10-1000/yr)		-1.8%	-1.6%	-2.1%	-1.5%	-7.2%	-19.4%	-17.1%	658
5	VMT Fee of \$0.02 per mile	Fees would be paid often, e.g., in the same manner as fuel taxes. This implies a potentially complex collection scheme involving real-time reading of the odometer, perhaps each time a vehicle is fueled. The simpler option of billing once a year based on the odometer reading likely would have less effect on travel and emissions	-4.4%	-4.2%	-6.2%	-9.0%	-4.5%	-4.2%	-3.8%	2024
	Example of Combined Effects: Moderate Impact	1, 2a, 3a, and 4a with maintenance of current transit service	-9.1%	-8.6%	-15.1%	-30.1%	-19.4%	-16.0%	-12.4%	6627
	Example of Combined Effects: High Impact	1, 2b, 3b, and 4b with extensive transit investment. (Revenue not reduced to reflect cost of new transit.)	-21.5%	-20.7%	-31.1%	-48.1%	-47.8%	-40.1%	-34.9%	11955

Notes: Revenue expressed in millions of dollars per year; VMT denotes weekday vehicle-miles traveled, VKT is weekday vehicle-kilometers traveled; PM10 is particulate emissions of 10 microns or less; trips are weekday vehicle-trips, time is weekday vehicle-hours of travel, delay is weekday vehicle-hours of delay, fuel is daily gallons of gasoline/diesel, CO2 is daily tons of carbon dioxide, ROG is daily tons of reactive organic hydrocarbons, CO is daily tons of carbon monoxide, and NOx is daily tons of oxides of nitrogen.

**Table 7.15
Analysis Results for the San Francisco Bay Area - 2010**

	Strategy	Description	Change From 2010 Base							Annual Revenue	
			VMT/KT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO		NOx
1	Regionwide Congestion Pricing (level-of-service D/E) - Average \$0.13 Per Mile In Peak	An Automatic Vehicle Identification (AVI) scheme would be used to price the regional freeway and arterial system to maintain level-of-service (LOS) D/E	-2.8%	-2.7%	-8.2%	-27.0%	-8.3%	-6.9%	-6.9%	-3.2%	2274
2a	Regionwide Employee Parking Charge of \$1.00 Per Day	All workers driving alone in the region would experience a minimum \$1.00 (1991) per day charge for parking at the workplace	-0.8%	-0.9%	-1.3%	-2.7%	-1.0%	-0.8%	-0.8%	-0.7%	473
2b	Regionwide Employee Parking Charge of \$3.00 Per Day	All workers driving alone in the region would experience a minimum \$3.00 (1991) per day charge for parking at the workplace	-2.1%	-2.4%	-3.5%	-7.0%	-2.4%	-2.3%	-2.4%	-2.2%	1399
3a	Fuel Tax Increase by \$0.50 (1991)	Fees would be paid at the pump	-3.6%	-3.4%	-5.3%	-8.5%	-8.8%	-3.5%	-3.5%	-3.3%	1332
3b	Fuel Tax Increase by \$2.00 (1991)		-11.7%	-11.3%	-16.8%	-25.5%	-30.6%	-11.6%	-11.5%	-11.1%	4053
4a	Mileage- and Emissions-Based Fee (Range Approx 40-400/yr)	Fees would average 1 cent per mile, and would be collected frequently, as for the VMT fee in alternative 4a, the fee would be based on annual mileage and average model year emissions as reflected in EMFAC7F in alternative 4b, the fee would be based on actual odometer readings and in-use tailpipe measurements	-2.2%	-1.9%	-2.9%	-3.6%	-3.9%	-5.4%	-5.3%	-4.5%	384
4b	Mileage- and Emissions-Based Fee (Range Approx 10-1000/yr)	Fees would be paid often, e.g. in the same manner as fuel taxes. This implies a potentially complex collection scheme involving real-time reading of the odometer, perhaps each time a vehicle is fueled. The simpler option of billing once a year based on the odometer reading likely would have less effect on travel and emissions	-1.6%	-1.4%	-2.1%	-2.5%	-6.6%	-17.7%	-17.5%	-14.9%	341
5	VMT Fee of \$0.02 per mile	Fees would be paid often, e.g. in the same manner as fuel taxes. This implies a potentially complex collection scheme involving real-time reading of the odometer, perhaps each time a vehicle is fueled. The simpler option of billing once a year based on the odometer reading likely would have less effect on travel and emissions	-3.9%	-3.7%	-5.7%	-9.0%	-4.1%	-3.8%	-3.7%	-3.6%	1122
	Example of Combined Effects Moderate Impact	1, 2a, 3a, and 4a with maintenance of current transit service	-8.9%	-8.4%	-16.2%	-36.5%	-19.9%	-15.3%	-15.3%	-11.0%	4073
	Example of Combined Effects High Impact	1, 2b, 3b, and 4b with extensive transit investment (Revenue not reduced to reflect cost of new transit.)	-19.5%	-18.9%	-31.1%	-57.7%	-47.1%	-37.9%	-37.9%	-32.0%	7026

Notes: Revenue expressed in millions of dollars per year, VMT denotes weekday vehicle-miles traveled, VKT is weekday vehicle-kilometers traveled, PM10 is particulate emissions of 10 microns or less, trips are weekday vehicle-trips, time is weekday vehicle-hours of travel, delay is weekday vehicle-hours of delay, fuel is daily gallons of gasoline/diesel, CO2 is daily tons of carbon dioxide, ROG is daily tons of reactive organic hydrocarbons, CO is daily tons of carbon monoxide, and NOx is daily tons of oxides of nitrogen

Table 7.16
Analysis Results for the Sacramento Region - 2010

Strategy	Description	Change From 2010 Base										Annual Revenue	
		VMT/VKT/MPM	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx				
1	Regionwide Congestion Pricing (level-of-service D/E) - Average \$0.08 per Mile in Peak	-1.5%	-1.4%	-4.8%	-16.6%	-4.8%	-3.7%	-3.9%	-1.7%				443
2a	Regionwide Employee Parking Charge of \$1.00 Per Day	-1.0%	-1.1%	-1.5%	-2.6%	-1.1%	-1.1%	-1.1%	-0.9%				142
2b	Regionwide Employee Parking Charge of \$3.00 Per Day	-2.6%	-2.8%	-3.9%	-6.5%	-2.7%	-2.8%	-2.8%	-2.6%				419
3a	Fuel Tax Increase by \$0.50 (1991)	-4.1%	-3.9%	-6.6%	-7.0%	-8.3%	-4.0%	-3.9%	-3.7%				414
3b	Fuel Tax Increase by \$2.00 (1991)	-13.2%	-12.7%	-17.6%	-22.0%	-31.8%	-13.0%	-12.9%	-12.5%				1245
4a	Mileage- and Emissions-Based Fee (Range Approx 40-400/yr)	-2.6%	-2.3%	-3.5%	-4.5%	-4.0%	-6.7%	-6.6%	-4.2%				116
4b	Mileage- and Emissions-Based Fee (Range Approx. 10-1000/yr)	-2.3%	-2.1%	-3.3%	-6.0%	-7.4%	-20.2%	-19.7%	-17.3%				102
5	VMT Fee of \$0.02 per mile	-4.4%	-4.1%	-5.9%	-7.6%	-4.4%	-4.3%	-4.2%	-3.9%				349
	Example of Combined Effects Moderate Impact	-8.7%	-8.2%	-14.1%	-26.6%	-17.6%	-13.4%	-13.6%	-9.9%				1018
	Example of Combined Effects High Impact	-21.0%	-20.2%	-30.2%	-46.1%	-46.6%	-39.3%	-39.1%	-34.6%				1922

Notes: Revenue expressed in millions of dollars per year; VMT denotes weekday vehicle-miles traveled; VKT is weekday vehicle-kilometers traveled; PM10 is particulate emissions of 10 microns or less; trips are weekday vehicle-trips; time is weekday vehicle-hours of travel; delay is weekday vehicle-hours of delay; fuel is daily gallons of gasoline/diesel; CO2 is daily tons of carbon dioxide; ROG is daily tons of reactive organic hydrocarbons; CO is daily tons of carbon monoxide; and NOx is daily tons of oxides of nitrogen.

**Table 7.17
Analysis Results for the San Diego Region - 2010**

	Strategy	Description	Change From 2010 Base										Annual Revenue
			VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx			
1	Regionwide Congestion Pricing (level-of-service D/E) - Average \$0.09 per Mile in Peak	An Automatic Vehicle Identification (AVI) scheme would be used to price the regional freeway and arterial system to maintain level-of-service (LOS) D/E	-1.7%	-1.6%	-5.4%	-18.5%	-5.4%	-4.2%	-4.3%	-2.0%	886		
2a	Regionwide Employee Parking Charge of \$1.00 Per Day	All workers driving alone in the region would experience a minimum \$1.00 (1991) per day charge for parking at the workplace	-0.9%	-1.0%	-1.4%	-2.5%	-1.0%	-0.9%	-0.9%	-0.8%	271		
2b	Regionwide Employee Parking Charge of \$3.00 Per Day	All workers driving alone in the region would experience a minimum \$3.00 (1991) per day charge for parking at the workplace	-2.4%	-2.6%	-3.8%	-7.0%	-2.5%	-2.5%	-2.5%	-2.4%	800		
3a	Fuel Tax Increase by \$0.50 (1991)	Fees would be paid at the pump	-3.9%	-3.5%	-5.5%	-8.0%	-9.1%	-3.8%	-3.6%	-3.3%	747		
3b	Fuel Tax Increase by \$2.00 (1991)		-12.5%	-12.0%	-17.1%	-23.0%	-31.3%	-12.2%	-12.2%	-11.8%	2257		
4a	Mileage- and Emissions-Based Fee (Range Approx 40-600/yr)	Fees would average 1 cent per mile, and would be collected frequently, as for the VMT fee in alternative 4a, the fee would be based on annual mileage and average model year emissions as reflected in EMFACTF in alternative 4b, the fee would be based on actual odometer readings and in-use tailpipe measurements	-2.5%	-2.2%	-3.2%	-3.5%	-4.1%	-5.5%	-5.4%	-4.6%	211		
4b	Mileage- and Emissions-Based Fee (Range Approx 10-1000/yr)		-1.9%	-1.7%	-2.6%	-3.5%	-7.1%	-19.6%	-19.2%	-16.2%	186		
5	VMT Fee of \$0.02 per mile	Fees would be paid often, e.g., in the same manner as fuel taxes. This implies a potentially complex collection scheme involving real-time reading of the odometer, perhaps each time a vehicle is fueled. The simpler option of billing once a year based on the odometer reading likely would have less effect on travel and emissions	-4.2%	-4.0%	-5.9%	-8.5%	-4.2%	-4.1%	-4.0%	-3.8%	629		
	Example of Combined Effects Moderate Impact	1, 2a, 3a, and 4a with maintenance of current transit service	-8.5%	-7.8%	-14.2%	-28.4%	-17.9%	-13.4%	-13.2%	-10.1%	1540		
	Example of Combined Effects High Impact	1, 2b, 3b, and 4b with extensive transit investment. (Revenue not reduced to reflect cost of new transit.)	-19.9%	-19.1%	-29.6%	-48.5%	-46.1%	-38.2%	-38.1%	-33.0%	3619		

Notes: Revenue expressed in millions of dollars per year. VMT denotes weekday vehicle-miles traveled, VKT is weekday vehicle-kilometers traveled, PM10 is particulate emissions of 10 microns or less, trips are weekday vehicle-trips, time is weekday vehicle-hours of travel, delay is weekday vehicle-hours of delay, fuel is daily gallons of gasoline/diesel, CO2 is daily tons of carbon dioxide, ROG is daily tons of reactive organic hydrocarbons, CO is daily tons of carbon monoxide, and NOx is daily tons of oxides of nitrogen

Table 7.18
Analysis Results for the Los Angeles Metropolitan Region - 2010

	Strategy	Description	Change From 2010 Base										Annual Revenue
			VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx			
1	Regionwide Congestion Pricing (level-of-service D/E) - Average \$0.15 per Mile in Peak	An Automatic Vehicle Identification (AVI) scheme would be used to price the regional freeway and arterial system to maintain level-of-service (LOS) D/E	-3.3%	-3.1%	-9.7%	-32.0%	-9.6%	-3.1%	-7.9%	-3.6%			7343
2a	Regionwide Employee Parking Charge of \$1.00 Per Day	All workers driving alone in the region would experience a minimum \$1.00 (1991) per day charge for parking at the workplace	-0.9%	-1.1%	-1.5%	-2.9%	-1.1%	-1.0%	-1.0%	-0.9%			1408
2b	Regionwide Employee Parking Charge of \$3.00 Per Day	All workers driving alone in the region would experience a minimum \$3.00 (1991) per day charge for parking at the workplace	-2.5%	-2.8%	-4.2%	-8.5%	-2.7%	-2.6%	-2.7%	-2.5%			4151
3a	Fuel Tax Increase by \$0.50 (1991)	Fees would be paid at the pump	-4.2%	-3.9%	-6.1%	-9.5%	-9.3%	-4.1%	-4.0%	-3.8%			3724
3b	Fuel Tax Increase by \$2.00 (1991)		-13.0%	-12.5%	-18.7%	-28.5%	-31.6%	-12.8%	-12.7%	-12.4%			11235
4a	Mileage- and Emissions-Based Fee (Range Approx 40-400/yr)	Fees would average 1 cent per mile, and would be collected frequently, as for the VMT fee in alternative 4a, the fee would be based on annual mileage and average model year emissions as reflected in EMFACTF. In alternative 4b, the fee would be based on actual odometer readings and in-use tailpipe measurements	-2.5%	-2.3%	-3.6%	-5.5%	-3.9%	-5.5%	-5.4%	-4.5%			1106
4b	Mileage- and Emissions-Based Fee (Range Approx. 10-1000/yr)		-2.1%	-1.9%	-3.3%	-6.0%	-7.2%	-18.9%	-18.6%	-15.8%			980
5	VMT Fee of \$0.02 per mile	Fees would be paid often, e.g., in the same manner as fuel taxes. This implies a potentially complex collection scheme involving real-time reading of the odometer, perhaps each time a vehicle is fueled. The simpler option of billing once a year based on the odometer reading likely would have less effect on travel and emissions	-4.3%	-4.1%	-6.4%	-10.5%	-6.2%	-4.2%	-4.2%	-3.9%			3144
	Example of Combined Effects: Moderate Impact	1, 2a, 3a, and 4a with maintenance of current transit service	-10.3%	-9.7%	-18.9%	-43.0%	-21.5%	-17.1%	-18.9%	-12.0%			12256
	Example of Combined Effects: High Impact	1, 2b, 3b, and 4b with extensive transit investment. (Revenue not reduced to reflect cost of new transit.)	-22.2%	-21.4%	-35.7%	-67.4%	-49.5%	-41.1%	-40.9%	-34.6%			20206

Notes: Revenue expressed in millions of dollars per year; VMT denotes weekday vehicle-miles traveled; VKT is weekday vehicle-kilometers traveled; PM10 is particulate emissions of 10 microns or less; trips are weekday vehicle-trips; time is weekday vehicle-hours of travel; delay is weekday vehicle-hours of delay; fuel is daily gallons of gasoline/diesel; CO2 is daily tons of carbon dioxide; ROG is daily tons of reactive organic hydrocarbons; CO is daily tons of carbon monoxide; and NOx is daily tons of oxides of nitrogen.

8. Equity

8.1 Overview

One of the biggest concerns about strategies that increase the price of transportation is that, while some people would benefit, others could be unduly hurt. Whether from an ethical or a pragmatic political perspective, these equity concerns, which stem from the possibility of unevenly distributed benefits and costs, are a central implementation issue for transportation pricing. Price increases are especially a worry for low income individuals who may not be able to afford the higher costs and hence might be priced out of certain travel options. Higher transportation prices also are a concern for moderate income people who have little flexibility about when or where they travel and hence might have to devote a larger share of their income to transportation.

On the other hand, one would not want to overstate equity issues. First, it might be argued that there is nothing inherently unfair about expecting people to pay for the services they consume, to cover the costs of damage they do to the environment, and so on, regardless of their socioeconomic status. In fact, this could be seen as a more equitable result, since it removes undeserved burdens from others. Second, it is important to note that for many pricing applications, and especially for congestion pricing, the dollar cost is higher for those who pay it, but time and other costs decline, many people should be better off despite the higher prices. Finally, for any of the measures, use of the revenues to improve transportation services could result in net benefits for most. In short, simply noting that prices are higher does not mean that the result is necessarily less equitable.

Nevertheless, it is important to have good information on the distribution of costs and benefits of various transportation pricing strategies, including the status quo, so that the social and political ramifications can be anticipated and dealt with and so that program designs can be structured to achieve a satisfactory level of fairness. While full treatment of the equity issues of transportation pricing would require a separate study, a portion of our

effort was devoted to exploring the impacts of the various pricing strategies on different groups and interests. Indeed, the analysis procedures described here were designed to produce as much information about the distributional consequences of pricing as possible.

8.2 Income and Travel

The distribution of impact and equity can be thought of along many dimensions - income, class, race, ethnicity, age, sex, and geography are among those commonly considered. For the illustrative purposes of this chapter, however, we have chosen to focus our attention primarily on differences by income level. We split the households of California into five household income groups of equal size, and used the resulting quintile boundaries to categorize our findings throughout the analysis of pricing policies. The five quintiles are

Quintile	Household Income Range (1994\$)
1	<= \$18,700
2	\$18,701-\$36,500
3	\$36,501-\$52,100
4	\$52,101-\$71,300
5	>=\$71,301

Tables 8.1 and 8.2 present a distillation of quintile data based on the 1990 U.S. Census Public Use Microdata Sample for California. It may be helpful to begin a discussion of equity by first looking at some basic facts about the distribution of income in California, as shown in these tables.

By definition, each income quintile contains one fifth of the total number of households in the state. But the distribution of household income within the state is uneven, there are notable differences among regions. For example, the San Francisco Bay Area is relatively well off, with 48 percent of its households in the top two quintiles and only 33 percent of its households in the bottom two quintiles. In contrast, the small urban and non-metropolitan

areas of the state have just 29 percent of their households in the top two quintiles and 51 percent in the bottom two quintiles. While housing prices and other cost-of-living factors may cloud the comparison somewhat, it seems clear that the ability to pay higher transportation prices is not distributed evenly around the state, but is higher in its metropolitan areas.

Other important points can be observed by examining the income quintile data. For example, population is not distributed evenly among the quintiles. Higher income households tend to be larger, such that 23 percent of the population is in the highest quintile and 15 percent in the lowest quintile.

Auto ownership increases with income. 53 percent of the vehicles for personal use in California are owned by the top two quintiles, while only 27 percent are owned by the bottom two quintiles. This suggests that policies which cause a general increase in the cost of auto ownership may apply disproportionately to upper income groups.

Households with workers tend to have higher incomes than those which do not. 56 percent of the workers statewide are in the top two quintiles, while only 24 percent are in the bottom two quintiles. This suggests that policies which cause a general increase in the cost of commuting may apply disproportionately to upper income groups.

Autos per worker is consistently high in all income groups. Table 20 shows that quintile 1 - the lowest income group - has the highest auto ownership per worker. This counter-intuitive result is due to the large group of retirees falling into that quintile. Removing the retirees from the data base produces a ratio of autos to workers of 1.25:1 for each of the five quintiles. While this does not have direct implications for pricing policy, it does suggest that access to an automobile for the commute is widely distributed in California.

Drive-alone share for commute travel rises with income. The drive-alone share statewide is about 59 in the lowest quintile and 78 in the highest quintile, with similar variation in each region. Putting the mode shares (including the shared ride data not shown here) together

with the proportion of workers in each quintile, it becomes clear that only about 6 percent of the commute vehicles statewide will have drivers in the lowest quintile, while about 35 percent will have drivers in the highest quintile.

Commute time per worker rises with income. The average self-reported commute trip time statewide is about 22.8 minutes for workers in the lowest quintile and 25.8 minutes for workers in the highest quintile, with similar variation in each region. Because many of the low income workers' miles are made by transit (or by foot) at speeds far below auto speeds, even on congested networks, it is clear that higher income workers' trips must be considerably longer (in VMT) than those of their lower income counterparts. This illustrates a crucial point for pricing studies: higher income workers are the largest contributors to work trip VMT, partly because high income jobs and high-end housing are relatively sparsely distributed around each region.

Both low and high income workers are more likely to work at home. About 3.5 percent of workers in the highest quintile and 4.1 percent of workers in the lowest quintile listed home as the primary place of work in 1990, compared to 3 percent of workers overall. While these phenomena are not well understood, it is said that participation rates by upper income households have been increasing in recent years. This may indicate that upper income households have an important way to blunt the effect of large price increases, namely by choosing to work at home some of the time.

To sum up, the PUMS data demonstrate one of the most important facts about equity of the current transportation system: Truly poor people make relatively little use of the highway system as it operates today and, consequently, would pay comparatively little under most transportation pricing scenarios (in absolute terms, not necessarily as a share of income).

8.3 Equity Analyses Using PUMS and STEP

An unstated implication of the PUMS analysis is that the lower middle class - say, quintiles 2 and 3 - would sustain much of the impact of pricing policies. This hypothesis was explored in a range of analyses using STEP, examples of which are shown in Tables 8.3 through 8.10. The STEP analysis framework allows us to examine equity issues in detail because it utilizes specific demographic information, at the individual household level, that can be associated directly with the effects of each pricing policy.

Table 8.3 presents results for VMT fees in the Los Angeles region at levels ranging between 1 cent and 10 cents per mile. The STEP analysis shows that daily VMT is skewed heavily toward the upper income quintiles - the highest income quintile accounts for about one-third of total VMT, while the lowest quintile accounts for less than 10 percent. Nevertheless, the absolute drop in VMT resulting from a VMT fee is largest in quintile 2 (the second lowest income level) and smallest in quintile 5 (the highest income level). The absolute drop in VMT is of the same basic magnitude in each of the first four quintiles, and the percentage drop is progressively larger the lower the income level. (Percentages are shown in the second part of the table.)

Table 8.4 presents results for congestion prices ranging from one cent to ten cents per mile, on average, for the San Francisco Bay Area. Here we find that absolute VMT decreases are roughly the same among the lowest four quintiles, while VMT for the highest quintile actually rises (as one might expect for high-value-of-time travelers).

Another way to think about equity is in terms of the daily payment by each quintile. Based on Table 8.3, the quintile total payments for a 5 cent VMT fee in the Los Angeles region would be as follows.

Quintile	Daily Payment (million \$)
1	0.9
2	1.8
3	2.4
4	3.3
5	4.5

Out of a daily total of \$12.9 million, 35 percent is paid by the top quintile and 61 percent is paid by the top two quintiles. Similarly, only about six percent of current fuel taxes are paid by members of the lowest income quintile and 10 percent by the second quintile. Thus, while the travel/mobility impact falls disproportionately on the lower income quintiles, the financial burden falls squarely on the upper income quintiles.

Tables 8.5 and 8.6 summarize the results of a parking price analysis for the Sacramento Region. One policy (Table 8.5) focuses the increase on core areas, with a \$5.00 surcharge in the CBD and a \$2.00 surcharge in the immediately surrounding ring. The second policy (Table 8.6) investigates the effect of a \$5.00 parking surcharge applied regionwide. The results suggest that while the regionwide surcharge has a larger overall effect, as one would expect, the spatial and income distributional effects are about the same even though one policy focuses on the core. This is because users of the core represent a cross-section of the region, even though more low income households are concentrated near the core, their use of the system does not expose them disproportionately to the effects of a core-oriented pricing strategy.

It is harder to say how fuel taxes and vehicle emissions fees would affect different income groups, we can estimate impacts on trip making and location choice, and can forecast auto ownership levels by income group, but we have no direct evidence on how the various groups would change the type and age of the vehicles they own in response to new fees. (Our analyses on vehicle type and age changes were based on assumptions provided to the models rather than computed outputs of the models.) Nevertheless, available data do provide some insights into equity impacts. Using data for the San Diego region collected by

Caltrans as part of a statewide travel survey (Tables 8 7 and 8 8), we find that about 63 percent of the vehicles over eight years old are owned by the top three income quintiles, mostly as second, third, or even fourth or fifth cars. The remaining 37 percent of the older cars are owned by the two-fifths of the households with low or moderate incomes. The same is true for VMT in vehicles eight years or older. Thus, to the extent that vehicle registration fees fall most heavily on these older vehicles, they would not fall disproportionately on low and moderate income households (though, of course, the burden on such households will be greater).

We also looked at a number of non-income-based distributional results from STEP (illustrated in Tables 8 9 and 8 10). Here we see that a VMT fee and a congestion fee would impact key ethnic groups in about the same way - and that both impacts track closely the average group incomes (8 9).

Gender-based results (8 10) tell a more interesting story. Women are less exposed to the most heavily congested locations, for a variety of reasons, but overall they travel nearly as much as men and have lower incomes. Thus, a VMT fee falls more heavily on women while a congestion fee falls more heavily on men.

8.4 Implications

The analyses presented here only begin to explore what could be done with existing data sets and models. They are sufficient to show, nevertheless, that lower income households likely would not pay a disproportionate share of the costs imposed by transportation pricing strategies of the sort considered in this study. For many pricing strategies, only a small fraction of total revenues would come from the poor, and the costs would fall most heavily on the wealthiest twenty percent. Furthermore, revenues would be available to offset burdens on the less affluent, should policy-makers decide that equity demands such action.

**Table 8.1: 1990 US Census California Statewide Summary
Public Use Microdata Sample**

Share of Households in Each State Income Quintile

Region	Share by State Income Quintile					Total Households
	1	2	3	4	5	
Sacramento Region	0 22	0 22	0 21	0 20	0 15	598405
San Diego Region	0 19	0 21	0 21	0 20	0 18	885574
San Francisco Bay Area	0 16	0 17	0 19	0 22	0 26	2242554
South Coast	0 19	0 19	0 20	0 20	0 22	4560620
Balance of State	0 27	0 24	0 20	0 17	0 12	1744923
California Combined Total	0 20	0 20	0 20	0 20	0 20	10032076

Share of Population in Each State Income Quintile

Region	Share by State Income Quintile					Total Population
	1	2	3	4	5	
Sacramento Region	0 17	0 21	0 22	0 23	0 17	1560521
San Diego Region	0 15	0 20	0 22	0 23	0 21	2386031
San Francisco Bay Area	0 11	0 15	0 19	0 25	0 31	5852335
South Coast	0 15	0 18	0 20	0 22	0 25	13233643
Balance of State	0 21	0 24	0 22	0 19	0 14	4930037
California Combined Total	0 15	0 19	0 20	0 22	0 23	27962567

Share of Autos in Each State Income Quintile

Region	Share by State Income Quintile					Total Autos
	1	2	3	4	5	
Sacramento Region	0 13	0 19	0 22	0 25	0 21	1080383
San Diego Region	0 10	0 17	0 22	0 25	0 26	1577796
San Francisco Bay Area	0 08	0 13	0 18	0 26	0 36	3941140
South Coast	0 10	0 15	0 19	0 24	0 31	8077199
Balance of State	0 17	0 22	0 23	0 22	0 18	3163821
California Combined Total	0 11	0 16	0 20	0 24	0 29	17840339

Share of Resident Workers in Each State Income Quintile

Region	Share by State Income Quintile					Total Workers
	1	2	3	4	5	
Sacramento Region	0 09	0 18	0 23	0 27	0 23	715029
San Diego Region	0 08	0 17	0 22	0 26	0 26	1145517
San Francisco Bay Area	0 05	0 12	0 18	0 27	0 37	2993791
South Coast	0 08	0 15	0 20	0 26	0 32	6237629
Balance of State	0 11	0 21	0 24	0 25	0 19	2010851
California Combined Total	0 08	0 16	0 21	0 26	0 30	13102817

**Table 8.2: 1990 US Census California Statewide Summary
Public Use Microdata Sample**

Autos per Worker in Each State Income Quintile

Region	Autos per Worker by Income Quintile					Regional Average
	1	2	3	4	5	
Sacramento Region	2.16	1.62	1.48	1.38	1.36	1.51
San Diego Region	1.75	1.37	1.33	1.33	1.36	1.38
San Francisco Bay Area	1.89	1.38	1.30	1.25	1.27	1.32
South Coast	1.75	1.28	1.24	1.23	1.28	1.29
Balance of State	2.37	1.66	1.47	1.37	1.42	1.57
California Combined Total	1.93	1.40	1.32	1.27	1.30	1.36

Work-at-Home Share in Each State Income Quintile

Region	Share by State Income Quintile					Regional Average
	1	2	3	4	5	
Sacramento Region	0.041	0.029	0.030	0.026	0.037	0.031
San Diego Region	0.042	0.033	0.026	0.032	0.039	0.034
San Francisco Bay Area	0.052	0.034	0.030	0.027	0.034	0.032
South Coast	0.035	0.023	0.022	0.022	0.032	0.027
Balance of State	0.044	0.038	0.032	0.031	0.047	0.037
California Combined Total	0.041	0.030	0.026	0.026	0.035	0.030

Commute Time per Worker in Each State Income Quintile

Region	Minutes per Worker by Income Quintile					Regional Average
	1	2	3	4	5	
Sacramento Region	19.17	20.28	21.55	22.89	22.53	21.71
San Diego Region	21.72	21.84	22.28	23.23	23.20	22.65
San Francisco Bay Area	23.24	23.64	25.35	26.20	26.37	25.65
South Coast	25.65	25.30	25.90	26.81	27.28	26.46
Balance of State	18.00	18.70	19.45	20.47	20.26	19.55
California Combined Total	22.84	23.04	24.03	25.20	25.83	24.63

Drive Alone Share for Workers in Each State Income Quintile

Region	Drive Alone Share by Income Quintile					Regional Average
	1	2	3	4	5	
Sacramento Region	0.65	0.71	0.76	0.79	0.77	0.75
San Diego Region	0.62	0.67	0.73	0.77	0.80	0.74
San Francisco Bay Area	0.54	0.61	0.67	0.71	0.73	0.69
South Coast	0.58	0.64	0.70	0.75	0.80	0.72
Balance of State	0.64	0.70	0.75	0.77	0.79	0.74
California Combined Total	0.59	0.65	0.71	0.75	0.78	0.72

Table 8.3
Equity Implications of a VMT Fee in the Los Angeles Region - 1991

VMT Fee (cents/mile)	Absolute Change in Daily VMT by Income Quintile					Total
	Q1	Q2	Q3	Q4	Q5	
1	-1.8	-1.9	-1.4	-1.1	-0.5	-6.6
2	-3.4	-3.7	-2.8	-2.2	-0.9	-13.0
3	-4.9	-5.4	-4.1	-3.3	-1.5	-19.2
4	-6.2	-7.0	-5.5	-4.4	-2.0	-25.2
5	-7.4	-8.6	-6.8	-5.6	-2.6	-31.0
6	-8.5	-10.1	-8.1	-6.7	-3.2	-36.6
7	-9.5	-11.5	-9.3	-7.8	-3.8	-42.0
8	-10.5	-12.9	-10.5	-8.9	-4.5	-47.2
9	-11.3	-14.2	-11.7	-10.0	-5.1	-52.3
10	-12.0	-15.4	-12.9	-11.1	-5.8	-57.3
Base VMT (millions)	25.5	45.0	54.8	71.9	92.8	290.0
Per Capita Daily VMT	11.7	17.3	19.1	22.0	25.8	20.0

VMT Fee (cents/mile)	Percent Change in Daily VMT by Income Quintile					Total
	Q1	Q2	Q3	Q4	Q5	
1	-7.0%	-4.2%	-2.6%	-1.5%	-0.5%	-2.3%
2	-13.3%	-8.2%	-5.1%	-3.1%	-1.0%	-4.5%
3	-19.1%	-12.0%	-7.5%	-4.6%	-1.6%	-6.6%
4	-24.3%	-15.6%	-10.0%	-6.2%	-2.2%	-8.7%
5	-29.1%	-19.1%	-12.4%	-7.7%	-2.8%	-10.7%
6	-33.5%	-22.4%	-14.7%	-9.3%	-3.5%	-12.6%
7	-37.4%	-25.6%	-17.0%	-10.8%	-4.1%	-14.5%
8	-41.0%	-28.7%	-19.2%	-12.4%	-4.8%	-16.3%
9	-44.2%	-31.5%	-21.4%	-13.9%	-5.5%	-18.0%
10	-47.2%	-34.3%	-23.5%	-15.4%	-6.3%	-19.7%

Note: Quintiles defined in terms of 1989 Census household incomes.
VMT is vehicle-miles traveled in millions per day. Sales tax relief,
improved transit, and other potential expenditures to mitigate
impacts on lower income households are not reflected here.

Table 8.4
Equity Implications of Congestion Pricing in the Bay Area - 1991

Average Peak Fee (cents/mile)	Absolute Change in Daily VMT by Income Quintile					Total
	Q1	Q2	Q3	Q4	Q5	
1	-0.2	-0.2	-0.1	-0.1	0.0	-0.6
2	-0.3	-0.3	-0.2	-0.1	0.1	-1.1
3	-0.4	-0.5	-0.3	-0.2	0.1	-1.6
4	-0.5	-0.6	-0.4	-0.3	0.2	-2.1
5	-0.6	-0.7	-0.5	-0.4	0.2	-2.5
6	-0.7	-0.8	-0.6	-0.4	0.2	-2.9
7	-0.8	-0.9	-0.7	-0.5	0.2	-3.3
8	-0.8	-1.0	-0.7	-0.6	0.3	-3.6
9	-0.9	-1.1	-0.8	-0.7	0.3	-3.9
10	-0.9	-1.1	-0.9	-0.8	0.3	-4.2
Base VMT (millions)	7.2	14.0	19.6	30.3	44.0	115.0
Per Capita Daily VMT	10.0	15.3	16.8	19.5	22.6	18.3

Average Peak Fee (cents/mile)	Percent Change in Daily VMT by Income Quintile					Total
	Q1	Q2	Q3	Q4	Q5	
1	-2.2%	-1.2%	-0.6%	-0.2%	0.1%	-0.5%
2	-4.2%	-2.3%	-1.1%	-0.5%	0.2%	-1.0%
3	-6.0%	-3.3%	-1.7%	-0.7%	0.3%	-1.4%
4	-7.5%	-4.2%	-2.2%	-1.0%	0.4%	-1.8%
5	-8.8%	-5.0%	-2.6%	-1.2%	0.5%	-2.2%
6	-10.0%	-5.7%	-3.0%	-1.5%	0.5%	-2.5%
7	-11.0%	-6.4%	-3.4%	-1.8%	0.6%	-2.9%
8	-11.8%	-7.0%	-3.8%	-2.0%	0.6%	-3.2%
9	-12.4%	-7.5%	-4.2%	-2.3%	0.6%	-3.4%
10	-12.9%	-8.0%	-4.5%	-2.6%	0.6%	-3.7%

Note: Quintiles defined in terms of 1989 Census household incomes.
VMT is vehicle-miles traveled in millions per day. Sales tax relief, improved transit, and other potential expenditures to mitigate impacts on lower income households are not reflected here.

**Table 8.5
Employee Parking Price Increases, Downtown and Core Areas Only
Sacramento Region - 1991
Number of Workers Diverted From Drive-Along
By PUMA of Residence and Household Income Quintile**

PUMA Name	PUMA Number	PUMA Residents: Number of Workers Diverted by Income Quintile					All Quintiles
		1	2	3	4	5	
Sutter, Yuba	800	200	223	138	84	41	686
Yolo	1000	867	929	611	458	301	3166
Placer	1100	305	451	413	419	363	1952
El Dorado	1200	142	194	174	150	108	768
Sacramento - Sacramento (Central)*	2801	1632	1940	1278	833	305	5988
Sacramento - Sacramento (East Side)**	2802	670	719	585	421	281	2676
Sacramento - Sacramento (South Side)**	2803	611	812	780	793	640	3636
Sacramento - Rio Linda/North Highlands	2901	244	380	344	284	113	1364
Sacramento - Citrus Heights	2902	220	385	308	270	147	1330
Sacramento - Folsom/Carmichael	2903	148	179	244	262	222	1056
Sacramento - Arden-Arcade	2904	298	499	316	195	198	1506
Sacramento - Rancho Cordova/Rosemont	2905	217	406	337	258	196	1414
Sacramento - Elk Grove/South Sacramento/Florin	2906	125	170	166	175	94	730
Total		5678	7288	5693	4603	3009	26271
Percent		21.6%	27.7%	21.7%	17.5%	11.5%	100.0%

Notes:
 \$5.00/Day Parking Price Increase for Employees Working in PUMAs Marked *
 \$2.00/Day Parking Price Increase for Employees Working in PUMAs Marked **

Table 8.6
Employee Parking Price Increase, \$5.00 Regionwide
Sacramento Region - 1991
Number of Workers Diverted From Drive-Along
By PUMA of Residence and Household Income Quintile

PUMA Name	PUMA Number	PUMA Residents: Number of Workers Diverted by Income Quintile					All Quintiles
		1	2	3	4	5	
Sutter, Yuba	800	1816	2030	1253	761	375	6235
Yolo	1000	2550	2732	1797	1346	885	9311
Placer	1100	1273	1880	1721	1746	1513	8133
El Dorado	1200	1289	1766	1583	1364	979	6983
Sacramento - Sacramento (Central)	2801	2092	2487	1638	1068	391	7677
Sacramento - Sacramento (East Side)	2802	1456	1562	1272	916	610	5817
Sacramento - Sacramento (South Side)	2803	1327	1765	1696	1724	1390	7903
Sacramento - Rio Linda/North Highlands	2901	1015	1583	1432	1183	472	5685
Sacramento - Citrus Heights	2902	916	1604	1283	1126	614	5542
Sacramento - Folsom/Carmichael	2903	619	748	1016	1092	924	4398
Sacramento - Arden-Arcade	2904	1240	2081	1315	814	826	6276
Sacramento - Rancho Cordova/Rosemont	2905	903	1693	1403	1074	818	5891
Sacramento - Elk Grove/South Sacramento/Floren	2906	1138	1542	1510	1589	854	6633
Total		17635	23473	18918	15805	10652	86484
Percent		20.4%	27.1%	21.9%	18.3%	12.3%	100.0%

Table 8.7
Distribution of Vehicles Older than Eight Years
San Diego Region - 1991
By PUMA of Residence and Household Income Quintile

County - Subarea	PUMA	Share of Older Vehicles by Income Quintile					Total
		1	2	3	4	5	
San Diego - Coronado/San Diego	3301	1.8%	2.2%	1.6%	1.4%	1.3%	8.2%
San Diego - National City/San Diego	3302	2.6%	3.1%	2.9%	2.3%	1.0%	12.0%
San Diego - San Diego	3303	1.3%	2.0%	2.5%	2.4%	2.0%	10.2%
San Diego - San Diego	3304	1.0%	1.2%	1.2%	0.9%	1.4%	5.8%
San Diego - Poway/San Diego	3305	0.7%	1.1%	1.7%	2.8%	2.9%	9.2%
San Diego - Chula Vista/Imperial Beach/San Diego	3306	1.6%	2.3%	2.3%	2.2%	1.4%	9.8%
San Diego - Alpine/Ramona/Lakeside	3307	0.9%	1.1%	1.4%	1.5%	1.1%	6.0%
San Diego - Casa de Oro/Lemon Grove/Spring Valley	3308	0.6%	0.9%	1.1%	1.1%	0.7%	4.4%
San Diego - El Cajon/La Mesa/Santee	3309	1.5%	2.1%	2.3%	2.1%	1.5%	9.5%
San Diego - Carlsbad/Encinitas/Solana Beach	3310	0.8%	1.0%	1.4%	1.6%	2.0%	6.8%
San Diego - Oceanside	3311	0.8%	1.5%	1.3%	1.0%	0.7%	5.3%
San Diego - Escondido	3312	0.9%	1.3%	1.3%	1.4%	1.1%	6.0%
San Diego - Fallbrook/San Marcos/Vista	3313	1.0%	1.6%	1.7%	1.5%	1.1%	6.9%
Total	Total	15.5%	21.4%	22.7%	22.2%	18.2%	100.0%

Table 8.8
Distribution of VMT in Vehicles Older than Eight Years
San Diego Region - 1991
By PUMA of Residence and Household Income Quintile

County - Subarea	PUMA	Share of VMT in Older Vehicles by Income Quintile					Total
		1	2	3	4	5	
San Diego - Coronado/San Diego	3301	2.0%	2.2%	1.6%	1.3%	1.2%	8.3%
San Diego - National City/San Diego	3302	2.8%	3.2%	2.9%	2.3%	1.0%	12.1%
San Diego - San Diego	3303	1.4%	2.0%	2.5%	2.3%	2.0%	10.1%
San Diego - San Diego	3304	1.1%	1.3%	1.1%	0.9%	1.4%	5.8%
San Diego - Poway/San Diego	3305	0.7%	1.1%	1.7%	2.7%	2.9%	9.1%
San Diego - Chula Vista/Imperial Beach/San Diego	3306	1.8%	2.4%	2.2%	2.1%	1.4%	9.8%
San Diego - Alpine/Ramona/Lakeside	3307	1.0%	1.1%	1.3%	1.5%	1.1%	6.0%
San Diego - Casa de Oro/Lemon Grove/Spring Valley	3308	0.6%	0.9%	1.1%	1.1%	0.7%	4.4%
San Diego - El Cajon/La Mesa/Santee	3309	1.6%	2.2%	2.3%	2.0%	1.5%	9.5%
San Diego - Carlsbad/Encinitas/Solana Beach	3310	0.9%	1.0%	1.4%	1.5%	2.0%	6.8%
San Diego - Oceanside	3311	0.9%	1.5%	1.3%	1.0%	0.6%	5.3%
San Diego - Escondido	3312	0.9%	1.3%	1.3%	1.3%	1.1%	6.0%
San Diego - Fallbrook/San Marcos/Vista	3313	1.1%	1.6%	1.6%	1.5%	1.1%	6.9%
Total	Total	16.6%	21.7%	22.3%	21.5%	18.0%	100.0%

Table 8.9
VMT Reduction by Ethnic Group
San Francisco Bay Area - 1991

Ethnic Group	Percent Change Resulting From:		Household Characteristics	
	Congestion Price Average \$.05/mile	VMT Fee \$.02/mile	Average HH Income (\$*1000)	Average VMT per Capita (Daily)
Asian	-2.2%	-4.2%	52	18.2
Black	-2.6%	-4.7%	42	16.7
Hispanic	-2.4%	-4.4%	47	17.4
Other	-2.1%	-4.0%	56	19.0
All	-2.2%	-4.2%	52	18.3

Table 8.10
VMT Reduction by Gender
San Francisco Bay Area - 1991

Gender	Percent Change Resulting From:		Household Characteristics	
	Congestion Price Average \$.05/mile	VMT Fee \$.02/mile	Average HH Income (\$*1000)	Average VMT per Capita (Daily)
Male	-2.5%	-4.0%	56	19.4
Female	-2.0%	-4.4%	49	17.2
All	-2.2%	-4.2%	52	18.3

9. Land Use Impacts¹

9.1 Overview

The land use impacts² of transportation pricing have been a matter of some dispute. Economists argue that more efficient transportation pricing would have beneficial land use impacts, producing more efficient land use patterns and inducing more efficient location and travel choices. Many business people, local officials, and citizen groups, on the other hand, fear such changes. Some worry that transportation pricing would reduce the attractiveness of destinations dependent on the auto. Others are concerned that pricing selected facilities or locations, as would be done under certain road pricing and parking pricing proposals, would accelerate movement to unpriced (perhaps underpriced) locations. Many in this latter group also believe that measures such as road pricing or parking pricing could create a negative image that could stymie business, developer, and consumer interest in the affected areas, that land regulations would largely block any higher-intensity center-oriented development that might be proposed, and that continued cross-subsidies of suburban and exurban highway construction and land development would undermine the effectiveness of the pricing strategies.

From a theoretical perspective, all else being equal, any policy that raises the cost of transportation would be expected to produce higher-density land use patterns and a more compact regional development pattern than would occur with lower prices. However, the cost of transportation is appropriately measured not just in terms of dollar costs but time costs as well. Since different travelers value time differently (and indeed the same individual values time spent in travel differently, depending, e.g., on trip purpose and travel

1 Portions of this chapter draw upon an earlier paper by one of the authors (Deakin) which appears as a chapter in Transportation Research Board Special Report 242, **Curbing Gridlock: Peak Period Fees to Relieve Traffic Congestion** (National Academy of Sciences, Washington, DC, 1994).

2 In this chapter we will frequently use the term land use as a shorthand for location, land use, development, and urban form.

conditions), figuring out whether overall costs are higher or lower is not necessarily a simple matter. Moreover, the expenditure of revenues from transportation pricing could make a big difference to perceived costs and benefits, and those affected by pricing could take steps to counteract the costs. These actions in turn could affect the incidence, nature, and magnitude of land use impacts. Sorting out and evaluating the land use effects of transportation pricing is, in short, a complex matter, requiring careful attention to the specifics of the proposals and the context in which they are to be implemented.

Models can help sort out, but are unable to resolve, many of the issues about transportation pricing's land use impacts. For example, the STEP modeling package presented in earlier chapters accounts for some location shifts but not others. Households' choice of work locations and their patterns of non-work travel are modeled for each region, as is the possibility that households will relocate in the face of changes in accessibility, further altering their destination choices. The STEP models do not, however, directly account for possible shifts in the location of workplaces or other commercial activities in response to changes in accessibility, nor do they address the possibility that changes in the efficiency of the transportation system, at least large ones, could alter inter-regional competitiveness and therefore affect the rate of regional growth. While other models have been developed which begin to address the business location and regional growth questions, none was available for application as part of this study.³

³ At the time of this study, none of the four case study regions was using an integrated transportation-land use model. In the Bay Area, the Association of Bay Area Governments (ABAG) used a land use allocation model called POLIS and provided the results to the transportation analysts at the Metropolitan Transportation Commission (MTC). The San Diego Council of Governments (SACOG) used the model DRAM/EMPAL to allocate land uses, but had not directly tied it into its transportation models. The Southern California Association of Governments (SCAG) was in the process of implementing DRAM/EMPAL but had not yet completed the model integration phase, and the Sacramento Area Council of Governments (SACOG) had just embarked on a DRAM/EMPAL implementation effort and was participating in a test of alternative land use models including MEPLAN and TRANUS. None of the regions' land use models incorporated a full set of travel- and price-based measures of accessibility, and all of the regional agencies made adjustments to their land use databases and modeling results based on exogenous information including expert judgment. While none of the regions was able to run their land use models specifically to test the pricing alternatives considered here, they did provide us with their land use databases and forecasts for future years, for use in conjunction with STEP.

What do modeling results tell us about the potential for land use changes in response to changes in transportation pricing? The STEP model applications indicate that, at least within the moderate range of cost increases and travel time changes considered in this study, accessibility changes and the resulting effects on household travel are likely to be small. In turn, this suggests that the impacts on business location are also likely to be small, and that the omission of explicit business location models is not a major limitation for the study, especially when one considers the many other factors besides transportation that affect business location decisions.

Equally important, however, is the recognition that stakeholder concerns about land use changes can be every bit as important as the actual changes themselves. Concerns about land use are often expressed in the context of short-term impacts on current businesses and patterns of development, and are often played out through the implementation of strategies designed to block policies seen as potentially harmful to these interests, or, failing that, to counteract the impacts of such policies. Hence an approach that more directly explores land use concerns through interviews, meetings, and other more interactive approaches is an important complement to modeling.

Developing a better understanding of the location and land use impacts of transportation pricing is important for several reasons.

First, to the extent that changes in land use, development, location, and urban form occur in response to pricing policies, the impacts are likely to vary with the design of the pricing system and the use of the revenues. The developers of transportation pricing programs need information and insights into these potential effects in order to capture benefits and avoid unintended and undesired consequences. They also need some information about the size, scale, and time frame of the impacts in order to assess their overall importance.

Second, anticipated (or feared) impacts on businesses and residents, and their likely travel and locational responses, will be a significant political issue in debates over transportation.

pricing, potentially affected groups may be sources of support or of opposition depending on the impacts predicted. Both the affected interests and the decision makers to whom the interest groups will plead their cases need well-founded information on potential impacts and their likely magnitude and timing.

Third, in a number of metropolitan areas there is concern about growth patterns and economic development and their social and environmental consequences. In these areas the question of the impact of transportation costs and subsidies on urban land uses and development is being debated directly. The assumptions underlying the contrasting arguments need to be clarified and made explicit.

This chapter thus proceeds to examine the probable land use impacts of transportation pricing strategies, drawing on both theoretical work and empirical evidence. The chapter begins with a brief review of the theory of transportation and urban form, focusing primarily on the effects of changes in accessibility on land use and location. We then discuss the many options available to travelers for responding to transportation prices, some of these options may considerably dampen or offset the potential for pricing policies to reshape urban form. Finally, we present the results of interviews with a small sample of business representatives and local government officials in which likely responses to one pricing measure, congestion pricing, were explored. The interviews, although carried out in general terms, indicate that here too a number of options for coping with price changes may be pursued, and at least some of the options could offset the potential for land use and development impacts.

9.2 Theory and Evidence on Transportation - Land Use Relationships

Land use-transportation interactions have been the subject of a long tradition of inquiry, and a strong framework for the understanding of key relationships has emerged. Economic

theories of location and land use are dominant, but sociological and historical theories also offer insights. A brief review of this work is presented here to serve as a framework for later discussions. Also presented are the findings of recent empirical studies of the land use impacts of transit, as well as the results of modeling exercises aimed at improving our understanding of transportation's role in location choice processes.

In broad terms, location theory is premised on the observation that businesses and households select their locations partly on the basis of travel times and costs to key locations (city centers, places of employment, transshipment points, concentrations of potential employee residences, etc.). The location of transportation facilities and transportation technology determine the relative location, or accessibility, of places. Thus land values as well as land uses reflect the relative locational advantages that transportation systems confer.

If transportation costs are changed, the rent gradients change, since land uses and rents for land are tied to each other by market processes, land use potentials are changed. All else being equal, it would be expected that investments that lower the cost of transportation to a center (attraction) would simultaneously reduce the value of land at the center and increase the value at the periphery. Conversely, when transportation costs increase, the price of land close to the center would increase to reflect the value of its accessibility, peripheral locations would be less valuable.

These impacts play out in different ways for residential development than for commercial development. In the case of housing, reduced commuting costs (or times, since time has value) would make it possible for commuters to spend more on housing, travel farther, or both. If, as is usually the case, transportation is cheap relative to housing and one can buy more house per dollar farther from the center, households will have an incentive to live farther away from their workplaces. All else being equal, then, investments in transportation are likely to decrease residential density and increase the size of the urbanized area.

Business location choice will be affected somewhat differently. Although some businesses are tied to particular sites because of needs for special qualities available only there, others can choose where to locate within an urban area by considering the relative costs and benefits of doing business at any particular place. Transportation is one such cost, businesses need access to goods and markets, and their labor costs reflect commuting costs.

If transportation costs are reduced at a particular place, businesses there will be more profitable and better able to expand, other businesses also will find the location comparatively advantageous because of accessibility to metropolitan-wide labor and customer markets, and will seek to locate there. Thus, in theory, businesses will tend to congregate at points where transportation costs are low.

Population-serving businesses, which sell frequently purchased goods and services, are a special case because their competitive edge depends in large part on their convenience to residences. If residences decentralize, these businesses follow, decentralizing this portion of the work force as well. The specific location of these businesses, however, still depends on the relative costs of transportation to alternative locations. A general reduction in shopping trip costs would permit population-serving firms to locate farther from residences and still be convenient to customers. Put another way, firms could attract customers from a wider area and still benefit from lower transport costs for inputs. In so doing, they might be able to lower costs, expand offerings, or both, and perhaps capture economies of scale and out-compete firms in less advantageous locations.

Overall, then, location theory holds that transportation improvements will tend simultaneously to increase employment at benefitted sites and to decentralize workers' housing. However, over time these very changes will stimulate countervailing effects: increased employment will generate demand for housing near the work sites, suburban housing will create a pull for service-oriented employment, and so on.

Although location theory focuses on economic factors in explaining the spatial distribution of various land uses, other theories of urban growth have emphasized historical and social factors and cycles of growth and decline. In one conception, industries located near the waterfront to utilize water transport and the water itself, their activities attracted workers' housing but repelled many other uses. The wealthier classes originally built houses near the center of the city, but as those houses grew obsolete, they chose to build new ones in outlying areas made accessible by new transportation systems. Their old houses filtered down to less affluent classes. Durability of buildings and infrastructure, along with patterns of blocks and ownership of parcels, retarded change in land uses by making land assembly, consolidation, and clearance difficult and expensive. Economies of scale in building made new construction cheaper on vacant land, and this, quite apart from land rents, further spurred suburbanization.

The need for specialized facilities and services (transportation and other), agglomerations that support mutual profitability, forced clustering of nuisances, and constraints working against alternative housing location choices (e.g., lack of money, race and class segregation) also have been identified as factors affecting development patterns. In one conception of urban growth, different activities would locate in distinct nuclei, or subcenters, because of the interplay of these factors. Transportation would exert a different influence over location in the various nuclei because of the different, specialized needs of the occupants.

Simulation models have been developed which draw upon both of these schools of thought in attempting to predict location decisions. The simplest versions of these models predict the locations of jobs and housing within a region as functions of accessibility, land availability, and population and employment levels. More complex models add realistic detail by accounting for such factors as land costs and conditions, building availability and quality, and the quality and cost of local government services, as well as detailed household socioeconomic and life-style descriptors (including the number of workers present, household income, age of household members, presence of children, race and ethnicity, etc.)

Models of this sort confirm what theory claims that decisions on the location of jobs and housing reflect concerns about transport costs. Other things being equal, congestion is associated with a preference for housing closer to work, long commutes are supported by better transport facilities. For the most part, however, these models also show that transport variables are no more critical to location decisions than such factors as housing type, size, and cost suitability, crime rates, and, for families with children, schools. Moreover life-style and life-cycle variations have been found to be equally important as (in some cases, much more important than) transportation as determinants of location and land use choices. Land use is a function of transportation, but it is not a simple function.

Empirical studies of the relationship between the cost of transportation and urban development also have been carried out, but overall, the studies fail to provide a generalizable metric of the role of transportation in land development. Instead, they point out that the effects of transportation investments vary with the specifics of the case and must be considered in the broader implementation context. Most of the highway studies have found that highway investments are but one factor in a larger growth and development equation, studies of transit have reached similar conclusions. Moreover many studies have concluded that measured changes in development levels are interregional shifts rather than changes in overall development levels.

Environmentalists sometimes argue that it is precisely this shift that is of concern, particularly if development is induced by transportation improvements that make possible more trips, longer trips, or relocation from high-density areas in which many trips would be made by foot or transit to low-density areas heavily dependent on the automobile. Among metropolitan planning organizations, scenario testing exercises and a few modeling efforts using real data have explored this issue sufficiently to support the conclusion that shifts could occur sufficient to offset at least some initial travel and environmental benefits of transportation investments. But the magnitude of the effect remains unclear, and controversy continues over when and to what degree a transportation improvement will induce trips, shift modes, and alter destination choices - or for that matter, when and to what

degree worsening conditions (whether from congestion or higher dollar prices) might do the same

For both highways and transit, many of the studies suffer from methodological and other limitations, including low explanatory power for observed correlations, difficulty in distinguishing cause and effect, failure to distinguish economic shifts within a region from investment-induced growth, and double-counting of benefits. Few have been scoped broadly enough to identify possible shifts in production processes and changes in economic and social organization that might occur as a result of important new transportation investments. Nevertheless, the studies offer useful insights. Overall, they find that transportation availability and quality are factors in location and development, but investments - at least the modest investments typical of today's transportation programs - will do relatively little absent other critical factors including appropriate land, labor, and capital. They also point to the difficulties in identifying and measuring the impact of transportation projects in real-world contexts.

To sum up, then, location theory, other theories of urban development, empirically estimated models of land use-transportation interactions and location choice, and case studies and statistical analyses of transport impacts all provide useful insights about transportation and urban form but no clear, singular findings concerning likely impacts. This wide-ranging body of work suggests that, all other things being equal, transportation investments that lower the costs of travel should decentralize housing and centralize employment but at the same time stimulate countervailing pressures for housing near the employment center and for service employment near housing. Conversely, worsening transportation services will favor decentralization of jobs but support higher densities of housing in more central locations, although the relationships are not a simple mirror image because of precedent conditions in the developed areas.

Moreover, the empirical work points out that many other factors may be equally as important as transportation, or more so, in location and land use decisions. Overall, then, the impacts of transportation projects on land use and urban form must be considered in

context with full recognition of the complexity and contingent nature of the phenomena being considered

9.3 Transportation Pricing, Travel Behavior, and Land Use Impacts

Transportation pricing strategies may affect land use and development in the short to medium run by inducing changes in travel behavior, particularly changes in trip generation rates and trip destination choices. Transportation pricing strategies may have even larger impacts, affecting the structure and physical size of the region, by affecting longer-term location decisions. The potential for these effects will vary with the specifics of the pricing strategy as well as with the ways in which pricing revenues are used, in particular, whether and what kind of infrastructure investments are pursued.

Table 9 presents a general overview of the possible land use and location impacts of the five transportation pricing measures considered in this study. Table 9.2 summarizes key impacts measure by measure, and Table 9.3 comments briefly on how these impacts might differ based on the salient characteristics of each of the four case study regions. In this section, these potential impacts are reviewed in greater depth, with congestion pricing used as the chief example because of its greater likelihood for location-specific implementation and impacts.

Traveler Responses

The introduction of new transportation pricing policies is likely to elicit a variety of traveler responses, some of which could have significant impacts on land use and urban form. However, the effect will be different depending on the traveler's income and the importance the traveler places on particular trips, as well as the degree of flexibility or constraint the traveler faces, including coordination requirements both at home and at work.

Consider congestion pricing affecting a major travel corridor. As noted earlier, congestion pricing is a complex policy to evaluate because it is not a straightforward matter to determine the change in costs resulting from implementation. In most cases some travelers will face higher generalized costs - money plus travel time - whereas others will find their overall time plus dollar costs reduced. Travelers whose time is worth more to them than the congestion charges will be better off, this group includes both current travelers and those who are now deterred from making particular trips because the peak-period (congested) time costs are too high. (This latter group would include certain high-income travelers and others of more modest income with regard to high-value trips such as airport access.) These travelers not only will continue pre-congestion-pricing travel behavior, but also may make more or longer trips, or both, in response to the improved level of service.

Other travelers will find that it is not worth it to them to pay the price for a particular trip. They may find that they have no choice but to make the trip anyway if the travel choice is highly constrained or the alternatives are unacceptable. Or they may be able to continue their current level of trip making by finding a way to offset the charges, using a different (less congested or unpriced) route, switching modes, or making the trip at a less congested (less costly) time. Alternatively, they may change their trip frequency, their destination choice, or even their location choice to avoid the charges.

Not all these options are likely to affect land use significantly. For example, a change in the time of day a trip is made, all else being equal, is unlikely to affect land use at all. One can imagine instances in which congestion levels along an arterial would make a difference in the attractiveness of a shopping destination, or where hours of operation could be affected by travel and traffic shifts, but in most cases such impacts surely would be minor. In contrast, changes in destination choice and trip frequency resulting from transportation congestion pricing could affect the relative competitiveness of different locales, which in turn could lead to changes in businesses' choices of whether or where to locate, expand, or move.

Impacts will also vary by trip purpose. Shopping trips are more price-elastic than work trips and so may be affected more (to the extent that they are affected at all, i.e., to the extent that they occur during the peak in congested areas). Impacts and responses will further vary by level of congestion, for example, it is harder to shift trips out of the peak if that peak lasts several hours than if the peak lasts an hour or less.

It is not always the case that congestion pricing on a particular facility will predominantly affect a specific place. (Here parking pricing clearly has a substantially different impact.) For congestion pricing, whether a locationally distinct impact would occur would depend on whether the congestion-priced route is critical to a specific place (or strongly identified with it, to the extent that perceptions are driving decisions). For example, although I-80 runs the entire length of Berkeley, CA's bay front, only a small percentage of the trips to, from, or within that city use I-80, and only a small percentage of I-80 traffic has a Berkeley trip end. Congestion pricing on this stretch of I-80 might well have a greater impact on San Francisco and Oakland than on Berkeley itself. Similarly, congestion pricing of the San Francisco-Oakland Bay Bridge might have as much employment impact on South San Francisco, some miles away, as on downtown San Francisco, because the South San Francisco employees are highly automobile dependent, whereas downtown employees are not.⁴

Finally, impacts will vary by whether congestion pricing is used only on one or a few facilities or is widespread (hence whether a route choice option is available), by whether the price varies across facilities (less shifting of locations should occur if the price variation is low), by whether there are competitive transportation alternatives, by whether there are competitive alternative destinations, and undoubtedly by many other factors.

⁴ Because of the complexity of the interactions involved, models are needed to trace impacts of route choice and locational impacts through the transportation-land use system.

The point is that both high-income and modest-income travelers can respond to congestion pricing in a variety of ways, some of which may redistribute or otherwise alter the level of activity at particular destinations, others of which would have little or no effect

Land Use Impacts Resulting from the Use of Pricing Revenues

How the revenues generated by a pricing strategy are used could substantially alter the strategy's land use impacts. Some projects funded by pricing revenues could themselves have land use impacts every bit as substantial, or perhaps more so, than those of the pricing strategy itself. Others would have negligible impacts on land use and urban form.

For example, using the revenues for transportation projects and programs would have far different impacts than using the revenues to augment the general fund, reduce other taxes currently paid by affected parties, or fund enforcement activities. The specific type of transportation investment chosen also would make a substantial difference in the type and magnitude of land use impacts likely to occur. Clearly, using the revenues to add transportation capacity would have a different effect than using the revenues to finance commute allowances or fund traffic calming programs for affected neighborhoods. Furthermore, increasing capacity by removing a bottleneck on a priced facility would be far different from increasing capacity by building rail transit.

It seems likely that numerous claims will be made on the revenues from transportation pricing, some by people and in places that perceive themselves to be disadvantaged by the price changes. For example, owners of businesses in centers that experience (or perceive) increased costs of accessibility due to congestion pricing (or parking surcharges) may seek to have pricing revenues invested in new facilities or expansions to existing facilities in order to improve their access. Alternatively, the affected areas might seek the revenues to fund alternative means of transportation access. Such uses of the revenues, if wisely done, could return accessibility to former levels, reducing the potential for direct land use impacts from the pricing strategies. At the same time, the new transportation investments

themselves could alter the relative attractiveness of the places they serve, alter travel behavior, and through by doing so alter land use patterns

9.4 Potential Responses of Business and Local Government

Just as travelers have a number of options in their response to transportation pricing measures, both business and local government could respond to transportation pricing strategies in a variety of ways, some of which would affect land use. To explore what responses might be considered, interviews were conducted with a small sample of elected officials, senior planning staff, business representatives, and development interests in the San Francisco Bay Area. We focused on congestion pricing in the interviews because congestion pricing ordinarily would be implemented in some locations but not others, and hence could have location-specific impacts on land use.⁵ In contrast, other transportation pricing measures (fuel tax increases, VMT fees, vehicle emissions fees) are likely to be implemented throughout a region, and while they all could result in higher densities and a more compact growth pattern, their location-specific impacts would be quite limited.⁶

We selected the Bay Area for the interviews because congestion pricing had been fairly widely discussed there at the time of the study, and hence many business and local government representatives were already familiar with the concept and knew the general outlines of the debate. Discussions of pricing strategies were not as far along in the other

⁵ As illustrated by the measures analyzed in earlier chapters, certain forms of parking pricing also would have location-specific impacts, other forms could be region-wide

⁶ VMT fees and gas tax increases could, of course, further reduce the attractiveness of areas with low regional accessibility, they also could have a somewhat larger than average effect on places which produce or attract very long trips - typically communities at the metropolitan fringe, central business districts, regional shopping centers, and certain other large employment centers. Vehicle emissions fees are not likely to have much location-specific land use impact at all - except to the extent that dirty cars, and heavy emissions from them, may be concentrated in certain neighborhoods or districts (in which case both benefits and costs would be concentrated there)

regions, so that interviews there would have been much more prone to "first impression" reactions

Four scenarios were discussed involving congestion pricing on different types of facilities and with alternative routes

- o Specific "gateway" facilities with no significant alternative routes (for example, the San Francisco-Oakland Bay Bridge)
- o Targeted limited-access facilities with comparable facilities not subject to congestion pricing (for example, Route 101 and I-280 on the San Francisco peninsula)
- o Targeted limited-access facilities with alternative routes via surface streets (arterials) (for example, I-80 and San Pablo Avenue along the East Bay shore)
- o All facilities as necessary (both limited-access facilities and surface streets may be priced)

In each case the respondent was asked what impacts might be anticipated and what his or her organization might do in response if such a congestion pricing strategy were implemented rather than whether he or she agreed that congestion pricing was necessary or desirable. Costs in the scenarios were approximately \$0.08/mi to \$0.10/mi except for the Bay Bridge, for which a toll of \$3 to \$5 was assumed.⁷

Altogether, 18 interviews were completed.⁸ Seven of those interviewed were representatives of businesses: two small business owners, one in downtown San Francisco

⁷ The Bay Bridge, 8 miles long including approaches, currently is tolled westbound only

⁸ Two other persons declined to be interviewed, even on a confidential basis, because they believe the topic is highly sensitive and the possibilities for misunderstandings are great. Eight of those interviewed asked that their comments not be for attribution. Because of such concerns, none of the respondents are identified except by general job title.

and the other in Emeryville, a representative of a large business headquartered in downtown San Francisco, a representative of a manufacturing concern in South San Francisco, a representative of the trucking industry, and two representatives of retail businesses. Five more were local elected officials, and five were local agency staff in planning and redevelopment departments. In addition, a representative of a union representing blue collar manufacturing employees in San Francisco and south San Francisco was interviewed. Although this sample obviously cannot support statistical analysis, the findings of the interviews, summarized below, are nevertheless revealing of some of the land use issues that may arise with congestion pricing proposals. Overall, both businesses and local officials indicate that they would pursue strategies that could compensate for the effects of higher transportation prices. Some of these strategies appear likely to be beneficial, others could be counterproductive. Almost all would be designed to preserve jobs and amenities thought to be threatened by the pricing strategies.

Potential Business Responses

A consistent reaction to the congestion pricing scenario involving only the Bay Bridge was that it would not affect a very large share of any one firm's employees (estimates of the share of employees coming from the East Bay ranged from 5 to 30 percent, some of whom cross the bay on another bridge or commute by transit, estimates of Bay Bridge users ranged from 2 to 10 percent⁹). Therefore, the respondents reasoned, few firms would find it necessary to do much to counter the effects of congestion pricing as an overall policy response. If congestion pricing were more widely implemented (i.e., on many facilities rather than on only one or two), respondents believed that it would be more likely to have an impact on location decisions and land uses, in particular on marginal uses in outmoded facilities.

⁹ These estimates are roughly compatible with Bay Area travel data.

Several respondents commented that for businesses most directly affected by congestion pricing, the size of the labor market could shrink unless higher wages were paid to offset the transportation cost premium. Only one respondent noted that time savings also would accrue to those who chose to pay the higher price. In contrast, half the respondents commented that those who could not afford the higher toll would have to use transit, which was seen as no faster than congested auto routes and fairly expensive in comparison to auto operating costs. For those who hire numerous low- to moderate-income workers, this was seen as potentially making the businesses noncompetitive. Employers of higher-income workers saw this as much less of an issue.

As the discussion progressed, however, several of the respondents altered their opinions on the potential severity of impacts. In particular, as they considered the matter further, several respondents lowered their estimates of impact on lower income workers. Many other factors were thought to make the impact on lower-wage workers a smaller reason for concern than it might have appeared at first glance, for example, low- to moderate-income workers generally are more likely to live nearby, commute by walking or transit, and so on.

Several respondents suggested that case-by-case adjustments for individuals who are adversely affected might be necessary or appropriate. For example, employees facing an expensive commute and who either lack reasonable transportation alternatives or cannot make use of such alternatives for some reason (e.g., the need to transport children on the way to and from work) might be allowed to

- o Change work start and end times to avoid the peak,
- o Change to a different shift (manufacturing jobs), or
- o Work at home some or even most of the time

Two of the employers thought that to avoid their becoming excessively entangled in their employees' travel decisions, congestion pricing might lead them to implement a commute allowance to replace current parking and transit subsidies. One speculated that it might be necessary to raise the current parking subsidy in order to offset the added costs of tolls.

Respondents, speaking generally, acknowledged that transportation is only one factor in business location decisions, and its importance varies with characteristics of the business, for many, costs of building ownership or leasing arrangements, taxes, crime rates, and the general business climate and image of a location are more important considerations. However, the respondents also noted that a number of businesses are located in places that are suboptimal under current conditions, in buildings that are outmoded, in labor markets that are costly, and so forth. Higher transportation prices due to congestion pricing could be the final straw for these businesses, forcing them to look for another location or even to close their businesses altogether. Most respondents believed that the impact would be greatest on industrial and retail uses rather than office employment, which they saw as already relatively footloose.

Companies that are adversely affected may not move initially because the costs of moving at that time may be too high. But the same firms may choose to expand elsewhere, relocate, or both, after the useful life of facilities is used up or a long-term lease expires. Hence some congestion pricing impacts may lag implementation by years.

One business representative with many highly paid workers believed that congestion pricing would be a major benefit, producing time savings for travelers, less stress, greater scheduling flexibility, and higher productivity. He argued that congestion has deterred some firms from locating in places like downtown San Francisco and that congestion relief due to pricing should remove a barrier to these firms, stimulating growth. He also argued that the revenues from congestion pricing, if used to improve congested facilities or to provide improved commute alternatives to those who are priced off, could result in an overall improvement in accessibility of the priced areas, and perhaps to an eventual lowering of the price charged.¹⁰ He saw the loss of certain marginal firms as inevitable and overall positive for the region, despite the likely hardship for some individuals.

¹⁰ Most others discounted this possibility, seeing it as "theoretically possible, but not likely in practice."

The impact of congestion pricing on trucking was deemed a major concern. Two of the respondents argued that truckers should find that congestion reduction more than offsets the congestion price, or that truckers should be able to avoid peak-hour charges by careful scheduling. Nevertheless, most business representatives believed that they would see congestion prices passed on through higher trucking fees. One business leader argued that large businesses could avoid paying truckers' congestion charges by scheduling deliveries and pickups to avoid peak hours and peak prices, however, smaller businesses (and truckers) have less flexibility in scheduling, so the impact would fall most heavily on these "small guys." Truckers offering just-in-time services also were thought to be likely to find peak-period travel unavoidable. The "lack of options" argument appears to be a persuasive one, for this reason, the majority of the respondents believed that truckers would seek exemptions from pricing and would likely be granted such exemptions, regardless of the benefits they would also be capturing.¹¹

Potential Local Government Responses

Just as private actors may attempt to counteract real or perceived declines in accessibility (increases in general costs), shrinkage of markets, or both, by using a variety of strategies, local governments can be expected to take action to protect their tax bases and constituencies. Among the means to do so that are commonly available to local government (depending on individual state laws) are land use regulations, redevelopment powers, the ability to create special districts, and the authority to tax and spend.

¹¹ Indeed, some trucking interests have suggested that they be given a discount or otherwise exempted from any congestion pricing policy for the Bay Bridge, claiming it could adversely affect their just-in-time services - despite the obvious economic value of the time savings that should accrue to them from reduced congestion.

Interviews with local government officials made it clear that they are well aware of these options and would consider exercising them. For example, planners noted that if the central business district were perceived to be adversely affected by road pricing, their local officials, or the affected businesses themselves, might decide to provide free parking to offset the cost of the road price. Or, if it is assumed that many of those affected will switch to transit, a convenient circulator bus or transit shuttle might be provided. In a deregulated ground transportation environment this might stimulate van and jitney services, but in the far more common restricted-entry situations, a shuttle probably would entail either government financing or funding through an assessment district or business association.

Attempts to offset perceived negative impacts of transportation congestion pricing are more likely in areas that have experienced difficulties in business retention and attraction (and among businesses that have experienced labor shortages or customer losses). City officials who commented on this matter argued that in a strong real estate market very little organized public or private response might be generated, on the assumption that there will be plenty of takers for available space (or jobs, or goods and services) even if some are pushed out by the impact of congestion pricing. In a weak market, however, local business people would almost certainly seek help to offset pricing impacts, and local officials would be sympathetic to their concerns and likely would look for ways to be of assistance.

City officials also expressed concerns about pricing strategies that would lead to increased traffic on arterials under their control, for example, traffic diverted from a priced limited-access facility. They would expect to be compensated for the added costs of handling such traffic and, in some situations, for additional traffic mitigation, especially if residences or retail uses abutted the affected streets. Off-street parking to replace removed on-street spaces, improved transit services and stops, improved sidewalks, trees and other landscaping, and better signalization might be demanded by localities should traffic diversion occur. On the other hand, there were mixed reactions to the prospect that traffic levels might decline on parallel arterials if they too were priced. Some believed that this would be an improvement, others worried that reduced traffic could cut down business activity.

With regard to possibilities for increased development, local government officials were somewhat skeptical. They noted that current land use regulations often limit market responses to transportation system changes, in some cases for very long periods. They acknowledged that some increases in density or changes in use could occur under current zoning through increased occupancy rates, shifts to higher-intensity allowable uses, and so on, but cautioned that in many areas, higher density and change in use may be substantially limited by restrictions on height, bulk, or use, by other development regulations, or simply by delays encountered in areas where development proposals often arouse strong political opposition.

Several of the respondents noted that their responses to congestion pricing were unlikely to be justified from an economic perspective and indeed that in some cases their responses were internally inconsistent. They nevertheless argued that proponents of congestion pricing would need to make the benefits visible and widespread in order to secure the allies they would need for implementation of pricing strategies.

9.5 Conclusions

Currently, some travelers undoubtedly would be willing to pay more to travel than they currently do, some presumably are being priced off the system by congestion (travel time) rather than dollar costs. Other travelers are using the roadways, making certain trips, and indeed living and working where they do in large part because travel costs as little as it does, at least some of these individuals would not be willing - or able - to pay more.

Given this heterogeneity in the travel markets and the evidence that there is considerable differentiation in traveler characteristics within particular travel corridors, it is difficult to say unambiguously and generally how pricing might affect location, land use, development, and urban form. Although in general, policies that increase the cost of transportation to an

employment center would simultaneously raise land prices and concentrate development there, many other factors must be considered, including the presence of specialized subcenters, land use regulations that retard market-driven changes, and the slowness of response in land use changes even when government policy does not discourage them (e.g., obsolete uses persist at sites for decades, even when land use changes would be highly profitable). Hence higher densities and more compact growth are a possible outcome of transportation pricing, but specific proposals, their impacts on accessibility, their interaction with land and labor markets, and the prospects for land use change in specific places all would have to be considered before reaching a firm conclusion.

Although increased economic and social differentiation of places could be one outcome of transportation pricing, and in particular congestion pricing, such changes could be greatly slowed by resistance to change or compensatory policies implemented by government or the private sector. Exploratory interviews conducted for this study, although limited in scope and extent, indicate that both government and business would be likely, at least in the short to medium run, to take action to offset perceived adverse impacts resulting from higher transportation prices. Such actions might range from providing travel allowances to increasing the subsidy for parking, shifting work schedules to avoid the peak periods, and subsidizing certain land uses or businesses. Impacts on land use would be moderated by such interventionist actions.

Table 9.1: General Impacts of Transportation Pricing Measures on Location and Land Use

- Any measure that increases the real generalized costs of travel (time, money) will reduce the accessibility of the affected areas.
- Conversely, any measure that reduces generalized travel costs (time, money) will increase accessibility
- Measures that increase generalized costs for auto users are likely to result in shifts to alternative modes, use of vehicles with lower operating costs, choice of closer destinations for shopping and other activities, and perhaps less overall tripmaking
- Measures that increase the generalized costs of certain auto routes are likely to result in route choice changes if other routes are available and competitive
- Over time, residents are likely to choose housing closer to work, and work closer to home Centers (downtown or other) that offer greater choices in mode, shopping options, work and housing types, etc. will be advantaged
- Locations with higher accessibility are likely to have higher land values, which will partly offset the location effect
- To the extent that drivers make unscheduled stops along their routes, diversion of traffic could have some impact on destination choices

Table 9.2: Key Location and Land Use Impacts of Transportation Pricing Measures

Measure	Impacts
Congestion Pricing	<ul style="list-style-type: none"> - Impact depends on relative time savings in response to dollar costs. Since value of time varies by trip purpose and traveler characteristics (especially, but not necessarily only, income), case by case impact analysis is - Work trips and certain other business travel (e.g., airport access) are generally higher value than non-work trips, so non-work travel is more likely to be diverted to other times of day, modes, or destinations - Impacts on specific areas must be determined case by case since pricing a congested facility will affect the areas served by that facility, not necessarily the areas through which it passes (depends on amount of through vs. local traffic)
Parking Pricing	<ul style="list-style-type: none"> - Impact depends on whether price increase is uniform across the region (e.g., a surcharge or tax) or is levied in some areas but not others - Impact is likely to be larger in areas where parking is currently free of charge than in areas that charge for parking (generally downtown areas) - However, since 90-95% of the travel zones offer free parking, the main effect will be a reduction in the attractiveness of auto-dependent areas
Fuel Tax Increases	<ul style="list-style-type: none"> - Unless implementation occurs differentially within the region, the main location and land use impacts will be the general ones described above
VMT Fees	<ul style="list-style-type: none"> - Same as for fuel tax increases
Emission Fees	<ul style="list-style-type: none"> - Same as for fuel tax increases

Table 9.3: Transportation Pricing Impact Differences Among Case Study Regions

Location	Difference
Los Angeles	<ul style="list-style-type: none"> - LA has the largest share of congested routes of the four regions, so congestion pricing could apply to more areas than in other regions
Sacramento	<ul style="list-style-type: none"> - Parking pricing is currently limited to the CBD (in the other regions, parking pricing is used in other subcenters to some extent), so the Sacramento CBD would benefit somewhat more from parking pricing elsewhere in the region - Fast, low density growth in outlying areas is expected to result in congestion levels comparable to those of the other regions by 2010, transportation pricing, especially congestion pricing, could provide market signals for more efficient land use
San Diego	<ul style="list-style-type: none"> - This region has adopted land use plans focusing development on centers, the land use plans would be supported by pricing strategies
Bay Area	<ul style="list-style-type: none"> - Higher levels of transit in central parts of the region make mode choice a more realistic alternative for many, the availability of mode choice alternatives may reduce land use / location impacts of pricing - Parking charges are in place in a somewhat higher percentage of subareas than in other regions, new or additional parking charges would have less impact in this region than elsewhere - Highly congested bridges for which there are essentially no alternative routes could lead to comparatively high mode shifts, time of travel shifts, and location shifts with congestion pricing - Key bridges are congested and lack alternative routes, congestion pricing of these bridges could result in relatively high shifts in mode, destination choice, and location choice compared to other regions

10. Politics and Public Opinion

10.1 Overview

What are the chances that transportation pricing strategies of the sort considered in this study would be accepted by the public? In more general terms, can such changes in transportation pricing be implemented? To explore the issues and examine citizen reactions to the measures, we held nine consumer discussion groups ("focus groups") in the Bay Area, Los Angeles, San Diego, and Sacramento. In addition, we carried out a series of interviews and participated in a number of small group meetings to obtain feedback from state and local agency staff members, elected officials, and representatives of the private sector. The results indicate that some transportation pricing strategies would be more acceptable than others, that matching the strategy to local conditions will be important, and that clear commitments about uses of pricing revenues will be a necessary prerequisite to public support.

This chapter describes the approach utilized and the major findings from the focus groups and interviews, and identifies several issues that designers of transportation pricing measures and programs would need to address.

10.2 Focus Groups: Research Approach

Focus groups are a useful method for eliciting citizen opinions and preferences and obtaining reactions to proposals. (See, e.g., Krueger, 1994.) The method is widely used in marketing studies for consumer goods and as a preliminary step in the design of surveys and polls. The number of participants in each group is kept small so that in-depth discussion can take place. Usually, the sessions are held in small conference rooms with a one-way mirror, behind which observers may watch the proceedings. The sessions also are

taped in most instances. Participants are informed that they are being observed and recorded, but the unobtrusive manner in which this is done rarely poses a problem. Only first names are used in the sessions themselves, and participants are informed that the results are for research purposes only and their anonymity will be preserved.

A focus group session typically begins with a brief presentation which is followed by open and participatory discussion of a set of questions (usually not more than 6-8). Open ended questions may be coupled with one or two "straw polls" or "votes", usually at the beginning of the session as a way of breaking the ice and getting the discussion going, and/or at the end of the session to sum up. The discussion leader or moderator's job is to keep the conversation going, assure that each question is addressed, encourage participation from all group members, and if necessary smooth over disagreements or redirect a discussion that begins to stray from the topic.

Most sessions are limited to 1 1/2 - 2 hours. With a few exceptions, the results are not statistically representative - the overall number of participants, even from a series of focus groups, is usually fairly small, and participants are not necessarily selected to be representative of the population as a whole. However, the material gathered from a successful focus group is richly informative and provides considerable insight on the way citizens think about the topic presented them.

For this project, eight focus groups were held in November 1993, two each in Sacramento, San Diego, Los Angeles (Encino), and the Bay Area (San Jose). A ninth focus group was held later (in April 1994) in Berkeley. In total, 100 people participated in the sessions.

Each focus group consisted of 8-13 participants. The first eight focus groups were recruited at their homes using a telephone survey. The ninth focus group was recruited at San Francisco workplaces using flyers and intercept recruiting, and consisted of persons who worked in San Francisco and lived in the East Bay, crossing the Bay Bridge at least twice a week during peak periods.

For each focus group, the recruitment screening questions were designed to produce a group with experience in commuting and auto operation. Criteria included

- no recent participation in a focus group
- a mix of men and women
- a mix of racial and ethnic groups
- a mix of incomes
- working age - no one under 18 or over 65
- must work at least three days a week
- must commute by car at least part of the time

Respondents who met these criteria were invited to participate in a group discussion of transportation strategies for alleviating congestion, air pollution, and petroleum dependence, and if they agreed, arrangements were made for their attendance at a session. A modest honorarium was offered for participation.

Two hours were allotted for each session. During the first half hour, participants signed in and were offered a light meal. They then were seated, and the moderator began with introductions and a brief discussion of ground rules. The moderator then made a brief (10 min) presentation on transportation problems and possible strategies to address those problems, including pricing. The ensuing group discussion lasted approximately 1 hr 30 min.

Participants first discussed the importance of congestion, air pollution, and petroleum dependence as problems, to them personally and as social issues. Each group then spent about an hour discussing one of four strategies: congestion pricing, vehicle registration fees, fuel tax increases, or parking pricing.¹ The groups spent the final twenty minutes discussing the other pricing strategies and their overall reactions to these proposals.

¹ At the time the focus groups were carried out, these four strategies were being considered. We later narrowed the vehicle registration fee strategy to focus on emissions, and added a VMT fee strategy.

Because of the complexity of the topic, a detailed script was prepared for moderator training and practice sessions. The moderators' presentations generally followed the script but were not tied to it word-for-word. A combination of story boards and graphics were used in the various sessions to illustrate the options being described. Moderators did explicitly utilize the list of questions prepared for the groups. (Both the presentation script and the set of questions are included in an appendix.)

10.3 Focus Group Findings

No consumer loves the idea of a price increase, still, many members of the public agree that good transportation and a better environment are worth paying for. Focus group members were no exception. Most were willing to consider higher transportation prices if they could be sure of two things: 1) that the funds raised would be devoted to transportation improvements, and not diverted to other uses, and 2) that the agencies in charge of the funds would be held accountable for providing real benefits to the public, and could have the funding taken away from them if they failed to do so.

A vocal minority was opposed to any increase in transportation prices. Members of this group argued that government is wasteful and indifferent to the needs of the working person, and that pricing policies would exacerbate both problems with little or nothing to show for it. At the opposite end of the spectrum, another minority felt that problems created by the automobile justified significant price increases as well as regulatory restrictions on auto use, and that such policies should be vigorously implemented. By far the most common reaction was a mild, somewhat grudging acceptance of the idea that price increases could help reduce congestion, air pollution, and fuel use, and would raise revenues for improving the overall transportation system. In addition, most thought that the funds could be used to provide important improvements if they were earmarked for such uses and expenditures had to be reported in detail.

Differences in the attitudes expressed by participants in the four metropolitan areas were notable. In particular, participants in Los Angeles and Sacramento expressed strong anti-tax sentiments and were cynical about the ability of government to manage programs efficiently or keep its promises. Participants in the Bay Area and in San Diego were more positively inclined toward government, more willing to pay taxes or fees for government programs, and more optimistic that government could deliver promised improvements using the taxes or fees wisely.

Severity of the Problems

Participants in all four metropolitan areas stated that air pollution is a serious problem both to them personally and for society. On a scale of 1-10, where 10 is a severe problem, the rankings were typically 9 or 10. Most also ranked congestion as a serious problem, although many felt it bothered others more than themselves (because they do not personally face much congestion on their work trips). Also, some who do travel under highly congested conditions say that they have become resigned to congestion and do not believe that anything will reduce it, this group rates congestion as less of a problem than do those who believe that congestion relief is possible.

There was considerably less concern expressed over petroleum dependence, this issue tended to be ranked in the 5-7 range. The global warming issue did not resonate with the participants and only one participant commented on it - to raise a question about whether this might not be a false alarm.

Fuel Tax Increases

Fuel tax increases were the most widely accepted of the strategies, although support for an increase was mixed. Most of the participants accepted the point that the gas tax had declined, in real terms, over the past several decades, and most felt that an increase would be acceptable, especially if implemented gradually. Some, however, characterized the gas tax as "just another way to gouge the middle class."

Some of the participants thought that an increase in fuel taxes would be an effective way to alter how much driving people do, in the short run, and what kind of cars they drive, in the longer run. However, most felt that a tax increase of less than 50 cents would have almost no effect on their own travel behavior, perhaps reducing a few discretionary trips off-peak.

Many of the participants thought that at-the-pump charges would be too blunt an instrument to be used for congestion relief or air pollution reduction. They saw only a small connection between fuel consumption and driving conditions or emissions, and felt that technologies to strengthen such a connection, e.g., on-board monitors or roadside sensors, were "Buck Roger-ish" - too futuristic and speculative to be considered seriously. Most all felt that revenues from any gas tax increase should be earmarked for transportation. The most frequently supported use for the revenues was to greatly improve transit and/or speed planned transit improvements. Some did not want to see more money spent on highways, a smaller number felt that this would be an important use of the monies.

Vehicle Registration Fees

Vehicle registration fees reflecting VMT, vehicle emissions, or fuel consumption were hard for most people to understand, though once explained, the concept seemed reasonable to most. On the other hand, most felt that considerable effort would be needed, either in the form of technology improvements or in the form of greatly increased surveillance and enforcement, to implement such a registration fee.

Several argued that tying vehicle registration fees to odometer readings and emissions tests would lead to widespread odometer tampering and test fraud, and many felt that passing the smog check should suffice as a check on emissions. Similarly, many of the discussants felt that fuel consumption was already addressed by the fact that the more fuel used (whether via VMT or via gas guzzler), the more tax paid, and there was little enthusiasm for adding new government incentives or disincentives in this regard.

Participants who owned old cars worried that they could face sharply increased fees, and owners of cars that had barely passed their last smog check were alarmed by this option. Several participants expressed concern over how higher vehicle registration fees would affect low income owners of old vehicles, but there was mixed reaction to a possible subsidy to offset this impact. Some thought that help in buying a reasonable quality used car would be a pragmatic and humane response, while others objected that the costs would be excessive and that moderate-income participants would also be hurt but would not get any help.

Vehicle buy-back programs were viewed positively by some, but others expressed strong reservations because the buy-back prices were rarely high enough to pay for a "good" used car as a replacement. There also was some concern that vehicle buy-back would have an inflationary effect on used car prices.

Owners of "classic" cars and other "old favorites" worried that they would not be able to keep their cars if they were forced to pay emissions fees as part of vehicle registration. Some in this group felt that a possible compromise would be to limit old cars that could not meet modern emissions standards to perhaps 500 or 1000 miles a year. Others, however, use their old vehicles more than that and would prefer a blanket exemption for classic cars or no emissions fee at all. On the other hand, group members who do not own such old cars tended to react with some impatience to these concerns, arguing that if a car is dirty it should be cleaned up or not used.

There was solid agreement that a VMT, energy use, or emissions fee should be based on actual vehicle performance, not a "typical" rate for a vehicle of a particular type and age, but there also was a great deal of skepticism about the amount of bureaucracy this might require, as well as the potential for fraud. Indeed, each group had at least one member who gave examples of ways to get a car to (temporarily) pass an emissions test, to show a low odometer reading, and so on.

Finally, many participants felt strongly that the current policy of allowing cars that are heavy polluters to continue to operate under waivers should be changed.² Furthermore, many of the focus group members did not realize that the cutoff point for passing the smog check varied with vehicle age and type, and a substantial number felt this too was unfair, preferring a uniform pass/fail cutoff point. (Others argued that the current approach is both acceptable and practical given the differences in vehicle technology.) A number of participants in the discussion groups felt that an emissions fee, as well as a flat prohibition against operating vehicles that produce very high emissions levels, would be a more equitable policy than the current one, if a reasonable method of implementation could be devised.

Congestion Pricing

Reactions to congestion pricing varied with urban area, the strategy was seen as potentially effective in the Bay Area and Los Angeles, but of limited relevance (because congestion was thought to be serious on only a couple of routes) in Sacramento and San Diego. In all four urban areas some of the participants said that, at least some of the time, they would pay a fee to avoid congestion during peak periods, but almost no one would willingly pay it on a regular basis.

² Many focus group members were unaware that waivers were permitted at all, and while California now limits the availability of waivers, most focus group members did not approve of the practice in any form or thought that waivers should be limited to a very short period, e.g., 30-90 days.

A number of participants felt that congestion pricing was basically unfair because the well-off who could afford to pay the fee already have many privileges (e.g., set their own work hours, work at home, etc.) while others, perhaps more time-constrained but less affluent, would either be forced to use far inferior options or to pay a fee they could ill afford. Several participants blamed unnecessarily inflexible employer work scheduling policies for much of the congestion, and felt that government should address this first rather than hit workers with higher fees.

The use of the revenues to improve commute alternatives was seen as dubious in Los Angeles and, to a lesser extent, in Sacramento. Participants in those cities opposed highway expansion, but also felt transit could never be competitive except, perhaps, to downtown. Many felt that the money would be wasted by incompetent bureaucracies or arrogant politicians. In contrast, in both the Bay Area and San Diego, many felt that useful transit improvements could be made and that other desirable projects could be implemented.

Congestion pricing was hard for most discussion group participants to understand, except for applications on bridges, toll roads, and special lanes. This is in part because few are familiar with toll tags or other automatic vehicle identification (AVI) and electronic toll collection (ETC) technologies, and imagined that toll booths would have to be added to collect the fees, but would make things worse. Once AVI/ETC was explained to the group, most saw it as by far the best way to implement congestion pricing. A small number worried about the government knowing who traveled where, but this was not a concern for most participants. Indeed, several scoffed at the issue, arguing that if government wanted to know the movements of particular individuals they could easily do so now using available technologies.

Parking Pricing

Policies which would charge for parking were the least supported by discussion group members. Most discussion group members felt that parking was already priced where it was most costly to provide, generally in downtowns and higher-density employment centers and shopping districts. Where parking is free and plentiful, the participants argued, it also is a necessity, because alternatives to driving and parking are too poor to be competitive, pricing such parking, they argued, would make little difference to the amount of driving people would do. In addition, few could imagine a government-imposed tax or fee on parking that would be substantial enough to alter behavior or fund significant improvements to commute alternatives, nor did they believe that employers or other private sector parking owners would make parking charge revenues available to improve commute alternatives. Finally, if a parking charge were imposed at their workplace, most thought they'd park elsewhere - on a nearby street or in a nearby shopping center, for example.

Asked to consider parking surcharges of the sort that might be implemented by local government or a regional agency, several participants voiced general concerns about another government regulation on business. Several expressed doubts that such surcharges would be implemented or enforced, they ventured that public officials would back off in the face of employer opposition, as had happened with trip reduction requirements. On the other hand, the participants who currently pay for parking thought that parking pricing should be employed more often, and that daily rates should be no higher than their proportionate share of monthly rates, to encourage part-time transit use.

10.4 Interviews with Local Officials and Interest Group Representatives

To further explore the acceptability of transportation pricing measures, we carried out a series of interviews with state and local government officials, legislative staff, and public and

private interests from all four metropolitan areas, with a greater number of interviews in the Bay Area and Sacramento. A total of twenty-eight individual interviews were completed. In addition, we participated in a number of small group meetings at which transportation pricing policies were discussed. Participants in the meetings included elected officials, planning and transportation staff members, representatives of business organizations, labor leaders, environmentalists, academics, staffers of organizations representing ethnic and racial minority groups, neighborhood activists, and realtors.

The interviews and meetings with officials and interest group members uncovered very similar reactions to those obtained from citizens in the discussion groups. Most of those interviewed believe that transportation pricing strategies could be effective in reducing congestion, emissions, and fuel use, if carefully implemented. However, there was a great deal of skepticism about the political viability of such strategies and government's ability to implement them effectively. Indeed, a number of those interviewed explicitly requested that not only their specific comments but their participation in the interviews be kept confidential, out of concern that their views might be misinterpreted.³

A number of those interviewed, both supporters of pricing approaches and skeptics, felt that this is a poor time to be discussing taxes and fees with a public that is trying to cope with a shaky economy, losses of military bases, and pockets of high unemployment. Some believe that widespread anti-tax sentiment would make open support for increased transportation prices and fees politically dangerous. Others feel that pricing measures might be accepted when the economy is strong, but that as long as the economy is seen as weak or only recovering, pricing measures would lose, resulting in a setback for policies that could do some good and might succeed if introduced at a better time.

Several of those interviewed argued that the state should not attempt to design uniform state-wide transportation policies. They argued that the need for revenues, congestion relief, and air pollution abatement vary widely in different parts of the state and the lack of

³ Because of the requests for confidentiality, we have not included the names of those interviewed for this study.

need for action in many areas might undermine an attempt to get a state-wide policy implemented. They recommended instead that the state should authorize local government - counties and in some cases regional agencies - to implement emissions-based registration fees, higher gas taxes with earmarked funds, etc. One partial exception to this preference for local action was in areas that cannot meet state and/or federal air quality standards, there, some felt that the state should mandate policies such as emissions-based registration fees rather than merely authorize local action. Another partial exception is in the area of VMT fees, some felt that over the long run these fees might substitute for the current bundle of fuel taxes, sales taxes, property taxes, and the like used to pay for transportation facilities and services, and that statewide action would be the preferred way to proceed with such a revenue program.

Fuel Tax Increases

Most of the persons interviewed acknowledged that gas taxes are far lower than those of other developed countries and probably too low to adequately finance existing transportation infrastructure, let alone pay for improvements. On the other hand, most also felt that higher gas taxes are a political non-starter at the current time, at least on a statewide basis. Some would support regional gas tax approaches, where the state would authorize regions to put a tax increase and expenditure plan on the ballot.

A smaller number believe that a state gas tax increase could be introduced right away, with the funds are earmarked for transit, air pollution reduction strategies, and other transportation improvements (in order of priority). They believe that such a tax increase could be sold to the public as a way to fund needed projects that will be good for the economy and produce jobs, as long as the projects are ones that have public support.

Vehicle Registration Fees

Interviewees were concerned about whether higher vehicle registration fees would have the desired effect on emissions or energy use. They argued that additional fees of more than a few hundred dollars maximum would be unlikely, but by the same token would be too low to substantially change auto ownership levels or auto type choices. Conversely some worried that fee increases of up to three or four hundred dollars could seriously impact low income households, who might then face sharp cutbacks in their mobility (being unable to afford a better vehicle). In some cases, they thought, people might simply decide to leave the offending vehicle unregistered.

In contrast to citizen-discussants, most public officials interviewed believed that it would make more sense to use CARB/EPA data on average vehicle emissions by vehicle type and model year, rather than to rely on emissions test results. A common reaction was that the latter approach would encourage "clean for a day" fix-ups to reduce emissions, or outright fraud of various sorts. The use of data for a typical vehicle, i.e., with the fee calculated based on registration data and listed on the mailed-out registration form, was felt to be simpler and hence more realistic than approaches that would require an elaborate measurement, monitoring, and reporting system. In addition, average emissions data were thought by several to be no less fair or accurate than many other commonly accepted fee calculation methods, such as using average trip rates (for example) to calculate traffic mitigation fees.

Wider use of vehicle buy-back programs would receive broad support from those interviewed, although several recommended a repair-or-retire approach rather than simply scrapping a vehicle. Support also ran high for programs that would get high-emissions vehicles off the road or limit their use (e.g., repair-or-retire requirements for all vehicle owners, policies that would disallow waivers for super-emitters after a specified date (e.g., two years following enactment) or limit the waiver to, e.g., six months, policies establishing a

high emissions and mileage fee for super-emitters after a specified date) Some favor pricing strategies to encourage these latter actions, others suggest that regulations should do so

Parking Pricing

Many local government officials argued that parking regulation was no business of the state's - that local governments were much better positioned to develop parking policies that made sense for their areas. Academics, environmentalists, and some business leaders, in contrast, argued that local governments' parking regulations tended to range from poorly conceived to downright irresponsible. Academics and environmentalists argued for a stronger state role in reducing mandatory parking requirements, whereas business people wanted less government involvement of any sort.

Several local government officials reported pressures to reduce impact fees due from developers and employers, and thought it very unlikely that parking pricing or similar strategies aimed at land owners and managers would be attempted or would succeed at this time, at least as a local initiative. The gradual elimination of tax benefits for employer-provided parking is an option that some would endorse, but others believe that anti-parking strategies will do more mischief than good, for example by leading to parking spillovers into residential neighborhoods.

Parking cash-out, the state policy that requires certain employers who purchase or subsidize parking for their employees to offer them the alternative of a cash equivalent, was known to only a few of those interviewed. To most, it seemed to be an interesting way to begin to rationalize parking requirements, but not a particularly efficient or "market-based" strategy.

Congestion Pricing

Congestion pricing made sense conceptually to most of those interviewed, but there was deep distrust among some about a policy that seems to reward the affluent and already privileged classes. One elected official took the position that policies that allowing the affluent to buy their way out of a problem reduced the probability that the problem would ever be addressed properly, and hence was socially irresponsible

The details of implementing congestion pricing worry many (E g , what if people try to pull over and wait for the price to change? What if people avoid the fee by crowding onto the local streets?) In addition, equity issues were raised the concern was for low and moderate income workers with little flexibility and no good alternative choices Using the revenues to improve travel alternatives was generally felt to be a prerequisite to congestion pricing, but there also were doubts that this would in fact be done, or that improvements such as additional bus services or pass discounts would be maintained for long

Several believed that some form of road pricing would be inevitable if a substantial number of alternate-fuel vehicles came into use, because then it would become clear that conventional fuel taxes were no longer working as a finance mechanism They also felt that, when that time came, differential charges by time of day might be implemented more easily

Enthusiasm for allowing solo drivers to buy into HOV lanes was decidedly mixed Some felt that this would be a fine way to pay for HOV lanes and related programs and saw this as the main way congestion pricing would be implemented in the foreseeable future Others felt that SOV buy-in would be unacceptable because it would violate agreements under which lane additions were approved on condition that they be restricted to HOVs during peak hours Both supporters and doubters expressed concerns over the feasibility and practicality of enforcing an HOV lane in which some SOVs were permitted, except with a very heavy dose of technology (SOV buy-in only with toll tags, video recording of all

vehicles without a toll tag, and either real time monitoring or imaging to detect a violator and trigger enforcement, or tickets by mail)

10.5 Overcoming Barriers

In both the focus groups and the interviews, many were skeptical that effective implementation of any significant change in transportation pricing would proceed, at least in the next few years. The barriers, in this view, are an apparent lack of broad-based support for action, the strength of the anti-tax movement, the high visibility of government action on most of the strategies, and the lack of clear precedent demonstrating overall benefits and an ability to offset inequities. On the other hand, many thought that these barriers could be overcome by a combination of public education, good planning, provision of safeguards to protect the public interest, and application of emerging technologies. Suggestions for overcoming the barriers included the following

- o If implementation is to proceed, business, environmental, and social justice communities must be willing to publicly advocate transportation pricing changes and to take on the effort needed to educate the public
- o Specific proposals must address the equity issues directly, and must offer concrete commitments for offsetting harm in an environmentally and socially acceptable way
- o The creation of public-private oversight committees and the use of independent audits to assure funds are being well used and programs are working as intended would help reduce, though not entirely dissipate, suspicions about government programs of this sort

- o Approaches that give local governments or regions authority to implement pricing programs matching their circumstances make more sense, for the most part, than uniform statewide approaches. Authorization for local action permits those communities that can build support for a measure to proceed without forcing the issue on those who are not prepared to act. In many cases a city- or county-level authority would be sufficient to avoid spillover problems, or a regional agency could be given implementation authority.
- o Two possible exceptions to the general preference for local or regional control are for emissions fees in nonattainment areas (where direct legislative mandates were suggested) and VMT fees to be used for revenue purposes (where a statewide program was suggested.)
- o Several transportation pricing measures may become more acceptable as new technologies are implemented. For example, AVI/ETC technologies will greatly aid in the implementation of road pricing, parking pricing, and perhaps vehicle registration fee policies, as consumers become more accustomed to the AVI/ETC technologies they may also become more accepting of pricing strategies which utilize these devices. New odometer designs will reduce the likelihood of tampering and make fees based on odometer readings easier to implement. On-board vehicle diagnostic equipment will help people keep their emissions equipment in good order. Experience with remote sensing should clarify the role of high-emitting vehicles in the overall pollution problem, and increase public acceptance of emissions-based fees.
- o Finally, as low emission and zero emission vehicles become a realistic option for more people, public willingness to accept road pricing, higher fees for petroleum fuels, and emissions fees also should increase.

11. Legal Issues ¹

11.1 Introduction

A number of legal issues will have to be confronted as policy-makers consider the use of transportation pricing to relieve congestion, improve air quality, reduce energy consumption, and lower greenhouse gas emissions. This chapter outlines key legal issues which must be considered in designing transportation pricing strategies. It is designed to aid policy-makers in understanding what can be implemented under existing law and what legislative issues must be dealt with in order to accomplish desired policy goals. The topics are complex and this brief treatment of them cannot replace a detailed legal review of specific proposals. Nevertheless, the chapter should provide a start from which interested public officials can move forward.

Because the relevant law is largely state law, and because our four case study areas are all California regions, we focus on California legal issues. California policy-makers are faced with a legal structure not ideally suited to the implementation of transportation pricing innovations and reforms. While a few such pricing strategies have been "pushed through the system," and more are possible, not only are there a host of general legal issues affecting implementation, but enactments over the last 15 years restricting new taxes, fees and assessments impose additional hurdles.

A variety of transportation pricing measures already exist under California law - tolls, fuel taxes, vehicle registration fees, vehicle licensing fees, and parking fees and taxes among them. The availability of these measures means, of course, that there is established law concerning their utilization, use of revenues, and so on. We start with a summary of these

¹ This chapter is based upon an outline developed by Geoffrey S. Yarema of Nossaman, Guthner, Knox and Elliott. Mr. Yarema was assisted by Winfield D. Wilson, Robert D. Thornton, Barney A. Allison, and Steven N. Roberts. Elizabeth Deakin prepared the final version of the chapter.

existing fees and taxes, to provide background for discussion of possible additional measures

We then turn to general considerations in designing transportation pricing strategies. Generally, the biggest legal issue facing a transportation pricing measure is whether it will be classified as a "tax" or a "fee," since the two are implemented under separate authority and are subject to different procedural and substantive requirements. The California rules are particularly strenuous, in addition to the concerns shared with other states over due process and equal protection, adequate nexus and appropriate use of funds, California must comply with a number of citizen-enacted propositions limiting and constraining the enactment of taxes and fees and the uses of the revenues therefrom. Hence, in this chapter we distinguish between "taxes" and "fees" under California law and discuss the advantages and disadvantages of each classification.

A number of other federal and state constitutional provisions and statutes, as well as common law, also affect the implementability of transportation pricing strategies. The conditions under which these measures may be lawfully imposed are reviewed and provisions governing collection and disbursement of proceeds are discussed.

We then apply these legal considerations to the set of pricing measures being evaluated in this study: road pricing and its variants (including tolling mixed flow highway capacity and charging for use of high occupancy vehicle lanes by non-high occupancy vehicles), parking pricing, increased at-the-pump charges (fuel taxes or other), and emission-based or VMT-based registration fees.² While the discussion is necessarily general, it does indicate some of the issues that might arise and points out some options for dealing with them.

We conclude with a brief review of the legal aspects of such frequently raised issues as whether extensive monitoring would constitute an unlawful search or invasion of privacy,

² The measures considered in this chapter are described in somewhat different terms than in preceding chapters, because here we focus on the implementation mechanisms that might be used and the legal issues surrounding them.

whether differential prices based on congestion levels, tolls, etc violate equal protection guarantees, and whether transportation pricing measures might amount to improper double-charging. Brief reference also is made to the issues that new technologies for implementing pricing measures might raise.

11.2 Current Transportation Fees and Taxes

At the time this chapter was prepared,³ a number of transportation fees and taxes are already in place or authorized under California law. At the following

-- Tolls

The Legislature has authorized the California Department of Transportation (Caltrans) and other public and private entities to impose tolls on a variety of transportation facilities, including bridges, highway crossings, tubes, tunnels, subways, underpasses and overpasses acquired or constructed pursuant to the California Toll Bridge Authority Act (Sts. & Hwys. Code § 30000). Tolls have been in place for some years on the San Francisco-Oakland Bay Bridge (Sts. & Hwys. Code § 30600), the San Pedro-Terminal Island Bridge (Sts. & Hwys. Code § 30680), bridges across Carquinez Straits (Sts. & Hwys. Code § 30750), the Antioch Bridge (Sts. & Hwys. Code § 30760), the San Francisco-Oakland Rapid Transit Tube (Sts. & Hwys. Code § 30771), the San Mateo-Hayward and Dumbarton Bridges (Sts. & Hwys. Code § 30790), and the San Diego-Coronado Bridge (Sts. & Hwys. Code § 30796). Recent legislative action authorized four demonstration projects selected by Caltrans to be developed by private entities (Sts. & Hwys. Code § 143): the tolled use by single-occupant vehicles of high-occupancy vehicle lanes on I-15 (AB 713), facilities constructed and tolled pursuant to the El Dorado County

³ The chapter was drafted in Fall 1993 and updated in June 1995. Legislative action and court decisions since that time may have altered certain provisions reported herein. The reader should confirm the current status of laws and regulations before utilizing this information.

Toll Tunnel Authority Act (Sts & Hwys Code § 31100), and bridge and major thoroughfare construction to be undertaken by the Orange County Transportation Corridor Agencies (Gov Code § 66484.3) The latter organization has recently opened tolled segments of its highways

Caltrans has general authority to grant toll franchises under certain specified conditions (Sts & Hwys Code §§ 30800, 30810), including public hearings on the toll rates to be established. It is unlikely that Caltrans or any other state agency could by itself authorize a local entity lacking police powers to levy a toll, whether in fact the toll was a "fee" or a "tax," since this would be exercising a legislative prerogative.

Boards of Supervisors have no authority to grant franchises or licenses to construct or collect tolls, but may construct or acquire a toll road, subject to restrictions imposed by any law authorizing the construction or acquisition of toll roads (Sts & Hwys Code § 30810, 30812)

-- Vehicle License Fee (Rev. & Tax Code §§ 10701 et seq.).

The vehicle license fee law currently (1996) provides for a "fee" equal to 2 percent of the value of the vehicle. Proceeds are allocated in part to counties to fund health services programs (Rev & Tax Code § 11001.5, Wel and Instit Code §§ 17600, 17604), in part to cities for lost property tax revenues (Rev & Tax Code § 11005(b)), and the balance to cities and counties based on population. Monies disbursed to cities and counties may be used for any county or city purposes.

-- Motor Vehicle Fuel License Tax (Rev. & Tax Code §§ 7301 et seq.).

The tax rate currently (1996) is \$ 18 per gallon (Rev & Tax Code § 7351), levied on distributors for the privilege of distributing motor vehicle fuel; i e , an "excise" tax Subject to the provisions of any budget bill, proceeds are deposited into the State Transportation Fund (Rev & Tax Code §§ 8352, 8352 2, 8353) Once in the Transportation Fund, the money is allocated to a variety of state and local programs (See, e g , Sts & Hwys Code § 2104 et seq)

-- Motor Fuel Use Tax (Rev. & Tax Code § 8601 et seq.)

The rate currently (1996) is \$ 18 per gallon, levied on the consumer (Rev & Tax Code § 8651) Proceeds are deposited into the Highway Users Tax Account and the Transportation Tax Fund (Rev & Tax Code § 9302)

-- Local Motor Vehicle Fuel Tax (Rev. & Tax Code § 9501 et seq.; PUC Code 99500 et seq.)

Counties may impose a motor vehicle fuel tax on a county-wide basis This tax may be expended only for the purposes authorized by Article XIX of the California Constitution Prior to imposition, the proposal must be approved by the Board of Supervisors, a majority of the city councils of the cities having a majority of the population in the incorporated areas of the county, and a majority of the voters The county and the majority of the cities having a majority of the population in the incorporated areas of the county must also have a written agreement with respect to allocation of the revenues between the counties and the cities (Rev. & Tax Code § 9502)

-- Local Vehicle License Fees (Rev. & Tax Code § 11101 et seq.)

Counties which have adopted a general plan providing for a network of county expressways and financing the first phase of constructing such highways from a county bond issue totaling at least \$70 million, may impose a county vehicle license fee not to exceed \$10 per vehicle. This vehicle license fee is imposed on the privilege of operating the vehicle upon the public highways and hence is an excise tax. Revenue from this source is to be distributed to the county for the construction of the expressway system.

-- Parking Fees and Taxes

Cities and counties, as well as private entities, frequently provide parking and charge for its use. In addition, some charter cities and counties have imposed taxes on parking revenues from private facilities (see discussion which follows on charter city authority.)

11.3 General Considerations in Designing Transportation Pricing Strategies

In designing transportation pricing strategies, one of the most important legal issues is whether to structure the charge as a fee or a tax, an issue which has serious procedural consequences, particularly in California. Other considerations stem from restrictions on the use of funds depending on the nature of the charges levied and the entity imposing the charges.

Classification of Charges as "Taxes" or "Fees"

In general, a monetary charge can be formulated as either a "tax" or a "fee". Whether a charge is classified as a "tax" or a "fee" depends upon the governmental entity's power and ability to impose the charge, as well as its amount in relationship to benefits received or burdens imposed. In addition, the classification determines the permissible use of the funds raised and, in California, may determine whether the charge is subject to voter approval.

"Fees" are considered to be charges (exactions) which compensate the government for a service rendered, a benefit conferred or a burden created by the payor. "Taxes" encompass exactions other than fees. Certain exactions may be properly classified as either a fee or tax. For example, persons using a segment of highway might be levied a fee for the benefit of using the highway, conversely, they might be charged an excise "tax" for the privilege of using the highway. (See Associated Homebuilders v City of Livermore (1961) 56 Cal 2d 847, 852-853, Westfield-Palos Verdes Co v City of Rancho Palos Verdes (1977) 73 Cal App 3d 486)

The classification, if necessary, of exactions as fees or taxes may depend upon legislative intent, or constitutional or statutory proscriptions against one or the other which cannot be avoided simply through a judicious choice of terms. (California Bldg Industry Assn v Governing Bd (1988) 206 Cal App 3d 212, 236, 237)

Constitutional/Statutory Basis for the Imposition of Fees or Taxes

Taxes are imposed through exercise of the taxing power. Fees are imposed through exercise of the police power. The California Legislature has inherent police and taxing powers, limited only by the federal and state constitutions. Thus, the state can directly impose through appropriate legislation whatever taxes and/or fees it might wish, subject only to constitutional constraints and federal preemption.

Federal and state constitutions provide for equal protection and due process to protect against arbitrary and unreasonable differential treatment of persons. Likewise, both constitutions protect property rights, prohibit impairment of contracts, secure privacy, and limit searches of persons and property. Assuming the tax or fee is designed and implemented in a manner which complies with these constitutional mandates and limitations, statutory law further governs permissible action.

The California State Constitution grants police powers to all cities and counties (Article XI, § 7). Consequently, all cities and counties may impose fees, subject to constitutional restrictions and such limitations as the Legislature may impose (California Bldg Industry Assn v Governing Bd (1988) 206 Cal App 3d 212, 234, 237). Local entities other than cities and counties lack the police power, however, and thus may impose fees only if the Legislature authorizes it.

Local governments' ability to impose taxes depends on the form of government and its organization. Under California law, the state may not directly impose taxes for local purposes, but may either (a) impose local taxes for state purposes or (b) authorize "local governments" to impose taxes for local purposes (Art XIII, § 24). California "charter cities" derive their taxing powers through their charters, subject to constitutional limitations and preemptive state and federal legislation (Art XI, § 5). Non-chartered (general law) cities and counties and other local entities have only such taxing powers as the Legislature vests in them (Art XIII, §24). City charters are likely to provide for more unlimited police and tax powers than the Legislature accords to "general law" cities (See, e.g., Stats 1971, Res Ch 183, p. 3759 [Vallejo] "The Council may provide for any tax, license or permit fee, service or charge or other kind of revenue permitted by this Charter or by the Constitution or general laws of the State").

As with fees, local entities other than cities and counties may impose taxes only if empowered to do so by a specific act of the Legislature.

In general, then, the State may impose either taxes or fees, California cities and counties have broad power to impose fees, cities and counties' ability to impose taxes depends on their form of organization and state authorizations, and other local government entities may impose fees or taxes only if specifically authorized by the state

Limitations on the Power of State and Other Public Entities to Impose Transportation Fees and Taxes

Both federal and state law restrict the power of the state and other public entities to impose transportation fees and taxes or otherwise limit the use of revenues generated.

Federal Statutory Provisions

-- Federal Highway and Transportation Law

Federal statutory law has long stipulated that no toll of any kind may be imposed on the use of Federal-aid highways, with specified exceptions including bridges, tunnels, and facilities initially built as toll roads (23 USC, Sts & Hwys Code § 2201) However, the Intermodal Surface Transportation Efficiency Act of 1991 created certain exceptions to this general rule

- o for the initial construction of federal aid, non-Interstate, toll highways, tunnels and bridges (23 U S C A § 1012(a))

- o for the reconstruction, replacement, resurfacing, restoration, and rehabilitation of existing federal aid toll highways, tunnels and bridges (23 U S C A § 1012(a))

- o for testing the use of congestion pricing on up to five existing federal aid highways, of which two can be interstate highways (23 U S C A § 1012(b)) At the time this chapter was being written, the Federal Highway Administration had authorized a larger number of planning studies, including several in California One such planning study is considering congestion pricing on the San Francisco-Oakland Bay Bridge, a second is evaluating a range of pricing strategies for the Los Angeles region, a third is evaluating pricing of HOV lanes in San Diego

The ban on tolls on most federal-aid highways is a serious limitation on the consideration of congestion pricing or other road pricing strategies While there has been considerable discussion both in Washington and elsewhere on the desirability of further loosening this restriction, the current Congress has substantially cut congestion pricing demonstration project funding, though work continues using funding authorized previously

The general federal restriction on tolls does not apply to gas taxes (293 U S 533 [79 L Ed 641]), registration fees (Carley & Hamilton v Snook, 281 U S 66 [74 L Ed 704]), or motor fuel dealer taxes (Anthony v Kozer, 11 F 2d 641 (D Or 1926))

-- The National Environmental Policy Act of 1969 (42 U.S.C.A. §4321 et seq.)

The National Environmental Policy Act - NEPA - establishes requirements for the evaluation and reporting of environmental effects stemming from a wide range of federal actions Detailed implementation guidelines have been issued by the federal Council on Environmental Quality and by individual federal agencies, including the U S Department of Transportation Depending on the specifics of the action in question, NEPA requirements could include an assessment of environmental impacts, consideration of alternatives, preparation of detailed statements or reports, and public notice and hearing Certain transportation pricing projects or proposals could be construed as "federal actions" within the meaning of NEPA and thus would be subject to NEPA provisions

Major State Constitutional Restrictions

A number of state constitutional and legislative provisions mandate a public vote, limit the use of revenues, or otherwise sharply restrict taxation in California. These provisions must be explicitly dealt with in designing transportation pricing measures. Key provisions are discussed below.

-- Article XIII A (Proposition 13)

Proposition 13, approved by the voters in 1978, has several important provisions which affect government's ability to levy taxes in California. First, any increase in state "taxes" leading to increased revenues must be approved by two-thirds of the total membership of each house (Art XIII A, § 3). Second, any new "special tax" imposed by any city, county, or "special district" requires the prior approval of a two-thirds vote of the electorate voting on the proposal (Art XIII A, § 4). The special tax 2/3 vote requirement does not apply to taxes where the proceeds are deposited in the general fund of cities or counties (City and County of San Francisco v. Farrell (1982) 32 Cal 3d 47), but does apply to taxes where the proceeds are deposited in the general fund of special districts (Rider v. County of San Diego (1991) 3 Cal 4th 1).

Districts formed prior to 1978 which lack the power to impose real property taxes are not "special districts" and thus are not subject to the two-thirds vote requirement of Article XIII A (Los Angeles County Transportation Commission v. Richmond (1982) 31 Cal 3d 197.) Recently a divided Court of Appeal in essence held that any tax imposed by any independent district, organized after 1978, requires a two-thirds vote (Santa Clara County Local Transportation Authority v. Guardino (6th Dist H010835 Nov 10, 1993). The Supreme Court upheld this decision.

-- Article XIII B (Gann Initiative)

Article XIII B establishes an appropriation limit for each governmental entity in California. In any year, governmental entities may not expend more than their appropriations limit for the prior year, adjusted for changes in cost of living and population. As a consequence, an entity which receives revenues in excess of its appropriations limit is required to transfer or refund the excess. For the state itself, fifty percent of any state revenues in excess of the state's appropriations limit must be transferred to the State School Fund, and the balance refunded by revision of the tax rates or fee schedules. Any excess revenues another entity of government receives must be returned through a revision of tax rates or fee schedules.

Proceeds from regulatory licenses, user charges and user fees are considered revenue under Article XIII B, except "to the extent that those proceeds do not exceed the cost to the entity in providing the regulation, product, or service" (Art XIII B, § 8(c))

Appropriation limits of existing governmental entities may be changed by the electors upon a majority vote, to last for four years. The appropriations limit for new entities is established by the vote of the people.

-- Proposition 62 (Gov. Code Section 53720 et seq.).

Proposition 62 requires that any taxes imposed for a specific purpose ("special taxes") be approved by two-thirds vote of the electorate and requires that any taxes imposed for general purposes ("general taxes") be approved by a majority vote. Government entities other than the State are facially subject to Proposition 62 (Gov Code § 53720 et seq). While Proposition 62 purports to apply to chartered cities, it probably does not as a matter of law since a statute (even if enacted by initiative) cannot amend municipal rights derived through the Constitution.

Several cases have held Proposition 62 invalid (City of Woodlake v Logan (1991) 230 Cal App. 3d 1058, City of Westminster v County of Orange (1988) 204 Cal App 3d 623) Two unreported cases have held that entities without the authority to impose property taxes may enact special taxes without any vote under Proposition 62 (Vernon v State Board of Equalization (1992) 2nd Dist B057899, Ward v State Board of Equalization (1992) 4th Dist G011284)

Other State Constitutional Provisions

Several other constitutional provisions could directly affect transportation pricing measures and are briefly mentioned here

-- Restrictions on Who May Levy Taxes and Assessments

Article XI Section 11 specifies that the Legislature may not delegate to a private person or entity the power to levy taxes or assessments. The Legislature has, however, authorized Caltrans to enter into agreements with private parties to establish toll rates and to impose tolls to repay the cost of developing and operating transportation facilities, together with a reasonable return on investment (Sts & Hwys Code § 143)

Article XI, Section 14 provides that any local government formed after 1976, the boundaries of which include all or part of two or more counties, cannot levy a property tax unless the tax has been approved by a majority vote of the qualified voters within that local government. A tax based on the value of a vehicle, rather than on the privilege of using it, would probably fall under this provision. If the tax were earmarked for a specific purpose by a city or county, or if it were imposed by a special district, it would also require a 2/3 vote under Proposition 13

-- Restrictions on the Allocation or Use of Funds

Article XIII, Section 1(a) provides that all property, real and personal, is taxable, but must be assessed at the same percentage of fair market value. This would restrict differential taxation of vehicles and might also affect differential taxation of parking spaces, e.g., ones used by single occupant vehicles vs. multiple occupant vehicles. (But differential fees still could be devised.)

Article XIII, Section 14 further provides that all property taxed by local government must be assessed in the county, city, and district in which it is situated. These provisions might, for example, prevent taxation of vehicles not garaged in the locality (further analysis would be needed to evaluate this issue.)

Section 15 of Article XI states that all revenues collected under the Vehicle License Fee law, above the cost of collection, must be allocated to counties and cities according to statute.

Article XVI, Section 6 specifies that neither the State nor other public body may make, or authorize, a gift or a loan of public funds to any other person, association or public or private corporation. Consequently, revenue of one entity cannot be transferred to another entity unless the first entity receives sufficient consideration for the transfer, or unless a "public purpose" for which the transferring entity is authorized is thereby served. The State may distribute revenue to local entities to carry out "State" purposes but a city, for example, could not transfer its revenues to another entity unless a municipal purpose would thereby be accomplished. Partly countering this restriction, Article XVI, Section 24 provides that the Legislature may authorize cities and counties to enter into contracts to apportion between themselves sales or use taxes imposed by them. However, a majority vote of the electorate is required before any such contract becomes operative.

Article XVI, Section 8 was added by Prop. 198 and provides that a fixed percentage of all state revenue must be set aside for the support of public schools. Increased revenue to the

state from transportation pricing measures thus will lead to automatic increased support of the school system. If the increased funds themselves are earmarked for other uses, the state may have to reallocate funds from other programs in order to meet its the fixed-percentage obligation to the schools.⁴

Article XVII, Section 3 specifies that no money may be appropriated by the State for any corporation or institution not under the exclusive management and control of the State. Notwithstanding this provision, private companies may be granted the right to levy tolls to improve preexisting public roads. Blood v. McCarty (1896) 112 Cal 561

Article XIX, Section 1 provides that State revenue from taxes on motor vehicle fuels, over and above the cost of collection, can be used for specified purposes only. These uses include the operation of public streets and highways, related public facilities for non-motorized traffic, the construction of public mass transit guideways, and mitigation of environmental effects of highways and mass transit. This provision limits the expenditure of the proceeds of any State tax imposed on motor vehicle fuel.

Section 2 of Article XIX further provides that revenues from (a) fees or taxes, (b) imposed by the State (c) upon vehicles or their use and operation, over and above the cost of collection, can be used for restricted purposes only. As in Section 1, these uses include the operation of public streets and highways, related public facilities for non-motorized traffic, the construction of public mass transit guideways, and mitigation of environmental effects of highways and mass transit. In addition, the mitigation of environmental effects of motor vehicle operation due to air emissions is a permitted use of the revenues. This provision would sharply limit the expenditure of the proceeds of any State charge such as tolls, fees for use of HOV lanes, road user charges, vehicle registration fees, or parking charges. However, charges imposed by another entity would not be so affected.

⁴ In fiscal 1993, the Legislature allocated local property tax revenues to local schools in order to satisfy this duty. See also County of Los Angeles v. Sasaki, 2d Civ. No. B077722.

Under Section 3 of Article XIX, revenues subject to Section 1 (motor vehicle fuel taxes) must be allocated by the Legislature in a manner which insures the continuance of existing statutory allocation to cities, counties and areas until a redetermination is made based upon equitable geographical and jurisdictional needs, with equal consideration given to the transportation needs of all areas of the State and all segments of the population. Furthermore, under Section 4, gas tax revenues cannot be used for mass transit until such use is approved by a majority vote of those persons within the area within which the revenues are to be expended.

Under Section 7, Sections 1-4 of Article XIX do not apply to fees or licenses imposed pursuant to the Sales and Use Tax Law or the Vehicle License Fee Law.

State Statutory Provisions Relating to the Adoption of Transportation Fees and Taxes

Finally, statutory provisions affect government's power to adopt transportation fees and taxes and the procedures which must be followed in doing so. Two such provisions deal with referenda and environmental review under the California Environmental Quality Act (CEQA).

-- Referendum Provisions:

If a transportation pricing revenue measure were to be adopted by a city, county, or most districts, it potentially could be subject to a referendum. Referenda are initiated by petitions which must be filed within 30 days after a local ordinance is adopted. The measure is then suspended until it is voted on.

The referendum is not available where the measure is for a tax levy (at least for the usual operating expenses of the entity), or where the Legislature has specifically designated the legislative body of the county, city or district to carry out the program. Some cases have

extended the prohibition to fee ordinances as well as tax measures (e.g. Dare v. Lakeport City Council (1970) 12 Cal App 3d 864, 868)

-- CEQA Requirements:

The California Environmental Quality Act (CEQA), like its federal counterpart NEPA, could apply to a number of transportation pricing proposals. CEQA is of broader scope than NEPA, a wider range of proposals require CEQA review than require NEPA review (In some cases both NEPA and CEQA reviews are necessary)

CEQA is particularly likely to apply to particularly to transportation pricing measures which use revenues to expand transportation facilities and services. CEQA generally requires a public agency, prior to taking discretionary action on a "project", to consider environmental impacts and to address mitigation measures. CEQA does not apply to the establishment or modification of rates, tolls, fares, and other charges by public agencies, if such charges fund capital projects necessary to maintain service within existing service areas (Pub. Res. Code § 21080(b)(8)) However, CEQA does apply to rate increases to fund capital projects for the expansion of systems (14 Cal Code Reg § 15273(b)) Moreover, although CEQA does not apply to the development or adoption of a regional or state transportation improvement program, individual projects developed pursuant to these programs are subject to CEQA (14 Cal Code Reg § 15276)

Actions taken by regulatory agencies, as authorized by State or local ordinance, to assure the maintenance, enhancement or protection of the environment, i.e., regulatory programs which involve procedures for protection of the environment, are exempt from CEQA, except for construction activities and relaxation of environmental standards

Implications: Advantages and Disadvantages of Classification as Tax or Fee

As the preceding discussion implies, a number of consequences will flow from the classification of a particular transportation pricing measure as a fee or tax. These are briefly outlined below.

Advantages to Classification as a Tax:

- o No limit on amount
- o No restriction on use of proceeds, except that proceeds may not be transferred to another entity unless a public purpose for which the first entity has been formed is thereby served
- o No need to establish nexus between the amount of charge and the burden created by or benefit conferred on the person, activity or thing being taxed

Disadvantages to Classification as a Tax

- o If imposed by the State, it would require a two-thirds vote of each house under Prop 13
- o The revenues generated would be included in the State's appropriations limit under the Gann Initiative
- o The revenue would factor into subsequent Proposition 198 (State School Fund) computations
- o If imposed at the local level by a city or county, it would require a two-thirds vote of the electorate, unless the proceeds were deposited into the city or county's general fund.
- o If imposed by any limited purpose special district formed subsequent to 1978, it would require a two-thirds vote of the electorate

- o If imposed by any local entity, it would be subject to a challenge that a vote is required under Proposition 62
- o If imposed by any local entity other than a chartered city or county, it would have to be authorized by the Legislature

Advantages to Classification as a Fee:

- o If imposed by a city or county, it may not require enabling legislation (i.e., it may lie within the locality's police power)
- o It would not be subject to voter approval under either Proposition 13 or Proposition 62
- o Proceeds do not affect the entity's appropriation limit

Disadvantages to Classification as a Fee:

- o The burden is upon the entity imposing a fee to establish the nexus between the amount of the fee and the burden created or benefit conferred (See Beaumont Investors v. Beaumont-Cherry Valley Water Dist. (1985) 165 Cal App 3d 227)
- o Proceeds must be earmarked to compensate for the benefit conferred or burden created

In general, transportation pricing measures would be easier to adopt if designed as fees rather than taxes, provided that a defensible nexus for the fee can be established and provided further that restrictions on the use of the funds are acceptable. Regardless of which approach is taken, note that for many transportation funding sources, provisions of the California Constitution restrict the use of funds to specified transportation purposes.

11.4 Applying These Legal Principles to Specific Pricing Measures

Tolls / Road Pricing in General

The most serious limitation on the use of tolls (road pricing) is the federal statutory restriction on tolls which applies to most federal-aid roads, and hence to most of the roads which would be likely candidates for tolls or congestion prices. While there have been some legal opinions to the effect that road user charges could be structured as "user fees" and thus avoid this restriction, such a claim almost certainly would lead to litigation. The removal of this restriction in favor of state discretion over whether or not to toll, or in the alternative a considerable expansion in the numbers of exceptions allowed and "demonstration projects" made available, would be likely prerequisites to the imposition of tolls on existing federal-aid facilities.

The use of tolls as a means of financing and managing new capacity seems more promising in the short run, along with the restructuring of tolls on existing toll facilities. Under California law, such toll charges could be structured either as taxes or as fees, and in either case would require authorization by the State Legislature. If a tax, Proposition 13 restrictions would apply, as well as other restrictions concerning the adoption of taxes and the use of tax revenues (discussed earlier).

Tolls may raise a variety of other legal questions. For example, the imposition of tolls could have an impermissible impact on contracts if, e.g., the tolls affected the state's ability to pay back bonds issued for road construction. Tolls also might have a questionable effect on contracts in cases where preexisting fixed price contracts involving the provision of transportation services might be affected (Article I, section 9 [U.S. Const., Art. I, § 10, subd. 1]. The Legislature may not impair the obligation of contracts.)

Tolling Mixed Lane Highway Capacity

If a toll were designed as a tax, there would be no limitation upon variable tolls conditioned upon level of congestion, time of day or other factors, as long as various categories or vehicles are treated equivalently. If the toll were a fee, a nexus between the amount of the fee and the burden created by, or benefit conferred upon, the driver or vehicle would have to be established. A fee could not arbitrarily distinguish between types of vehicles (e.g., commercial and passenger) without justification, nor could it differentiate by time of travel without an evidentiary basis for doing so. However, a certain amount of latitude would be permitted in establishing presumed impacts of a particular class of vehicles. Russ Bldg Partnership v. City and County of San Francisco (1987) 199 Cal App 3d 1496, 1511-1516

Charges for Use of HOV Lanes by Non-HOVs

A charge for the use of HOV lanes by non-HOVs would in essence create a "toll lane" with the toll being waived for certain vehicles (i.e., HOVs). However, State law provides for the exclusive or preferential use of designated lanes for HOVs (Sts. & Hwys. Code § 142). Any system therefore would have to ensure the "preferential" treatment of HOVs over non-HOVs, i.e., ensure that non-HOVs be allowed only if there is excess capacity in the HOV lanes.

Under federal law, in addition to the general prohibition against tolls on federally funded highways which would require waiver, a charge to use an HOV lane could violate contractual agreements with the federal government regarding funding for HOV lanes. This is because HOV lanes are generally for the exclusive or preferential use of HOVs, though there is no blanket statutory prohibition on the use of such lanes by non-HOVs (23 U.S.C.A. § 142).

Such a toll could probably be justified as either a fee or a tax. It could be a tax for the privilege of using such a lane, or a fee to compensate for the benefit intended to be conferred, i.e., a more rapid commute.

Parking Charges

As current practices indicate, a tax can be imposed on the operators or users of private and/or public parking facilities, and fees can be levied to recover the costs of providing public parking. In addition, a variety of tax policies and statutory requirements can be used to influence the private sector's pricing of parking, although some of the mechanisms range far afield from economic principles.

Public entities as owners and operators of parking generally have wide discretion in establishing fees for its use. Fees for parking on public property could be more widely implemented to include a fee for all on-street parking, since a private benefit is being obtained at public expense. However, the total amount of the fee could not exceed the value of the benefit conferred/burden created without becoming a tax.

The more difficult and interesting question is whether government can impose a fee on all parking including private parking facilities, structured as an impact fee. For such a fee to withstand legal scrutiny it would have to meet the nexus test and be roughly proportional to the costs imposed on the public.

A government-imposed parking fee levied on private parking facilities would have to be justified on the basis that a burden is created by bringing a vehicle into a given area, or like ground. It would probably not be enough to state that the mere parking of a vehicle creates a public burden, but a justification based on congestion, emissions, or other environmental impacts might be established.

Other requirements that might be structured to meet the nexus test include requiring employers to charge employees for parking and requiring commercial leases to separate out the cost of parking and make such costs optional. However such provisions would raise the issue of whether the fee requirement could be construed as an interference with contracts if, for example, a long-term lease provides for free parking or union agreements stipulate it. Structuring the requirement to avoid this result might entail exempting existing contracts.

Tax policy itself could be used as a mechanism for providing incentives for the private sector to charge for parking. For example, "free" parking could be made taxable to the employee and/or nondeductible to the employer. Tax policy has moved in a somewhat different direction, however, recent changes in federal law have capped the value of free parking that is treated as a "de minimus" employee benefit, and upped the value of permissible non-taxed transit and ridesharing benefits (though the amount is still well below that for parking). In addition, both California law and a recent federal proposal provide for parking cash-out, a program through which certain employers who provide free parking must also offer their employees the option of taking the cash value instead.⁵

Increased At-the-Pump Charges

At-the-pump charges could be imposed on (a) the quantity of fuel sold, (b) the act of selling fuel, or (c) the act of buying fuel. The charge could be classified as either a fee or tax in the first case. In the latter two cases the charge would be a tax and its amount could be based on the quantity or value of fuel sold, or just a set amount.

At-the-pump charges based on the quantity of fuel sold would qualify as fees only if adequate findings or studies justify the nexus between the amount charged and the benefit conferred or burden created. Benefits and burdens could be justified in a number of ways,

⁵ At the time of this writing, the California parking cash-out program resulted in differential federal and state tax treatment and in general was not being greeted with much enthusiasm by employers.

with varying difficulty in defending the justification. For example, costs related to the production and transport to point of sale of transportation fuels are at least roughly proportional to amounts sold, as are carbon dioxide emissions.

Charges on fuel purchases are often termed "road user fees" on the grounds that the amount paid by the purchaser reflects how much use his or her vehicle makes of the roads. However, fuel consumption deviates considerably from VMT, and hence is a very imprecise measure of benefit conferred or burden created. Air pollutant emissions are even less directly related to fuel use because of differences in emissions controls among vehicles. Technically, then, charges on fuel sales generally would be more accurately classified as taxes than as fees.

For user fees, advanced technologies can be imagined which could accumulate information on miles driven, emissions produced, facilities used, etc., and then be read by scanners at the pump, but these technologies are a long way from being available. In the meantime, simpler at-the-pump charges proportional to fuel use are the most likely approach, with simple vehicle identification technology (e.g., smart license plates) perhaps becoming available in a few years, allowing vehicle characteristics to enter the calculations. (The legal issues raised by the use of such technologies are outlined later in this chapter.)

In any event, charges on fuel sales probably would be subject to state constitutional provisions restricting the use of revenues (for example, transit operations may not be funded with these revenues.)

Vehicle Registration Fees

Vehicle registration "fees", currently a flat amount plus a market value component, could be modified to include fees for actual or estimated VMT, emissions, or other costs imposed through the use of the vehicle. As in the case of at-the-pump charges, such fees would be greatly facilitated by still-to-be-developed advanced technologies. Simpler methods could be

used, however. A VMT fee, for example, could be justified as a (rough) charge for road use, and levied on the basis of owner/lessee-reported odometer readings at the time of vehicle registration (where the registration record would include previously reported odometer reading and the fee would be based on the difference in readings). Since under-reporting could be a problem, such an approach would likely require a carefully designed set of enforcement provisions, including sealing the odometer, requiring tamper-resistant odometers, requiring periodic odometer inspection and third-party reporting of readings (e.g., by inspection/maintenance technicians), providing for a penalty or fee for a non-functional odometer, etc.

As a second best strategy an average VMT for vehicles of a particular type and age could be attributed to the vehicle and used as the basis for the fee. However, because of individuals' variable driving habits, such a "fee" might be subject to challenge. Even if the fee were collected in arrears, paid at the time of registration and based on miles driven the previous year, it might be challenged if based on VMT alone, since the burdens created and benefits conferred are commensurably different depending on the facilities used, driving conditions, and so on. For example, persons who drive predominantly on surface streets could challenge portions of a fee allocated to the freeway system, and vice versa, though the agency might be able to successfully defend this approximation as reasonable under the circumstances.

An agency might, however, be successful against such challenges by establishing the reasonableness of its classifications. For example, the use of average VMT estimates for a particular vehicle type and year might be defended on the grounds that the VMT estimates are based on a statistical sample of vehicles in use in the state. A provision allowing for the estimate to be periodically "corrected" based on an actual VMT reading, e.g., at the time of vehicle registration or sale, also would offer evidence of reasonableness.

One issue would be how the VMT fee would be justified - how nexus would be established. If the VMT fee were to be used to pay for road improvements, double-charging might be an issue. The need to show costs imposed or benefits conferred may require a distinct showing.

separate from other existing charges. For example, if a road were built and maintained with assessment district funds (where persons within a given area are levied a fee for the road based on benefit conferred), a VMT fee to recompense for use of the road could not be justified, although an additional fee for extraordinary repairs, or for emissions damages, might be. Of course this is a legal issue only if the charge is characterized as a fee, since if treated as a tax double-charging is irrelevant.

An emissions-based registration fee might be levied on each vehicle in an amount necessary to compensate for the damage caused by pollutants created by the vehicle. The vehicle's emissions could be measured at an annual or biennial vehicle inspection testing (with, however, considerable possibility for inaccuracies and/or fraud).⁶ As in-use vehicle monitoring technology improves, emissions might eventually be tested on a continual basis. This might be accomplished through roadside remote sensors or on-board emissions monitors. The critical issue then would be the quantification of the cost of pollution caused by a particular vehicle. That is, what is the monetary cost of damages attributable to a pound of NO_x?

Alternatively, an emissions fee could be based on CARB/EPA estimated average emissions for the type of vehicle and model year. As in the earlier VMT example, a fee based on such averages rather than actual vehicle performance might be challenged on the ground that a particular vehicle was cleaner than others of like year and type and, hence, the fee is a tax. The defense, however, would be that such a classification is reasonable, the courts would be likely to permit a certain latitude in establishing the presumed impacts of a particular class of vehicles. The defensibility of using such average data would be buttressed by frequent surveys of actual emissions levels of a sample of vehicles (a strong evidentiary basis for the emissions level), as well as by the availability of fee adjustments if a car is tested and found to be substantially cleaner than the average.

⁶ Knowing that their vehicle registration fee would be lower if their car is clean at the time of inspection would give motorists an incentive to have repairs or other adjustments made just before the inspection takes place. The resulting measure would not necessarily be representative of average emissions during the year. (At the opposite extreme, consider the hapless motorist whose vehicle emissions control, unbeknownst to her, breaks down just before the inspection takes place.)

A "tax" based on emissions could be more flexible than a fee in that it could be arbitrary in amount, but differentiation between vehicles of different types and ages would still require a rational basis for distinctions to avoid equal protection concerns. Under California law such a tax would also be subject to Article XIX, section 2, unless it were imposed under the Vehicle License Fee Law, in which case section 2 would not apply (Art XIX, § 7)

With either a fee or a tax, a heavily polluting vehicle might incur a charge that approaches or actually exceeds the value of the vehicle. In these circumstances the question will arise, does this amount to a regulatory taking? The California Constitution Article I, section 7(a) and the 14th Amendment of the U S Constitution provide that persons may not be deprived of property without due process. Here, the result will depend on the reasonableness of the charge and the fairness of the process through which it is imposed.

A second issue concerns the potential for such a fee or tax to amount to an impairment of contracts - for example, where an existing fixed price contract does not contemplate a substantial new charge.

It should be noted that the vehicle registration fee would not reach out-of-state vehicles without substantial change in state law and increased enforcement concerning treatment of vehicles temporarily in the state. While provisions for implementing charges could be devised, such provisions may not discriminate against or unfairly assess out-of-state vehicles or interfere with interstate commerce.

The expenditure of proceeds from such vehicle registration fees would probably be subject to California Constitution Article XIX, Section 2. Thus, in order to be classified as "fees", the proceeds from such a program would have to be allocated to remediating the problems caused by such pollutants. However, as is the case for fees or taxes on fuel sales, permitted uses of the revenues could be fairly broadly encompassing and still pass a reasonableness test.

11.5 Other Legal Issues: A Brief Comment

The preceding discussion shows how various transportation pricing strategies might be implemented, with some effort, under existing laws which limit taxes, set strict standards for justifying fees, and restrict use of funds. Other legal issues also will be raised by these strategies, however. Not infrequently, questions about unfair treatment of different user groups, invasions of privacy, and the like have significant legal as well as political components. These issues are discussed here briefly, a more specific discussion would require the development of specific proposals to be evaluated.

-- Do Transportation Pricing Measures Create Unreasonable Distinctions Among Transport Users?

Many transportation pricing measures would distinguish transport users in a variety of ways - whether they are using facilities which are congested or not, whether they travel alone, whether their vehicle gets high or low gas mileage. Questions may arise about the legality of these distinctions, since federal and state constitutional provisions limit unreasonable or arbitrary classifications or differential treatment of persons. Article I, Section 7(a) of the California Constitution and the 14th Amendment to the U.S. Constitution provide that no person may be denied equal protection of the laws. The ban against unreasonable distinctions does not, however, prevent classification by the Legislature or require that statutes operate uniformly with respect to persons or things which are in fact different. Classifications are valid unless unreasonable or arbitrary.

Similarly, California Constitution Article I, section 7(b) and the 14th Amendment stipulate that no citizen or class of citizens may be granted privileges or immunities not granted on the same terms to all citizens. As with the equal protection clause, however, this does not

prevent classification by the Legislature or require that statutes operate uniformly with respect to persons or things which are in fact different

Finally, California common law provides that the highways within the State are deemed to be public roads held in trust by the State. All members of the public have the right to use highways, subject to reasonable police regulation. (Ex parte Daniels (1920) 183 Cal. 636, 639) Here again, this does not prevent reasonable classifications for taxation or fee purposes. For example, classifications differentiating trucks and automobiles, single occupancy vehicles and high occupancy vehicles, and so on have been justified in the past.

In general, then, distinctions among users are acceptable as long as the classifications are reasonable.

-- Do Monitoring Aspects of Transportation Pricing Measures Invade Privacy or Constitute Unreasonable Searches?

The development of transportation pricing strategies will depend in many cases on the monitoring of vehicles and their use. Monitoring may rely on very simple methods, such as mandatory reporting of vehicle odometer readings at time of registration, vehicle inspection, and sale, use of parking tickets which record time of entry and exit, and so on, to approaches which apply advanced technologies such as toll tags, video imaging, or smart license plates together with systems of roadway sensors which can identify when a vehicle crosses a certain point or measure in-use emissions. Whether high tech or low, monitoring approaches raise concerns about potential violations of state and federal constitutional bans against unreasonable searches and protections of the right of privacy.

Would monitoring of emissions, VMT, or highway use constitute a search within constitutional meaning of the term? Article I, Section 13 of the California State Constitution and the 4th Amendment of the U.S. Constitution provide that there may not be unreasonable searches of persons or their effects. However, there is no "search" in the

constitutional sense unless there is an invasion into some area reasonably regarded by the victim as private (Katz v United States (1967) 389 U S 347, 351, see also People v Hyde (1974) 12 Cal 3d 158, 166 [searches conducted as part of regulatory scheme with administrative purposes rather than as part of criminal investigation to obtain evidence of a crime need not necessarily be supported by probable cause].)

Certain monitoring approaches might also raise concern over invasion of privacy Under Article I, section 1 of the California State Constitution, privacy is an inalienable right, and this right is broader than the federally recognized right of privacy (City of Santa Barbara v Adamson (1980) 27 Cal 3d 123, 130 n 3) However, in matters relating to governmental intrusions into privacy, the right does not arise where the individual does not have a reasonable expectation of privacy (Wilkinson v Times Mirror Corp. (1989) 215 Cal App.3d 1034, 1046-48)

The privacy issue with respect to those who voluntarily agree to participate in transportation pricing by having sensor devices placed in their cars will be a matter of contract. The incentive for contracting to have devices placed in their cars is that they need not stop at toll booths but can be charged automatically The implanting of the sensor devices in their automobiles can contractually be conditioned upon the agreement that the manager of the highway may monitor their vehicles for the purposes of collecting the correct tolls The uses to which this information can be put should be limited, but probably could include transportation planning and forecasting as well as direct billing of users

A more difficult issue is when the surveillance devices are used to identify motorists who have not voluntarily agreed to such surveillance However, while motorists may claim that their privacy is being invaded, it is unlikely that such claims would have merit, so long as the monitoring was for an authorized public purpose

Overall, invasion of privacy and unlawful search claims are unlikely to have legal merit as long as the transportation pricing measures are well designed and implemented

-- Would Standardizing Monitoring Equipment Raise Intellectual Property and Anti-Trust Issues?

A technology which will permit several transportation costs all to be billed to a central account will in the end be more economical. For example, if an individual passing through the toll plaza at the San Francisco-Oakland Bay Bridge can receive a bill also containing charges incurred in using the Golden Gate Bridge, operated by a different authority, the cost of the monitoring and billing systems will be reduced and convenience to the motorist will be increased. Parking charges at public and private facilities also might be added to the same bill, further increasing convenience and efficiency. Consequently, rather than setting up competing technologies on different facilities, government may wish to ensure that technologies are compatible.

In order to do this, it will be necessary to establish certain rules about the "architecture" of any systems which will be used and to set forth other criteria in vendors' contracts which will not permit normal intellectual property rules to get in the way of unifying this technology. Any system on which several vendors are agreeing to the standards also raises anti-trust issues. These latter issues can normally be eliminated by government's insistence on certain standards, relieving the private parties from any accusation that they are conspiring to eliminate competitors. However, the seriousness and complexity of the issues mandates that detailed attention should be paid to them once specific proposals are on the table (Nossaman, Guthner, Knox & Elliott, 1993a). Finally, the development of technology carries with it a possible allocation of tort liability to third parties for property damage or personal injury. Sovereign immunity and insurance can be ways of dealing with these concerns (Nossaman, Guthner, Knox & Elliott, December 1993b,c,d,e).

12. Implementation

12.1 Overview

Designing a transportation pricing measure which is estimated to have the desired impacts, is acceptable to the public, and can pass legal muster is a major undertaking. However, a well designed, politically and legally feasible measure is only a starting point. Successful implementation of the measure requires that attention also be given to a number of other issues. This chapter provides an introductory discussion of such issues.

Implementation planning activities typically include resolving who will be responsible for various implementation steps, what specifically they will be expected to do, what funds they will have to pay for their activities, when they will be expected to have carried out each step, where specifically the measure is to be implemented, what objectives it is to be measured against, and how it is to be enforced, monitored, evaluated, and revised as necessary. Specific items that in most cases will need to be dealt with include the following:

- o deciding which details of the measure should be specified in its authorizing legislation (if needed) and which ones left to implementing agencies (and/or private entities) to develop or refine
- o determining what organizations - public or private - will be responsible for development of the measure and its various implementation elements, including monitoring, enforcement, evaluation, and periodic updating or revision
- o providing funding for the initial planning and implementation of the measure, or re-allocating existing funds for this purpose (even revenue generating measures generally require up-front planning and implementation expenditures)
- o establishing a schedule for detailed planning and initial implementation

- o assigning responsibilities for monitoring implementation and possibly, for periodically reporting progress to decision-makers
- o defining violations of the measures, classifying the offenses and penalties (e g , civil or criminal, points against the driver's license, fines, etc), and providing for enforcement against violators (who is responsible, how enforcement will be paid for, etc)
- o developing performance objectives and criteria for evaluating the success or failure of the measure
- o evaluating the measure's effectiveness over time and making or recommending adjustments if necessary or desirable (including periodic price adjustments)

Each of these tasks involves consideration of existing organizations' current responsibilities, staff skills, and experience, assessment of the compatibility of the new assignment(s) with organization missions or outlooks, evaluation of the costs and benefits of assigning responsibility to an existing unit, potentially changing its mission and scope of control, vs creating a new organization, and the assessment of the need for and likely costs and benefits of coordinated involvement of multiple organizations or multiple levels of government. Different transportation pricing strategies would impose different demands on implementers and so each implementation plan must be tailored to the specifics of the case.

The chapter does not attempt to recommend a "best" implementation strategy, since that is not only context-specific but depends to a considerable degree on the results of a lot of hard work with elected officials, business and community groups, and other stakeholders. The work program for this study called for the project sponsors and advisory committee members to carry out the implementation planning task as a joint effort with the authors. However, although the subject was discussed at several meetings, the sponsors and advisors chose to leave this task entirely to the authors. Many of the committee members felt that they lacked the authority and organizational and public support to seemingly commit

their organizations to a specific set of preferred actions, and should not in any case do so until their own planning and outreach efforts had been carried out. Without such specifics, of course, cost analysis and other aspects of implementation planning can only be done at a general level or using scenarios and examples. We do that here, leaving the details and the choices for local planning processes to work out.

12.2 Implementation Approaches

The speed at which implementation of a transportation pricing strategy occurs, the magnitude of the change involved, and the scope and scale of the introduction all have important institutional and administrative implications. A program could be implemented all at once or gradually, the price could be gradually increased or simply changed to the desired level, the measure could be introduced on a limited basis or everywhere at once. Each option and combination of options offers different opportunities and presents different problems.

One possible approach involves the gradual implementation of price increases on an areawide basis. For example, an emission-based vehicle registration fee might initially involve a very small charge, e.g., zero for the cleanest cars, \$5 for the average vehicle, and up to \$15 for the dirtiest vehicles. The initial fees could be accompanied with a public education effort designed to inform the public of the actual cost of vehicle emissions and ways individuals could reduce the costs they impose. Then, over time, the fee could be increased to levels commensurate with actual costs.

A gradual but areawide approach also could be used for measures designed to replace another program, for example, phasing out fuel taxes or transportation sales taxes and replacing them with VMT fees. Initially the VMT fee could be implemented at a modest level, perhaps a penny per mile, implementation would allow administrators to test out their collection mechanisms, accounting and auditing functions, and the like, and to make

corrections as needed. Once the new systems were running smoothly, the VMT fee could be raised to its intended level and the other funding sources terminated.

Large scale but gradual implementation would require careful building of a coalition supporting the pricing strategy beginning in the planning stages, and nurturing of the relationships and agreements over an extended period. It also would require an active public information and education program so that citizens understand where the program is heading and why. A possible downside is that the modest first increments of the program may not have the same impacts as later phases. For example, a \$10 per year vehicle emissions fee is unlikely to generate much of a reaction, the amount is too small to generate concern for cleaning up one's vehicle, nor is it large enough to induce many people to seek ways to avoid compliance. A fee of up to \$200-\$400 or more would surely produce different responses.

A second implementation approach would rely upon capturing opportunities to introduce pricing in particular market niches, building support for more widespread pricing based on the results of those projects. Participation would be both narrower (because fewer are directly affected) and more focused (because the project is more limited in scope). The latter approach is certainly more in keeping with the demonstration project tradition, and seems simpler than the extended gradualism of outlined earlier. The problem with this demonstration project approach, however, is that it may have unintended side effects in other parts of the system - diverting traffic to an underpriced parallel arterial and creating serious congestion there, for example - that could create a very bad, and misleading, public impression of pricing and the effects it would have if implemented more broadly.

Regardless of which implementation strategy is selected, there is an expectation that transportation analysts will be able to predict the impacts of transportation prices reasonably accurately. Hence implementation planning must be closely tied to analysis of alternatives, both quantitatively and qualitatively. As earlier chapters explained, some impacts and issues can be dealt with through models and data analysis, while others require legal, political, and administrative know-how.

Models will not always be able to produce the quantitative results sought. Even when the issues are ones susceptible of resolution through technical analysis, in many instances available modeling capabilities are not up to the task. In part these are correctable problems. For example, many traffic assignment models in common use rely on only travel times, omitting travel costs, prices (such as tolls or congestion fees) are not explicitly represented. Many models do include price as a variable in mode choice, but theory says that price also would affect destination choices, trip generation rates, auto ownership levels, and in the longer term, location choices, and few models currently represent these linkages. Price, of course, is relative to income (higher income people being less sensitive to out-of-pocket cost), so income should be explicitly represented in transportation models. Here, too, though, many models fall short. Such models will have to be substantially improved if they are to deal with pricing strategies in a believable way, but we know how to make the improvements.

Other modeling and forecasting limitations are less easily overcome. For example, even advanced modeling systems represent the choice of what time of day to travel only crudely, modeling of land markets is only sketchily done, emissions calculations reflect an average pattern of accelerations and decelerations that may only roughly represent actual travel characteristics on particular facilities. Additional research and model development would be required to overcome these limitations.

Still, the key issues will be how to select reasonable first steps and assure that they are not misleading or even harmful, and how to assure that the equity issues are dealt with. In this regard a fairly simple technical analysis backed up by a carefully reasoned, almost certainly qualitative, analysis of other key issues of concern is probably the best course of action. Carrying out these analyses with participation of interest groups who would be affected by the policy changes would increase the chances of success, by helping the various parties to find points of agreement and to understand the tradeoffs that may need to be made to move ahead.

12.3 Opportunities for Implementing Transportation Pricing Strategies

In part, successful implementation depends on good timing. Sound and sensible proposals can be rejected if they are introduced at the wrong time, and worse yet, such failures may block further attempts at implementation for a considerable period. Selecting a time when implementation can be easily accomplished and/or when it solves a critical public problem can be a key to success.

Along these lines, a number of commentators have argued that the best opportunities for introducing congestion pricing will occur when new toll roads are built and when toll increases are considered for currently tolled facilities (TRB, 1994). In each case, the congestion pricing component of the toll could be an added feature rather than the major focus of the policy. Following similar reasoning, opportunities for introducing a VMT fee may be highest during public debates over how to address a transportation funding shortfall or replace a sales tax that is about to expire. Emissions fees might be introduced to replace an ineffective or unpopular transportation control program or as an element in a vehicle emissions inspection program, included in return for fewer requirements on cars whose emissions controls are still under warranty. A parking tax might be implemented as an element of a local government's specific plan, a parking fee could be part of a traffic impact mitigation program.

As suggested earlier, demonstration projects can be a reasonable way to test out the impacts of certain measures. Carefully designed, they can provide solid data on travel behavior, transportation impacts, and their environmental and energy consequences, and can offer insights into larger social and economic responses (though measurement problems are likely to prevent a fully controlled experiment). In addition, in practical terms, demonstration projects may be the only way to proceed, because policy-makers and the

public may be willing to try a demonstration project, or a series of them, for proposals about which they have reservations too large to permit unrestricted implementation

A certain amount of caution is in order about what can be learned from project-level implementation, however. Consider the following hypothetical case of a new toll facility built at the suburban fringe. Residents and property owners in the suburban area are in broad support of highway improvements and agree to building the new facility as a toll road, believing that it is the only way to quickly obtain the funding for a significant capacity expansion. As part of the project design, revenues are committed not only to pay for the facility but also to offset any negative impacts it creates, for example, relocation assistance, sound walls, buffer parks, landscaping, commute alternatives programs, ridesharing services, and shuttle buses are to be funded with part of the revenues. A peak/off-peak price differential is introduced as a way to assure sufficient revenues and avoid congestion on the new facility and is accepted as an element of the project's design without generating significant public reaction.

The resulting project pays for itself and successfully increases public benefits both for those who choose to use the new tolled facility and for those who remain on previously available routes. (The latter are better off because congestion declines over the entire area network with the provision of the new toll road capacity.) Overall, the assessment of the project is highly positive, and indicates that similar projects are also likely to be successful.

However, if ultimately congestion pricing is of greatest interest on existing facilities in built-up areas where capacity expansion would be difficult or impossible, the lessons learned from our example may be only partially relevant and in some cases could be misleading. In the built-up area, pricing an existing facility could divert traffic to already congested routes, and without additional capacity in the system traffic conditions could get worse for some. Impacts could be far more extensive in a built up area, and means of compensating those harmed could be harder to devise and more complex to evaluate. In short, the different situation would produce different issues and impacts and make the analogy to the demonstration project a tenuous one.

This example illustrates the need to select demonstration projects that will serve as representative examples, and to have a sufficient number and range of demonstrations to cover the range of implementation contexts of concern to the program

12.4 Specific Implementation Issues Raised for Each Transportation Pricing Measure

In addition to the general considerations outlined above, which are broadly applicable, each transportation pricing measure raises its own set of implementation issues. Here we briefly touch on a few of them, as a guide for future planning efforts

Congestion Pricing

-- Key Implementation Issues

Probably the biggest issues with congestion pricing are how high to set the fees and how often to vary them. A link-by-link variable pricing scheme would probably be the most efficient, but it would also might be extremely difficult to explain to the public, administer, or enforce. Deciding what to do with the revenues of congestion pricing would be another major issue, if the focus group and interview findings indicating conflict over appropriate expenditures hold up.

-- Implementation Steps and Time Frame

The federal limitations on tolls substantially restrict congestion pricing to existing toll facilities (in California, bridges), to new toll roads currently under development, to any demonstration projects that might be approved and implemented, and possibly to certain

non-federal-aid facilities Unless the facilities in question fall under one of these exceptions implementation of congestion pricing would appear to be stymied.

Demonstration projects now underway should offer some insights into the likely implementation steps and time frame for various congestion pricing schemes, although for the reasons stated earlier in this chapter extrapolation from the cases must be done only to comparable situations

-- Possible Assignment of Lead Responsibility for Implementation

Existing agencies such as Caltrans or the MPOs could administer a road pricing scheme, but would need to add personnel MPOs have limited experience with toll administration (though some have roles in toll analysis, toll setting, and revenue allocation) and until recently Caltrans' experience was limited to conventional tolling approaches and demonstrations of new technology (Caltrans is now a partner in the S R 91 demonstration project)

The use of prices to manage congestion would be a departure from previous approaches used by public agencies, and conflicts with existing agency missions could arise, which might lead to pressure for creation of new agencies specifically dedicated to this policy. An alternative approach would be to contract for private operators to run the pricing program, as is being done for S R 91 and for several facilities in other states

-- Technology Required for Implementation

Congestion pricing could be implemented with conventional toll booths, although delays at the booths would be an issue at locations where there is not enough room to implement a sufficient number of channels to avoid congestion

Automatic vehicle identification/electronic toll collection (AVI/ETC) technologies are not strictly necessary but have proven highly beneficial in overcoming the toll booth delay issue. Either debit cards or vehicle identifiers (or both) are already available and have been implemented on toll roads in a number of states including Texas, Kansas, and New Jersey.

AVI/ETC technologies would be the only practical way to price all the facilities in a corridor, freeways and arterials. Such multi-route pricing might be necessary to avoid undesirable levels of traffic diversion.

Parking Pricing

-- Key Implementation Issues

As earlier chapters have illustrated, a variety of measures fall under the general rubric of parking pricing. Specific measures could range from a surcharge on all parking arrivals and departures during the peak periods, designed to recoup the cost of congestion and environmental damage, to changes in the tax treatment of parking benefits, designed to alter supplier as well as consumer behavior. Implementation issues will depend heavily on which of the many possibilities is selected.

A major issue is how to design a parking pricing strategy that actually would affect travel behavior. For example, a surcharge on employee parking would change travel choices if the employee pays the surcharge, but not if the employer covers the cost. Similarly, elimination of employer tax deductions for parking provided to employees would alter travel choices only to the extent that employers take steps resulting in employees paying for parking.

Probably the biggest issue facing parking pricing implementation, however, is that in most metropolitan areas, responsibility for parking currently is dispersed among scores of government agencies and hundreds of private owners and operators. Devising a policy that will work given such an institutional context could be a very big challenge.

-- Implementation Steps and Time Frame

Specific steps and the time frame for implementation are highly dependent on the specific strategy or strategies selected. Many parking pricing strategies would require policy formulation, detailed analyses, drafting of ordinances, preparation of staff reports, environmental review and possible preparation of a detailed environmental impact report, and public hearings and other outreach efforts, implementation of such strategies could take a year or more, and follow-up outreach efforts, inspections, enforcement actions, and evaluations would be needed. Many other changes in parking ordinances and regulations could be developed and implemented administratively, perhaps requiring six months on average. If local actions are to be coordinated on an areawide basis a long lead time would almost certainly be required (and success can by no means be assured.)

Some strategies most likely would be phased in over a period of several years, e.g., provisions that leases must separately identify parking costs, and possibly provisions removing parking subsidies' tax deductibility.

-- Possible Assignments of Lead Responsibility for Implementation

Most parking is privately owned and operated, although government also is a provider of both on- and off-street parking. Changes in parking pricing policy could arise as a matter of private sector / government owner-operator decisions (perhaps in response to tax policies or other incentives and disincentives) or could be induced or imposed by changes in government rules and regulations. Parking regulations are generally considered to be a local government responsibility, although state legislation establishes much of the basic framework (including tax provisions and other basic policy). However, some forms of parking pricing, such as a surcharge or impact fee on employee parking, could be implemented by a regional agency such as an air district or an MPO if that agency had the legal authority and political will to do so.

Requirements for employer-based trip reduction and parking cash-out provisions appear to have generated a certain amount of interest in parking pricing among employers, although government retreat on these policies has removed some of the earlier incentive and many employers remain reluctant to terminate existing free parking benefits in any case. Employers might be more interested in implementing parking pricing if there were tax or other incentives for them to do so. For example, employers that charge market rates (or some minimum rate) for employee parking might be exempted from other traffic mitigation requirements, or might be allowed a lower traffic impact fee, on the grounds that parking pricing would be the most effective strategy available to most employers.

-- Technology Required for Implementation

Modern computer-based parking control equipment can simplify the implementation of parking pricing strategies, particularly ones with complex fee structures based on time of

day, vehicle occupancy, validation, etc. However, pricing strategies are routinely and successfully implemented without such technologies

Enforcement is somewhat more complicated where record-keeping is not computerized. However, hand-held-computers for vehicle identification and ticketing are already in widespread use in parking operations and have greatly speeded enforcement, improved the accuracy of the data base, increased yields from tickets, and reduced opportunities for evasion (previously time limits were commonly evaded by moving the vehicle a few spaces or removing tire markings). AVI and/or ETC equipment would speed the effort even further.

Fuel Tax Increases

-- Key Implementation Issues

From a technical perspective, fuel tax increases are in some ways the simplest of the transportation pricing measures to implement, because they are well tested and well understood. However, if the tax increases are to be based on cost internalization (e.g., adding the cost of pollutant emissions, etc. to the tax bill), a detailed and complex cost accounting and cost allocation effort may be needed.

-- Implementation Steps and Time Frame

Building support for fuel tax increases, especially ones characterized as at-the-pump fees, could be a major uncertainty in implementation planning. Typically it has taken several years for tax increase proposals to proceed to a vote.

-- Possible Assignments of Lead Responsibility for Implementation

The fuel taxes would probably be collected as at present. Assignments of responsibility over disbursements of the tax would likely be the major issue here.

-- Technology Required for Implementation

No new technologies are required for a standard fuel tax, although taxes with a variable component based on vehicle emissions or safety characteristics would necessitate additional vehicle identification and monitoring technologies. If gas station owners demand prepayment due to higher amounts involved, technologies that allow credit card or cash payment at the pump may become more popular.

VMT Fees**-- Key Implementation Issues**

VMT fees could be based on estimated averages for each vehicle type and age, or could be determined from odometer readings, roadside sensors, or on-board monitors. The specific design would depend on the objectives to be served, which could range from adding a charge to cover the costs of auto-highway externalities, to establishing a fee that would replace current transportation taxes. A broad characterization of the purposes of this strategy might generate more support than a simple "tax on mobility" could garner. Depending on the specific approach chosen, however, federal limitations on the imposition of tolls, discussed earlier, could apply.

-- Implementation Steps and Time Frame

VMT fees could be phased in or implemented all at once, on a facility basis, a regional basis, or a statewide basis. Over time, if alternative fuel vehicles begin to increase as a percentage of the vehicle fleet, the reasons for this means of pricing may be more obvious than they are now, and VMT fees might be more readily accepted as a supplement to or replacement for existing sources of revenue such as the fuel tax.

-- Possible Assignments of Lead Responsibility for Implementation

If a simple fee structure based on typical mileage ranges for a vehicle make and model were implemented, the VMT fee could be a straightforward add-on to motor vehicle registration and licensing, handled by the Department of Motor Vehicles or a private contractor. A more complex VMT fee requiring odometer readings, etc. might be implemented through the vehicle inspection and maintenance program. New technologies might allow direct billings to the vehicle owner or at-the-pump charges based on readings of on-board monitors, with either a public agency (probably the regional MPO or Caltrans) or a private firm (owner/operator of a private toll road using VMT fee pricing, or a contractor to a public agency) handling the program administration.

-- Technology Required for Implementation

Either a low-tech or a high-tech approach could be used to implement a VMT fee. For example, in a low-tech approach, VMT fees could be based on a simple schedule (in turn based on periodic surveys of motorists) listing average VMT per year by age of vehicle. A high-tech approach might depend on on-board electronics to keep track of VMT and to signal a reader in each filling station, thereby allowing an at-the-pump charge to be added with each refueling.

Emissions Fees**-- Key Implementation Issues**

Calculating the marginal cost of emissions of various sorts and translating these costs into per-mile equivalents is a complex task but one that is important to the credibility of this pricing measure. Designing the program to minimize the potential for fraud also could be very important.

-- Implementation Steps and Time Frame

Any near-term implementation probably would begin with a simple fee based on model year average emissions and odometer readings, perhaps supplemented by on-road monitoring studies. Over time, a more sophisticated treatment of emissions could be introduced as technologies for on-board emissions monitoring are proven and become widely available. However, given the slow turnover of the fleet, substantial market penetration by new technologies could take a decade or more following their introduction.

-- Possible Assignments of Lead Responsibility for Implementation

Programs could be designed and implemented by state agencies or could be handled by regional agencies such as air districts or possibly MPOs. Administration also could be handled under contract with a private firm or firms, who (for example) could provide the equipment for monitoring, carry out monitoring studies, handle billings, and so on.

-- Technology Required for Implementation

Both low-tech and high-tech implementation mechanisms could be designed. Implementation based on actual emissions (rather than a schedule of average emissions) would lead to a significantly more effective (but also more complex) fee implementation.

Tamper-proof odometers also would be highly beneficial to this program, as would remote sensors.

12.5 Costs of Implementing Transportation Pricing Measures

Like other elements of implementation, the costs of implementing transportation pricing measures largely depend on the specifics of design and the timing of implementation. However, in practically every case it should be possible to hold costs to a small percentage of overall revenues, generally no more than 5-10 percent.

Keeping costs of implementation low is largely a matter of using common sense in the design of the implementation plan. For example, a cost-effective implementation plan generally would use proven methods and technology rather than rely on previously untested approaches and new technology; innovations could certainly be tested as part of an implementation effort, but through a low-risk approach (for example, first trying the innovation out in a small-scale demonstration project). Also, cost-effectiveness requires that program designers select approaches that minimize administrative overhead, apply the measure only where it is effective and practical, use enforcement only to the extent that the added revenues produced exceed enforcement costs, and incorporate procedures for periodic update of prices, so that the effectiveness of the pricing measure is not lost to inflation.

As the preceding discussion indicates, timing will significantly affect what is feasible and practical over the next twenty years. Technological advances are likely to vastly increase the range of methods that can be cost-effective in implementing pricing strategies. For example, automatic vehicle identification, advanced traffic detection and management systems, video image processing, smart card billing systems, and on-board and roadside emissions monitoring devices are some of the technologies currently being implemented across the US and abroad that could have transportation pricing applications. As these technologies are refined and experience with them mounts, implementation strategies relying on advanced technologies are likely to be favored not only as more accurate but also as lower-cost than low tech alternatives. AVI and smart card technologies, for example, are already proving to be cost-savers for toll collection and could easily handle variable congestion pricing, parking charges, and VMT fees. Emissions monitoring devices are still in the early stages but are steadily advancing in accuracy and sophistication. Available technology includes the on-board devices that warn the driver of excessive emissions rates, currently being introduced to the vehicle fleet, as well as the remote sensing devices currently being used for monitoring and enforcement programs. Technologies are being developed that could record cumulative emissions, running time, etc., and could be available in the next 10-15 years (Sawyer, 1995 and 1996, personal communication.)

In the short term, however, simple methods which do not rely on advanced technologies are more likely to be implemented. As noted earlier, a fuel tax increase or a change in the tax treatment of parking could simply build upon existing programs. An emissions fee or a VMT fee could be based on average levels for each vehicle type and age, and collected through the vehicle registration process (which could be annual, or could be changed to a quarterly or even monthly billing.) Congestion pricing could be implemented on existing toll facilities by instituting a peak period toll surcharge at toll booths or on specially designated lanes open only to cars that agree to the tolls and to equip their vehicles with toll tags. Employee parking charges could be handled through payroll deductions.

Whether implementation occurs in the short term or in the longer run, then, it should be possible to design a fairly straightforward implementation strategy whose costs are modest

To illustrate this point, we consider in more detail the costs of specific ways in which each of our five pricing measures could be implemented

Congestion Pricing

In a study of road pricing for all limited access facilities in the Seattle region, researchers estimated that costs of collecting the tolls (including equipment, installation, maintenance, operation, and administrative costs) would average, at current rates, about one cent per vehicle mile traveled (VMT) over all VMT, or two to three cents per peak period vehicle mile traveled (Pozdena, 1994). The researchers expect that costs would substantially decline as equipment costs drop, as would be expected if road pricing comes into widespread use or if the equipment is used for other purposes such as traffic management.

The cost of installing toll collection equipment on single facilities varies considerably. Reported equipment costs per lane currently range from \$15,000 to \$100,000, the lower costs are for automatic vehicle identification (AVI) / electronic toll collection (ETC) only, while the higher costs include a manual toll collection component. AVI/ETC costs, including the costs of a "control center" for processing the AVI readings, are already dropping and are expected to further decline as the use of this equipment becomes more common, as expected.

Costs of toll facility operations and maintenance are similarly varied, ranging from less than \$5,000 per lane for AVI lanes to as much as \$200,000 per lane for manual toll booths. Clearly the AVI option, or a combination of AVI and automatic cash collection equipment, is the more practical approach for widespread congestion pricing. (See Pietrzyk, 1994.)

Suppose we have a five mile, four lane limited access facility on which we install a combination of AVI equipment and staffed toll booths, for a total capital cost of \$50,000 and an annual operating cost of \$100,000. If 4,000 vehicles per lane per day are subject to tolls (producing a total of twenty million tolled vehicle-miles per year on the facility), the facility

will generate \$200,000 a year per penny of toll per vehicle mile. With a one cent toll, \$50,000 in equipment costs could be paid off in the first year of operation while covering all operating costs and generating revenues of \$50,000. Subsequent years would generate \$100,000 in revenues. A congestion price averaging five cents per mile would, in the first year, produce gross revenues of about \$1 million and net revenues of some \$850,000. A single five mile dedicated lane with AVI access only would incur much lower expenses - first year equipment, operations, and maintenance of perhaps \$20,000 - and so would produce considerably more net revenue.

Of course, there is no specific reason why a one year payback would be necessary, the appropriate period for payback would depend on the useful life of the equipment and the cost of money, among other things. Since the useful life of tolling and monitoring equipment should be considerably longer than one year, calculations based on a one year payback are highly conservative. In addition, public ownership, operation, and management are not the only, and not necessarily the best, ways to proceed. Private provision of facilities and services, public-private partnerships, arrangements for leasing equipment from a vendor, and contracting for both equipment and program management are all options that deserve consideration.

Since equipment costs are fixed, the cost-effectiveness of congestion pricing would be greater if implemented on a facility for which pricing is justified for a number of hours each day, such as is the case with many toll bridges and major commuting corridors. If tolls were to become an accepted way of collecting general transportation revenues, perhaps replacing part or all of other taxes (sales, property, fuel) now used to fund transportation, cost-effectiveness would further increase.

Use of tolls as a general transportation funding mechanism also would be important to the cost-effectiveness of pricing on arterials. Pricing major arterials frequently will be necessary to avoid negative traffic spillover impacts from pricing limited-access facilities. However, urban arterials carry substantially lower volumes of traffic than limited-access facilities (a four lane facility carrying 25-45 thousand vehicles per day with 10,000-18,000 vehicles

during congested periods is typical), so costs of equipment would be spread over fewer vehicles than is the case on most limited-access facilities. At the same time, arterials present greater opportunities for toll avoidance if collection devices are sparsely distributed, so more equipment may be needed than in the limited access case.

Consider a four lane divided arterial with major intersections at quarter-mile spacing, carrying 32,000 vehicles/day (12,000 vehicles during peak hours). Conventional toll booths or automatic collection devices are impractical in this setting, so AVI equipment will be used. If it proves necessary to install AVI readers at every intersection, one per approach lane, four per intersection, to capture a sufficient percentage of trips, the cost per intersection of AVI equipment (at \$15,000 per reader) would be about \$60,000 (i.e., \$240,000 in capital costs per mile). Operating and maintenance costs would add some \$20,000 per intersection - \$80,000 in operating costs per mile per year.

Borne by the peak period users only, and assuming some 10,000 - 11,000 vehicles per day remain peak users, a charge of about nine cents a mile would be needed to recapture capital costs in one year. (Again, however, note that there is no magic in a one-year payback, or indeed in a system in which equipment is purchased rather than leased. Paid back over a ten year period at ten percent interest, a \$240,000/mi capital cost could be paid for with charges of about 1 1/2 cents per mile.) Operating costs would be about 2 1/2 cents per mile per year.

Clearly, the cost of pricing arterials is fairly high, at least compared to the cost of pricing limited access facilities. However, such costs are not so high as to render arterial pricing infeasible. Rather, they point to the need for careful consideration of the amount of equipment actually needed, recognizing the tradeoff between measurement of all vehicle movements vs. costs, and suggest that some arterials would not be priced unless the costs of equipment dropped substantially. Also, because the cost per vehicle mile of AVI equipment would be much lower if the cost applied to all vehicle miles, not just peak period miles, congestion pricing might be a special feature of general road pricing.

Note that the estimate of \$60,000 per intersection used for estimation purposes here is far in excess of the costs of automated traffic surveillance and control systems (ATSAC). For example the ATSAC system being implemented in Los Angeles has been estimated to cost about \$9,000 per intersection (\$7,000 in 1988 dollars), these costs include a proportionate share of control center costs. The equipment is estimated to have a fifteen year life and is being implemented at about 250 intersections per year (Los Angeles Dept. of Transportation, June 1987). Technological advances such as spread spectrum radio communications rather than hardwire connections are likely to further reduce these costs (Skabardonis, 1995). If the costs of equipment for arterial pricing were more like those for traffic control systems - i.e., lower by nearly a factor of seven - such pricing obviously could be used more readily.

Other costs associated with implementation of congestion pricing would include smart cards for each user vehicle, equipment to add money to the cards in a deduction system or, in the case of a billing system, to handle the billing, enforcement costs, and general program administrative costs. Smart cards or other vehicle identification devices currently cost from \$2 to \$60, depending on the type, read-and-write cards cost more than debit or read-only cards. In some toll road applications the user purchases or "leases" this equipment with a deposit, although elsewhere the card/transponder is provided free of charge with prepayment of a minimum balance. Toll road experience suggests that many agencies prefer a debit card (prepayment) approach rather than a read-only card with billing for charges, prepayment appears to avoid the burden of bill processing and bill collection. Debit cards nevertheless require some mechanism for replenishment of the card, either at fixed or mobile stations or through the mail. A variety of mechanisms for handling either billing or account replenishment could be utilized, in particular, this function could be a road authority function or could be handled by a private vendor, much as transit passes are now handled by transit agencies, banks, transportation commute stores, large employers, etc. A multi-purpose card, which would allow payment for tolls, parking, or a variety of other transportation services, is also an option.

Enforcement costs would need to be considered. High-speed video camera evidence is accepted in several states and abroad and is a relatively inexpensive way to enforce ETC violations. Alternatively, police enforcement can be used. Some attention may have to be given to guarding against illegally obtained or counterfeit toll tags, much as we currently have to guard against illegally obtained parking permits and transit passes and counterfeit credit cards. Levels of enforcement and fines for most violations could be set to be self-financing, the more serious offenses might be treated as thefts or as fraud.

Parking Pricing

Proposed measures which would reduce or eliminate tax deductions for employer-provided parking, make employer-provided parking a benefit taxable to the employee, etc. would increase state and federal tax receipts. Responses of employers and employees would be likely to vary with location, business type, employee income, and so on, the employer who stops leasing parking for employees because of the change in tax treatment would experience a reduction in paperwork, whereas the employer who continues to provide free parking but now must account for it in tax reporting would face increased costs. Such costs might amount to a few dollars per employee per year.

Shoup (1994) calculates the likely federal income tax revenues from a parking cash-out variant of this proposal at nearly \$1.2 billion a year, if implementation costs from all sources (employer record-keeping and reporting, government accounting, audit and enforcement, etc.) were to amount to \$6/employee a year - more than most experts believe these items would cost - and the program applied to 100 million workers, revenues would exceed costs by a factor of two.

Consider next a parking surcharge levied by an air district (or a transportation authority) on all daytime employee parking, defined as parking spaces utilized by employees between the hours of 6 am and 6 pm weekdays. A surcharge set at 25 cents to one dollar per space per

day might be thought of as a rough approximation of an emissions charge; a surcharge of \$1-\$5 might be thought of as a rough approximation of a congestion fee

The costs of implementing such a surcharge would vary substantially with the implementation design. A simple approach, and one that would cost relatively little to implement, would be to require employers to report the number of parking spaces they provide to employees each month and simply transmit the amounts due on an annual, quarterly, or monthly basis. Further, the surcharge could be collected on behalf of the responsible agency by an existing tax collection agency, avoiding the need for a special bureaucracy to handle payments, audits, enforcement actions, etc. As an add-on to existing reporting and collection activities, the marginal costs of the program would be quite low, probably in the range of five percent of revenues. (As with other fees collected via taxes, special provision would have to be made for those who are exempt from filing, the same would be the case if the fee were attached to a business license, etc.)

Such an approach would result in substantial revenues, and could be an important source of funding for transportation improvements to alleviate air pollution and/or congestion, but (as has been discussed elsewhere) its direct impact on travel behavior is less clear. Some employers might decide to pass the surcharge along to their employees, and some of the employees would likely reduce their parking use, but many other employers might decide to simply pay the surcharge as a cost of doing business, with no change in parking policy for employees.

If the intent is to require the employee-parking consumer to pay a government-mandated parking fee, a simple implementation strategy would be to require the employee to pay the fee directly. Because there is no existing mechanism for charging for parking in most locations, implementation of a fee might most easily be done in through a payroll deduction, to be transmitted with other income or payroll taxes and thence distributed to the responsible agency. There would be some added costs to the employer for accounting (somewhat higher than in the variant presented earlier) and some added costs to the tax collection agency, but again, these costs should be no more than a few dollars per affected

employee per reporting period. Cost-effectiveness would depend entirely on how large a parking charge was imposed, but if the administrative costs amounted to \$5 per month per employee and the parking fee was set at \$3/day (\$60-\$66/mo) costs would be 7-8 percent of revenues.

Fuel Tax Increases

A fuel tax increase is the easiest of the five transportation pricing measures to implement, all the mechanisms for collecting and disbursing fuel taxes are in place and changing the tax rate would be a very simple procedure. The costs of implementation would be accordingly low, a negligible percentage of revenues. A possible exception is that with a substantial tax increase, e.g., 50 cents or more a gallon, there would be the possibility of increased levels of tax evasion, smuggling of untaxed fuel, or other illegal activity. The costs of enforcement associated with such criminal activities are highly uncertain.

VMT Fees

Consider a VMT fee based on average annual mileage for the vehicle type and model year. Such a fee could be automatically included in the amount billed to each owner as part of the regular vehicle registration fee. A continuous vehicle mileage sampling program (or a continuous panel of vehicles) could be implemented to provide the basis for average annual mileage, and could be designed to produce statistically valid data on a statewide or regional level. Such a program might cost \$200,000 annually, including data sampling and analysis. (These data would have value in a variety of programs, including traffic management, energy conservation planning, and air quality planning.) If the VMT fee were applied to 20 million vehicles, the annual per vehicle cost of the VMT sampling program would be trivial, only a penny per vehicle. Similarly, costs of developing, testing, and implementing software and forms to calculate the fees and add them to each registration fee billing would be negligible on a per-vehicle basis.

A public information campaign involving mailings to each vehicle owner could be considerably more expensive. For example, a brochure providing an explanation of what the VMT fee is, how it works, and why it is being established might be mailed to each vehicle owner during the first year of the program at a one-time cost of, say, \$2.00 - \$5.00 per vehicle. This could be backed up with an information sheet inserted each year in the registration billing, at a cost of less than \$1.00 per vehicle including preparation and handling costs. With a modest one cent per mile VMT fee the typical vehicle would be assessed \$50 - \$150, so these costs are a small fraction of revenues - not more than 10 percent in the first year and less, perhaps one percent, thereafter.

Additional collection and enforcement costs could be covered by late fees and perhaps fines for seriously late payments and other minor violations, although some types of illegal activity would probably be treated as criminal offenses.

A VMT fee also could be implemented as a toll, either for specific facilities or on a broader basis (See the discussion of implementation costs under congestion pricing for cost implications)

Emissions Fees

An emissions fee calculated based on average data (emissions per mile for the vehicle type and model year times average VMT for the vehicle type and model year) could be implemented much like the VMT fee just described, again with costs amounting to a small fraction of revenues. An emissions fee based on the emissions measurement taken at the time of the vehicle's inspection and maintenance test also could be done fairly simply - for example the fee could be billed upon receipt of the vehicle's mailed-back emissions test certification, or by electronically transmitting the emissions test as it is performed to a file which then would be linked to the registration data for the vehicle.

Suppose the design of such a program, including revision of billing processes and so on, costs one million dollars. Applied to a fleet in of more than 20 million vehicles, this cost would amount to less than a nickel a vehicle. It should be possible to hold the annual cost per vehicle of public information, billing, collection, and enforcement to a few dollars per vehicle. Costs totaling \$5-10 per vehicle would require less than 5-10 percent of likely revenues for emissions fees set at a one cent per mile rate.

Emissions fees also could be based on in-use emissions, much like congestion pricing or VMT fees, by adding information on the vehicle make and model to determine the price per mile. A billing system could be used, or a debit card system might be devised in which the card was attached to a particular vehicle. The development of on-board vehicle emission monitoring equipment capable of accounting for cumulative cold starts, tailpipe emissions, etc , would allow for much more sophisticated emissions fees. As noted earlier, such equipment is currently being developed or is in the planning stages, costs are not yet known.

Implications for Cost-Effectiveness

For each transportation pricing measure discussed here, we have shown that it would be possible to design an implementation strategy which would be cost-effective. It should in general be possible to hold costs to no more than 5-10 percent of revenues even in the first year, in many cases much lower implementation costs should be achievable. Clearly, however, cost-effectiveness depends on the details of the proposed action. Specific, reliable cost-effectiveness calculations thus must await the development of a detailed program design.

To illustrate, however roughly, the magnitude of transportation pricing measures' effectiveness over costs, we have prepared a series of tables which describe implementation scenarios and associated implementation costs for the five pricing strategies. The scenarios and cost estimates are for the Los Angeles region in the year 2010. Table 12-1 sets forth assumed collection methods for the various measures, and describes the basis for the associated cost estimates, assuming that the capital costs of AVI/ETC equipment are fully allocated to each measure using them. (The capital costs are assumed to be amortized at 10 percent per year over a ten year period.) Table 12-2 then presents a series of cost-effectiveness and revenue generation metrics for the five measures using these assumptions. In Tables 12-3 and 12-4, an alternative assumption is made, namely that AVI/ETC capital costs have already been covered (for example, traffic monitoring and other advanced traffic operations programs might implement AVI technologies, which then could be used for ETC purposes.) Hence in these tables, only annual operations and maintenance costs are included.

Note that all of the scenarios created here assume low implementation costs. For example, the percent of gross revenues estimated to be needed for administration ranges from 1.2 percent for fuel tax increases to 15 percent for VMT fees (using Table 12.1 assumptions, administrative costs drop to 5.9 percent of VMT fee revenues using Table 12.3).

assumptions, and would drop to under 3 percent if the fee went up to, say, five cents from the 2 cents shown here) In an actual implementation, of course, any of these numbers could go up, or down, depending on the choices made by program developers These tables illustrate how much cost-effectiveness measures depend on the specifics of program design, since the numbers for the two high tech options change considerably depending on how equipment costs are allocated

The calculations also illustrate the difficulties in interpreting cost-effectiveness data For example, a simplistic reading of Table 12 2 would suggest that fuel taxes are more cost-effective than VMT fees However, that is because the table assumes that the administrative apparatus for the gas tax is already in place, and only small additional costs must be expended in implementation of the higher tax amount, VMT fees, in contrast, are assumed to be a new program requiring significant expenditures for implementation In Table 12 4, where both fuel tax increases and VMT fees are assumed to utilize facilities and procedures already in place, differences are much smaller

Cost-effectiveness numbers also are dependent on the uses to which net revenues are put. Treatment of the revenues are omitted here, which amounts to an assumption that the revenues will be spent such that the resulting benefits are at least as great as the costs to users (amounts paid) In such circumstances the revenues (amounts collected from consumers) are a transfer, not a real cost

12.6 Conclusion

Implementation planning for transportation pricing strategies needs to be carried out in an intensively participatory and well integrated planning process While implementation considerations should inform the earliest steps of planning and analysis, specific proposals must be on the table and stakeholders must be involved if a full analysis of implementation options is to be carried through to the selection of a feasible, equitable, desirable course of action In the absence of such specifics and without the committed participation of

stakeholders, we can only touch upon implementation considerations and offer scenarios. More specific analysis must await more specific proposals. Nevertheless, the chapter illustrates that means for implementing pricing strategies in a cost-effective way should be within reach.

Designing a sound implementation plan is not an easy matter, it requires attention to institutions and organizations, budgets and accounting, and it often involves tradeoffs between accountability and flexibility, technical precision and ease of implementation. Attention to these implementation issues should pay off, however, in a smoother, more credible, and more effective program.

**Table 12.1: Implementation Scenarios and Cost Estimates - South Coast, 2010
Example 1: Full Cost Responsibility for High-Tech Approaches**

Policy	Collection Method	Basis for Administrative Cost Estimate
Congestion Pricing	AVI/ETC equipment installed on a majority of the freeway and arterial systems, cards on all vehicles	About 18,000 arterial and freeway locations would have to be instrumented. Amortized annual capital costs for each location could be about \$2,000, with an additional \$5,000 for maintenance. Annual cost per vehicle (for ID cards and billing) could be about \$20.00. The annual administrative cost of congestion pricing thus might be \$346 million for the region's estimated 11 million vehicles.
Parking Pricing	Surcharge collected by the employer and transmitted as per payroll taxes	\$5.00 per worker per month, for about 10,000,000 workers (\$50 million total).
Fuel Taxes	Collected through existing mechanisms.	5 percent of revenue, for enforcement and information dissemination (\$186 million total).
VMT Fees	AVI/ETC equipment installed throughout the freeway and arterial systems, and on a portion of the collector system.	Cost of a congestion pricing system, plus an additional 18,000 instrumented locations (\$472 million total)
Emissions Fee	Collected by the DMV with the registration fee	5 percent of revenue, for enforcement and information dissemination (\$55 million total)

Table 12.2: Selected Cost-Effectiveness Estimates, South Coast - 2010
Example 1: Full Cost Responsibility for High-Tech Approaches

Administrative Cost (\$)		Administrative Cost Per.....				
Policy	Total Administrative Cost	Vehicle Mile Reduced	Delay Hour Reduced	Ton of ROG Reduced	Gallon of Fuel Reduced	
Congestion Pricing (\$.15/mile, peak only)	\$ 346,000,000	0 1162	1 5318	135607	1 1064	
Parking Pricing (\$3/day)	\$ 50,000,000	0 0222	0 8464	61050	0 5685	
Fuel Tax (\$.50/gallon)	\$ 186,000,000	0 0336	2 4441	98643	0 4205	
VMT Fee (\$.02/mile)	\$ 472,000,000	0 0833	5 1685	244360	1 9085	
Emissions Fee (avg. \$.01/mile)	\$ 55,000,000	0 0167	1 8068	21744	0 2965	

Total Revenue (\$)		Revenue Per.....				
Policy	Gross Revenue	Vehicle Mile Reduced	Delay Hour Reduced	Ton of ROG Reduced	Gallon of Fuel Reduced	
Congestion Pricing (\$.15/mile, peak only)	\$7,343,000,000	2 4662	32 5091	2877915	23 4811	
Parking Pricing (\$3/day)	\$4,151,000,000	1 8403	70 2666	5068376	47 1959	
Fuel Tax (\$.50/gallon)	\$3,724,000,000	0 6731	48 9340	1974979	8 4196	
VMT Fee (\$.02/mile)	\$3,144,000,000	0 5551	34 4273	1627683	12 7128	
Emissions Fee (avg. \$.01/mile)	\$1,106,000,000	0 3358	36 3326	437249	5 9628	

**Table 12.3: Implementation Scenarios and Cost Estimates - South Coast, 2010
Example 2: Partial Cost Allocation for High-Tech Approaches**

Policy	Collection Method	Basis for Administrative Cost Estimate
Congestion Pricing	AVI/ETC equipment installed on a majority of the freeway and arterial systems; cards on all vehicles	Assumes that instrumentation for vehicle detection would be in place for other purposes (no additional equipment needed) but that enforcement and information dissemination costs would be similar to those required for fuel taxes (\$186 million total)
Parking Pricing	Collected by the employer	\$5 00 per worker per month, for about 10,000,000 workers (\$50 million total)
Fuel Taxes	Collected through existing mechanisms.	5 percent of revenue, for enforcement and information dissemination (\$186 million total)
VMT Fees	AVI/ETC equipment installed throughout the freeway and arterial systems, and on a portion of the collector system.	Assumes that instrumentation for vehicle detection would be in place but that enforcement and information dissemination costs would be similar to those required for fuel taxes (\$186 million total)
Emissions Fee	Collected by the DMV with the registration fee	5 percent of revenue, for enforcement and information dissemination (\$55 million total)

**Table 12.4: Selected Cost-Effectiveness Estimates, South Coast - 2010
Example 2: Limited Cost Responsibility for High-Tech Approaches**

Policy	Total Administrative Cost	Administrative Cost Per.....			
		Vehicle Mile Reduced	Delay Hour Reduced	Ton of ROG Reduced	Gallon of Fuel Reduced
Congestion Pricing (\$.15/mile, peak only)	\$ 186,000,000	0 0625	0 8235	72898	0 5948
Parking Pricing (\$3/day)	\$ 50,000,000	0 0222	0 8464	61050	0 5685
Fuel Tax (\$.50/gallon)	\$ 186,000,000	0 0336	2 4441	98643	0 4205
VMT Fee (\$.02/mile)	\$ 186,000,000	0 0328	2 0367	96294	0 7521
Emissions Fee (avg \$.01/mile)	\$ 55,000,000	0 0167	1 8068	21744	0 2965

Policy	Gross Revenue	Revenue Per.....			
		Vehicle Mile Reduced	Delay Hour Reduced	Ton of ROG Reduced	Gallon of Fuel Reduced
Congestion Pricing (\$.15/mile, peak only)	\$7,343,000,000	2 4662	32 5091	2877915	23 4811
Parking Pricing (\$3/day)	\$4,151,000,000	1 8403	70 2666	5068376	47 1959
Fuel Tax (\$.50/gallon)	\$3,724,000,000	0 6731	48 9340	1974979	8 4196
VMT Fee (\$.02/mile)	\$3,144,000,000	0 5551	34 4273	1627683	12 7128
Emissions Fee (avg \$.01/mile)	\$1,106,000,000	0 3358	36 3326	437249	5 9628

13. Assessment

13.1 Transportation Impacts and Policy Effectiveness

How do transportation pricing measures affect travel behavior and transportation system performance? How effective are they in reducing congestion and emissions and in conserving fuel? Overall, the study found that these measures could have significant, positive impacts in each of the four major metropolitan areas of California

Congestion Prices Congestion prices sufficient to keep both freeways and arterials operating close to capacity (level of service D/E) were evaluated. During the peak periods of demand, such prices would average about 4 cents a mile in Sacramento, about 6 cents a mile in San Diego, about 9 cents a mile in the Bay Area, and about 10 cents a mile in the South Coast region. Actual costs would vary considerably from these averages, from zero (where there is little or no congestion) to as high as 75 cents to a dollar on the handful of highway links with the very worst congestion. Such charges would reduce overall VMT and PM₁₀ by only one or two percent, in most cases, because those who can do so would shift to their routes or times of day, however, emissions and fuel consumption reductions in general would be higher than proportional because less travel would be in stop and go conditions. Both prices and benefits would be higher in Los Angeles and the Bay Area than in San Diego and Sacramento, which are less congested.

Parking Fees A region-wide employee parking fee of a minimum of \$3.00 per day - approximately the minimum cost of providing an employee parking space in most metropolitan areas - was examined. (In areas where current parking charges are higher than the \$3.00 amount, the current rates were assumed to remain in place.) Such a fee for parking would result in a reduction of VMT and trips in the 2-3 percent range and a similar reduction in fuel use and emissions. Notably, the effect would be smallest in the Bay Area, because a higher proportion of that region's employees already pay for parking.

Gas Tax Increases: Two levels of gas tax increase were examined. A 50 cent increase would reduce VMT and trips by amounts ranging from 3.9 - 4.3 percent. A \$2.00 gas tax - an amount that would bring fuel prices to mid-range European levels - would reduce VMT and trips by 12-14 percent. Pollutant emissions reductions are approximately proportional to the reductions in travel. However, fuel consumption and greenhouse gas (CO₂) reductions would be significantly larger, ranging from 5 - 6 percent for the 50 cent tax increase to 31 - 33 percent for the \$2.00 tax increase. The difference between changes in VMT and changes of fuel use is because many consumers would purchase more fuel efficient vehicles (and would use their more fuel efficient vehicles more often than their less efficient ones). The more fuel efficient vehicles would help bring the cost of travel back down, hence overall travel (trips, VMT) and pollution (largely proportional to trips and VMT) would drop less than fuel use and greenhouse gas emissions.

Vehicle-Miles Traveled (VMT) Fees: Flat VMT fees were analyzed in a range from 1 cent to 10 cents per mile. Detailed results for 2 cents per mile indicated that VMT, fuel use, and all emissions would drop by about 4-5 percent. At 5 cents per mile, these performance measures drop by about 10 percent, and at 10 cents per mile they drop by nearly 20 percent.

Vehicle Emissions Fees: Two fee alternatives based on emissions were evaluated. In the first alternative, the fee would be based on the statewide averages of emissions per mile for a vehicle of the age and type being driven, multiplied by the vehicle's mileage accumulated since its last recorded odometer reading. This approach would charge older cars higher fees on a per mile basis, offset in part by the somewhat lower average mileage per year for these older cars. In the second alternative, the fee would be based on measured emissions and mileage based on the vehicle's odometer reading. This second alternative would result in much higher fees per mile driven for high emitters of any age, and only modest fees per mile driven for clean vehicles. Similarly, it would result in modest fees for a car that is driven a modest amount, and much higher fees for a car that is heavily used. For a fee set to average about 1 cent per mile, costs per vehicle would range initially from \$40 to about

\$400 per year under the first alternative and would range initially from \$10 to about \$1000 under the second alternative. With either alternative, the main impact would be on emissions, as many consumers would retire or repair heavy emitters to reduce their fees, and would continue (or resume) their previous driving patterns. VMT and PM₁₀ reductions of about 2 percent would result, but emissions reductions of as much as 4-8 percent for the first approach, and 15-20 percent for the second approach, could be obtained.

Joint Effects Combinations of the measures also were considered. A package combining congestion pricing, employee parking charges of \$1.00 per day, a 50-cent gas tax increase, a 2-cent VMT fee, and emissions fees based on statewide averages for each vehicle type (the first emissions fee approach described above) and model year would reduce VMT, trips, and PM₁₀ by about 8-9 percent, and would reduce fuel use, pollutant emissions, and greenhouse gas emissions by some 10-17 percent. A package with congestion pricing, employee parking charges of \$3.00 per day, a \$2.00 gas tax, a 2-cent VMT fee, and vehicle-specific registration fees would reduce VMT, trips, and PM₁₀ by about 19-22 percent and would reduce emissions and fuel use by 30-50 percent.

Land Use Impacts Changes in transportation pricing policies of the type and magnitude considered here are unlikely to significantly alter the rate of growth of the region, but they could alter patterns of development, principally by encouraging more compact growth around centers and more efficient travel choices. Location-specific impacts are likely only for those measures that result in differential price changes within the region, as congestion pricing and parking pricing might do. These location-specific impacts may be seen as positive or negative, depending on the viewpoint of those affected. Businesses, households, and local governments all can take steps to reduce the impact of land use changes and some of their responses may in fact alter the cost impact of the measures.

13.2 Equity Issues

Transportation price increases are especially a concern for low income people who have a limited ability to "choose" to pay the higher costs and hence would be priced out of routine use of certain high-cost travel options. Higher transportation prices also are a worry for moderate income people, especially those who have little flexibility about when or where they travel and hence might have to devote a larger share of their income to transportation.

A major finding of the study is that most households in the lowest income group - the one-fifth of the California households that make less than \$18,676 per year - would not be affected by charges for parking at the workplace or by congestion pricing. This is because few of these households contain a worker, and of those who do, a very high percentage use transit or walk to work.

Overall, the households in the lowest income quintile (lowest fifth) produce only about 7 percent of the VMT. However, they would be the most likely to change their travel behavior if transportation pricing strategies were implemented. The next-to-lowest income group, the quintile with household incomes between \$18,676 - \$34,518, would feel a moderate impact, but a substantial number of this group also commutes by transit or carpool or works off-peak hours.

The biggest impact of these policies would fall on middle income households, who currently tend to drive to work and have free parking. The highest income group also would pay more, although in all four urban areas it is this upper income group that is most likely to already pay for parking.

Gas tax increases also would fall most heavily on middle and upper income groups. Only about six percent of current fuel taxes are paid by members of the lowest income group,

while this group owns cars, they drive them only modest amounts. The twenty percent of the state's households in the second-to-lowest income group pay about 10 percent of fuel taxes currently, also reflecting their moderate use of their cars. Both groups would reduce fuel use, at least in the short run, if prices increase. Again, it is the middle and upper income groups that would pay most of the tax increases.

Because of data limitations, it is harder to say how vehicle registration fees would affect different income groups, particularly for the more complex policy options such as emission-based fees. (Data sets report auto age and the owner's household income, or auto emissions rates, VMT, and area of residence, but no available data set directly links emissions levels and the incomes of vehicle owners.) Nevertheless, the available data do provide some insights into equity impacts. Using data collected by Caltrans as part of a statewide travel survey, we find that about 55% of the vehicles over eight years old are owned by the upper middle and affluent households, mostly as second, third, or even fourth or fifth cars. The remaining 45% of the older cars are owned by the two fifths of the households with low or moderate incomes. To the extent that vehicle registration fees fall most heavily on these older vehicles, they also would fall somewhat more heavily than proportional on low and moderate income households.

Equity can also be examined by looking at the distribution of impacts by location in the region (e.g., central city vs. suburbs), by gender of the traveler, by race and ethnicity, and so on. For the policies considered, impacts do not appear to be strongly place-specific. Furthermore, exploratory analyses done for this study show that the distribution of impact is more strongly dependent on income than on demographic factors, i.e., differences between the sexes and among racial and ethnic groups basically track income differences.

13.3 Using the Revenues from Transportation Pricing Strategies

One way to overcome concerns about adverse effects of transportation price increases is to use the funds raised from the pricing strategy to improve the transportation system. For example, congestion pricing revenues could be used to remove bottlenecks, fund traffic operations improvements such as coordinated traffic signal timing and faster accident clearance, or otherwise increase transportation capacity and eliminate design problems which lead to congestion. Such revenues also could be used to support transit improvements or carpool and vanpool programs, better alternatives to driving would make increased costs for the auto more palatable.

Revenues also could be targeted to particular problems or needs. For example, some or all of the net revenues generated by emission fees could be earmarked to help low-income households clean up their dirty vehicles or replace them with cleaner used cars. In the latter case a cash payment could be provided, or a voucher might be offered, permitting the recipient to buy transit passes or to obtain another car at a subsidy which would vary with income (following the model used in housing programs). The vehicle repair element of this program would have the added benefit of stimulating employment. The vehicle buy-back or voucher program would require detailed planning to avoid excessive costs (for example, it might be necessary to limit buy-back eligibility to individuals, limit applications to one per individual, and require that the vehicles must have been registered in California for at least 120 days at the time of program adoption). Everyone could benefit from a well-designed program of this sort: the low income household would have a cleaner, better running car, and the general public would have cleaner air.

A limited number of analyses were carried out as part of this study to examine the effects of "mitigation measures", i.e., implementation of strategies thought to be able to offset certain adverse impacts of price increases. The mitigation measures were proposed by the advisory committee to the study and were based on the long-range transportation plans of

each region. The mitigation measures, analyzed in conjunction with parking charges, gas tax increases, and congestion pricing, focused on transit improvements which would reduce wait times (by increasing the frequency of service) and increase accessibility (by extending services to more users). These mitigation measures would enhance the effectiveness of pricing measures by a moderate amount (e.g., by adding the Los Angeles transit improvements proposed for the year 2010 to the package of pricing measures, ROG reduction would increase from -39% to -41%, a 5% improvement in effectiveness). Such investments could offset many of the difficulties posed by higher prices and could substantially increase user benefits if carefully deployed. However, the mitigation measures considered did not necessarily represent the optimal use of funds from a cost-benefit perspective nor the most effective strategies from an equity viewpoint. Since it is possible to overspend on mitigation, or to otherwise select projects which result in net welfare losses, it will be important to evaluate both costs and benefits of mitigation measures and to focus investments on cost-effective mitigation strategies in follow-up studies.

Another possibility would be to use the revenues from transportation pricing strategies to reduce, or eliminate, a tax currently paid by consumers. For example, policy-makers could eliminate the sales tax currently used in many counties to fund transportation, and replace it with fuel taxes or VMT fees. While this approach provides no money for transit improvements and other program enhancements (since no net revenues are produced), it would replace a relatively regressive tax with a fairer set of charges based on transportation use and social welfare in that fashion.

13.4 Public Acceptability

What would it take to win public acceptance of transportation pricing measures? The results of focus groups with members of the general public and interviews and discussions with policy-makers and interest group representatives indicate that some pricing strategies would be more acceptable than others, that matching the strategy to local conditions would be

important, and that clear commitments about uses of pricing revenues would be a necessary prerequisite to public support

Focus group members understandably were not enthusiastic about transportation price increases, but they did agree that good transportation and a better environment are worth paying for. Most were willing to consider higher transportation prices if 1) they could be sure that the funds generated would be devoted to transportation improvements, and not diverted to other uses, and 2) they could feel confident that those in charge of the funds would be held accountable for providing real benefits to the public, and could have the funding taken away from them if they failed to do so.

A vocal minority was opposed to any increase in transportation prices. These individuals believe that government is wasteful and indifferent to the needs of the working person, and that transportation pricing strategies would only exacerbate both problems. At the opposite end of the spectrum were individuals who felt that problems created by the automobile justified significant price increases as well as vigorous regulatory restrictions on auto use. By far the most common reaction was a mild, somewhat grudging acceptance of the idea that price increases could help reduce congestion, air pollution, and fuel use, and would raise revenues for improving the overall transportation system. In addition, most thought that the funds could be used to provide important improvements if they were earmarked for such uses and expenditures had to be reported in detail.

Gas tax increases were the most widely accepted of the strategies, although the reviews were mixed. Most of the participants accepted the point that the gas tax had declined, in real terms, over the past several decades, and most felt that an increase would be acceptable, especially if implemented gradually. Some, however, characterized the gas tax as "just another way to gouge the middle class."

Some of the participants thought that an increase in at-the-pump charges would be an effective way to alter how much driving people do, in the short run, and what kind of cars they drive, in the longer run. However, most felt that a tax increase of less than 50 cents

would have almost no effect on their own travel behavior. Many thought that at-the-pump charges would be too blunt an instrument to be used for congestion relief or air pollution reduction. Almost all felt that any gas tax increase should be earmarked for transportation, the most frequently supported use for the revenues was to greatly improve transit and/or speed planned transit improvements. Some did not want to see more money spent on highways, a smaller number felt that this would be an important use of the moneys.

Vehicle emissions fees were hard for most of the focus group participants to understand, though once explained, the concept seemed reasonable to most. Many felt that passing the smog check should suffice as a control on emissions. Participants who owned old cars worried that they could face sharply increased fees, and owners of cars that had barely passed their last smog check were alarmed by this option. Several participants expressed concern over how such a fee would affect low income owners of old vehicles, but there was mixed reaction to a possible subsidy to offset this impact. Vehicle buy-back programs were viewed positively by some, but others expressed strong reservations because the buy-back prices were rarely high enough to pay for a "good" used car as a replacement.

There was solid agreement that an emissions fee should be based on actual vehicle performance, not a "typical" rate for a vehicle of a particular age (etc), but there also was a great deal of skepticism about the amount of bureaucracy this might require, as well as the potential for fraud. A number of participants felt strongly that the current policy of allowing certain cars that are heavy polluters to continue to operate should be greatly curtailed or eliminated.

VMT fees were also difficult for many to understand, and many argued that the issues a VMT fee would address were already covered by fuel taxes (or could be so addressed if the fuel tax were raised). One strong point in favor of VMT fees is the prospect of a vehicle fleet fueled in part by electricity. Under those circumstances many would favor replacing fuel taxes with a VMT fee as the means of paying for road use.

Reactions to congestion pricing varied with urban area, the strategy was seen as potentially effective in the Bay Area and Los Angeles, but of limited relevance in Sacramento and San Diego. In all four metropolitan areas some of the participants said that, at least some of the time, they would pay a fee to avoid congestion during peak periods, but almost no one said they would willingly pay it on a regular basis. A number of participants also felt that congestion pricing was basically unfair because the well-off who could afford to pay the fee already have many privileges (e.g., set their own work hours, work at home, etc.) while others, perhaps more time-constrained but less affluent, would either be forced to use far inferior options or to pay a fee they could ill afford. Several participants blamed unnecessarily inflexible employer work scheduling policies for much of the congestion, and felt that government should address this first rather than hit workers with higher fees.

Congestion pricing was hard for most discussion group participants to understand, except for applications on bridges, toll roads, and special lanes. This is in part because few are familiar with toll tags or other automatic vehicle identification technologies (AVI), and imagined that toll booths would have to be added to collect the fees. Once AVI was explained to the group, most saw it as by far the best way to implement congestion pricing. A small number worried about the government knowing who traveled where, but this was not a concern for most participants.

Parking pricing policies were the least supported by discussion group members. Most felt that parking was already priced where it was most costly to provide, and that where it is free and plentiful, the alternatives to driving and parking are too poor to be competitive, so that pricing would make little difference in travel behavior. On the other hand, the participants who currently pay for parking thought that parking pricing should be employed more often. Several participants expressed concern about another government regulation on business, several others doubted that such policy would be implemented or enforced. Few could imagine a government-imposed tax or fee on parking that would be substantial enough to alter behavior or fund significant improvements to commute alternatives, nor did they believe that employers or other private sector parking owners would make parking charges available to improve commute alternatives. Finally, if a parking charge were imposed at their

workplace, most thought they'd park elsewhere - on a nearby street or in a nearby shopping center, for example

Although most participants believed that pricing strategies would generate significant amounts of revenue, there was no clear consensus on how such revenue might be used. The use of transportation pricing revenues to improve commute alternatives was seen as quite ineffective in Los Angeles and, to a lesser extent, in Sacramento. Participants opposed highway expansion, but also felt transit could never be competitive except, perhaps, to downtown. Many felt that the money would be wasted by incompetent bureaucracies or arrogant politicians. In contrast, in both the Bay Area and San Diego, many felt that useful transit improvements could be made and that other desirable projects could be implemented.

Interviews with local officials and interest groups have uncovered very similar reactions. Most believe that pricing strategies could be effective in reducing congestion, emissions, and fuel use, if carefully implemented. However, many also were skeptical that effective implementation would proceed. The barriers, in this view, are an apparent lack of broad-based support for action, the strength of the anti-tax movement, the high visibility of government action on most of the strategies, and the lack of clear precedent demonstrating overall benefits and an ability to offset inequities. Suggestions for overcoming the barriers included the following:

- 1) If implementation is to proceed, business, environmental, and social justice communities must be willing to publicly advocate transportation pricing measures and to take on the effort needed to educate the public.
- 2) Specific proposals must address the equity issues directly, and must offer concrete commitments for offsetting harm in an environmentally and socially acceptable way.
- 3) Approaches that give local governments or regions authority to implement pricing programs matching their circumstances make more sense than uniform statewide ap-

proaches, with measures designed primarily for revenue generation (e.g., a VMT fee designed to supplement or replace current funding sources) the primary exception Authorization for local action permits those communities that can build support for a measure to proceed without forcing the issue on those who are not prepared to act. In many cases a city- or county-level authority would be sufficient to avoid spillover problems.

4) Several transportation pricing measures may become more acceptable as new technologies such as AVI, tamper-resistant odometers, and remote sensing are implemented. These new technologies would greatly aid in the implementation of congestion pricing, VMT fees, parking pricing, and perhaps vehicle registration fee policies, as consumers become more accustomed to new technologies they may also become more accepting of pricing strategies which utilize these devices. Furthermore, if low emission and zero emission vehicles become a realistic option for more people, public willingness to accept road pricing, higher fees for petroleum fuels, and emissions fees also should increase.

13.5 Implementation Planning Issues

Finding effective, politically plausible transportation pricing measures is a major accomplishment, but additional steps must be taken if implementation is to proceed and be effective. A number of legal and institutional issues must be addressed, ranging from the characterization of the measure as a tax or a fee to the selection (or creation) of public or private organizations to carry out each step of the implementation process. Among the items that always need to be considered in implementation planning are specific assignments of responsibility, schedule, and funding for carrying out the detailed program design, actual implementation, public outreach and liaison, implementation monitoring and enforcement, evaluation and reporting, and periodic updating or revisions to the measures. Specific measures raise numerous other implementation issues that would have to be addressed, and of course political feasibility would have to be continually evaluated as the details of the design are worked out.

Implementation could proceed in a variety of ways for most transportation pricing measures. For some measures, the most plausible designs would build upon existing programs and assignments of responsibility. For others, new technologies and new institutional arrangements seem to be the preferable way to go. Implementation strategies also depend, however, on the timing, scope and scale of implementation. Designs which provide for learning from initial implementation stages, whether in market niches or at "introductory prices", have great potential both as a test bed for new ideas and as a device for introducing new approaches to the public.

Cost-effectiveness is an important element in implementation planning, as are solid estimates of implementation costs and net revenues (along with a revenue expenditure plan). Rough estimates suggest that the costs of implementing transportation pricing strategies can be kept to 5-10 percent of gross revenues, the resulting revenue projections and cost-effectiveness metrics would be highly favorable. However, cost, revenue, and cost-effectiveness estimates are highly dependent on the details of the implementation design, so are rightfully done only after a specific proposal has been set forth.

13.6 Conclusion and Recommendations

Transportation pricing measures offer substantial potential for reducing congestion, improving air quality, reducing energy consumption, and increasing the overall efficiency and effectiveness of California's transportation systems. Assuming that prices are set at levels justified by long-run marginal social costs and revenues are spent in efficient ways, our analyses show that such measures would be

- o effective at achieving environmental, social, economic, and operational objectives, at prices that are justifiable on economic grounds,

- o unlikely to alter land use patterns substantially, at least at the pricing levels considered, but mildly supportive of higher densities and more efficient location choices,
- o capable of generating large net revenues, assuming a moderate level of cost control in the design,
- o mostly incident on middle and upper income travelers, though lower income travelers would feel the effects most sharply,
- o enhanced by mitigation measures, including measures that offset income effects for the lower income groups,
- o implementable in a variety of ways, involving the private sector as well as public entities, and utilizing either existing technologies or new ones as they become available

In short, transportation pricing strategies could be cost-effective alternatives for improving the overall function of the transportation system

A major issue, however, is whether transportation pricing measures can garner sufficient political support to be implemented. Most transportation pricing measures require, or would be greatly enhanced by, new legislative mandates or delegations of authority, but political leaders are skeptical. They look at the long-established record of resistance to tolls and fees, note current attitudes opposing taxation, and doubt that public opinion would support transportation pricing any time in the near future. While polls and focus groups indicate that public opinion is not so negative as this view would suggest, the lack of substantial, visible support for pricing (despite stalwart efforts on its behalf from a few) suggest to political leaders that the effort required for implementation is great and the likely rewards few.

At the same time, there is deep sentiment in elements of the planning, engineering, academic, environmental, and business communities that the failure of current prices to convey accurate signals to travelers is a root cause of many of the problems our transportation systems now face. Partly because of this sentiment, some of the institutional and technological impediments to transportation pricing recently have eased. Nevertheless, it is far from clear that this support is strong enough and focused enough to keep pricing options on the agenda and increase their feasibility.

Many transportation pricing proposals when introduced to the average citizen sound like ordinary taxes clothed in extraordinary rhetoric. Work with focus groups shows that this cynicism about government revenue collection is a deep-seated impediment to transportation pricing, but it is not insurmountable. In particular, attitudes about pricing appear to respond strongly to information about its rationale, its workings, and its potential benefits, as well as to specific commitments about how revenues would be used. In terms of public education, there is the possibility that a few well-crafted, representative pricing demonstrations which succeed in a very public way could produce a rapid shift in public attitudes. This is why new toll road and HOV buy-in projects such as S R 91 and the ISTEA congestion pricing demonstration projects around the country have assumed such importance.

Another common objection to transportation pricing concerns the effect on the poor. For example, congestion pricing as we have presented it here is a policy designed explicitly to help the transportation system and the economy function more efficiently by persuading those with the lowest values of time not to use the system during peak periods. Income certainly is a factor (though not the only factor) in determining values of time. Our work shows that the poor do not travel as much as is commonly assumed, especially by highway, although those who do travel would be disproportionately affected by higher prices. The Bay Bridge work, for example, shows that only about 3 percent of morning commuters on the Bridge fall into the lowest income quintile. This means both that the potential for devastating impacts on the poor is not large and that such impacts could be mitigated with a relatively modest commitment of resources. Focus group discussions revealed mitigation to be a touchy issue, however. People generally felt that improved transit in appropriate corridors

would be good, but that any program of direct compensation (such as a "lifeline" subsidy for toll tags) would have to be very tightly controlled

A more serious political issue for transportation pricing may well be the effect on the middle class, especially on the second and third income quintiles. Households in this income range would not be considered poor, but generally do operate under tight budget constraints. Much of the effectiveness of pricing derives from changing the behavior of this group who often must travel but cannot afford a significant additional outlay. Subsidies to transportation and to mortgage lending since World War II have promoted a level of daily travel among this group that could not be sustained if prices were more closely aligned with the marginal social costs.

For pricing to occur in more than a token way, the electorate - including, presumably, the bulk of the middle class - must understand and agree that the benefits of marginal social cost pricing outweigh the costs. Two paths to this awareness have been suggested. The first path rests on an argument that the rapid growth of congestion over the past two decades and the deterioration of conventional funding mechanisms such as fuel taxes are clear evidence that our historical subsidies to the transportation system have become increasingly dysfunctional. As this argument goes, subsidies simply will have to decline in order to keep the transportation system functioning, a move which the electorate will come to support as it learns the dimensions of the problem. The real policy question then revolves around how to smooth the transition of the lower middle classes to a regime of significantly higher mobility costs. The essence of this argument is that realignment of transportation pricing is inevitable, and the role of the professional community should be to point toward the most ethical and efficient strategies.

The second path rests on a more aggressive set of assertions about the benefits of pricing. Pricing, in this line of argument, is seen as a way of making transportation funding more progressive by inducing higher income travelers to pick up more of the costs. At the same time, it is argued that some pricing measures could have the effect of improving transit and HOV alternatives to such a degree that everyone is better off despite higher prices for

driving alone. For example, this kind of win-win outcome is a real possibility with congestion pricing, which would allow buses and perhaps carpools to reap the travel time advantages without incurring additional costs (though environmental impacts could be a concern if highway expansion were an element of the strategy). This approach has the advantage of being much more positive than simply relying on a perception of crisis, though without real-world examples it relies heavily on modeling and analysis for its credibility. Again, we reach the view that highly visible, representative demonstrations of successful pricing are essential to moving public opinion.

In conclusion, there is little doubt that transportation pricing can be economically efficient and effective at reducing mobile source emissions. However, pricing at the levels required for significant effect would represent a major institutional change in the transportation system. While many will fear such a change even if technical assessments suggest a benign outcome, our work hints that a majority would be open to persuasive arguments about the rationale for pricing. Thus, the real unanswered questions revolve around implementation: are the arguments really persuasive enough? Is it possible to reach a broad enough sector of the electorate with these arguments? Are the potential benefits of pricing to key stakeholders large enough to induce the kind of sustained effort that will be necessary to achieve such a substantial institutional change? We do not know the answers to these questions, but experience with tentative efforts at pricing now underway could teach us a great deal. Beyond that, further research on implementation issues, and especially the political and institutional aspects of implementation, is highly recommended.

References

- Apogee Research (1990) **TRIP National Survey** Maryland
- Bay Area Economic Forum, (1990) "The Missing Transportation Link. The Economic Impacts of the Closure of the Cypress on the San Francisco Bay Area," San Francisco
- Behbehani, Redha, V Setty Pendakur, and Alan T Armstrong-Wright (1984) **Singapore Area Licensing Scheme: A Review of the Impact** Washington, D C The World Bank, Water Supply and Urban Development Department, July
- Bhatt, Kiran and Michael E Beesley " Planning and Implementing a Congestion Pricing and Transportation Improvement Package " Urban Institute Working Paper No 5050-3-1(3), Washington D C
- Borins, Sandford F (1988) "Electronic Road Pricing An Idea Whose Time May Never Come " **Transportation Research** Vol 22A, No 1
- Cambridge Systematics, Inc (1976) **SRGP - A Short Range Generalized Policy Analysis Program** Cambridge, July
- Cambridge Systematics, Inc (1978a) **Urban Transportation Energy Conservation: Final Report** (5 Vols) Report prepared for the U S Dept of Energy, Washington, D C
- Cambridge Systematics, Inc (1978b) **Implementation and Administration of Transportation Air Quality Controls: An Analysis of the Denver, Colorado Area** Report prepared for the U S Dept of Transportation, Report No DOT-P-78-001, Washington, D C
- Cambridge Systematics, Inc (1986) "An Analysis of Central Area Pricing to Reduce Manhattan CBD Traffic " CSI, Cambridge, MA, December
- Cambridge Systematics, Inc (1988) "Urban Freeway Gridlock Study Technical Report." Cambridge, MA
- Cameron, Michael. (1992) **Transportation Efficiency: Tackling Southern California's Air Pollution and Congestion** Environmental Defense Fund, Oakland, California
- Cameron, Michael (1994) **Efficiency and Fairness on the Road: Strategies for Unsnarling Traffic in Southern California** Environmental Defense Fund, Oakland, California
- Catlin, Ian and Brian J Harbord (1985) "Electronic Road Pricing in Hong Kong 2 The Technology " **Traffic Engineering and Control**, No 26
- Cheslow, Melvyn (1978) "A Road Pricing and Transit Improvement Program in Berkeley, California " Urban Institute Report 5050-3-6, Washington D C
- Crain and Associates (1981) **1981 Bay Area Travel Survey** Report prepared for the Metropolitan Transportation Commission, Oakland
- Dawson, J A L , and Fred N Brown, (1985) "Electronic Road Pricing in Hong Kong 1 A Fair Way to Go " **Traffic Engineering and Control** Vol 26

Deakin, Elizabeth (1994) "Urban Transportation Congestion Pricing. Effects on Urban Form " in Transportation Research Board Special Report 242. **Curbing Gridlock: Peak-Period Fees to Relieve Traffic Congestion** National Academy Press, Washington, DC

Dittmar, Hank et al (1994) "Institutional and Political Challenges in Implementing Congestion Pricing A Case Study of San Francisco Bay Area " in Transportation Research Board Special Report 242 **Curbing Gridlock: Peak-Period Fees to Relieve Traffic Congestion** National Academy Press, Washington, DC

Downs, Anthony (1992) **Stuck in Traffic: Coping with Peak-Hour Congestion** The Brookings Institute, Washington, D C

Duguay, G , W Jung, and D McFadden (1976) "SYNSAM: A Methodology for Synthesizing Household Transportation Survey Data" **Working Paper 7618**, Travel Demand Forecasting Project, University of California, Berkeley

Elliot, Ward (1986) "Fumbling Toward The Edge of History California's Quest For a Road Pricing Experiment " **Transportation Research** Vol 20A, No 2

Environmental Protection Agency. (1996) **Guidance On the Use of Market Mechanisms to Reduce Transportation Emissions**, Oakland, California May

Fairbank Bregman and Maulin (1990) "Transportation Planning and Management Public Opinion Survey " Final Report for SCAG Santa Monica

Fauth, Gary R et al (1978) "Central Area Auto Restraint A Boston Case Study " Report R78-2, Dept of City and Regional Planning, Harvard Univ , Cambridge MA

Gillen, David (1994) "Peak Pricing Strategies in Transportation, Utilities and Telecommunications What Lessons Do They Offer For Road Pricing?" in Transportation Research Board Special Report 242 **Curbing Gridlock: Peak-Period Fees to Relieve Traffic Congestion** National Academy Press, Washington, DC

Giuliano, Genevieve (1994) "Equity and Fairness Considerations of Congestion Pricing " in Transportation Research Board Special Report 242. **Curbing Gridlock: Peak-Period Fees to Relieve Traffic Congestion** National Academy Press, Washington, DC

Glaister, S (1991) "UK Bus Deregulation The Reasons and the Experience," *Investigaciones Economicas*, Vol 15, No 2, pp 285-308 May

Gomez-Ibanez, J A and K Small (1994) **Road Pricing for Congestion Management: A Survey of International Experience**, NCHRP Synthesis 210, National Academy Press, Washington, D C

Government of Hong Kong "Electronic Road Pricing Result Brief and Consultation Document " Hong Kong

Greater London Council (1975) **Supplementary Licensing**, Greater London Council Pub 71680540 5 The County Hall, London

Gruenspecht, H and L Lave, (1989) "The Economics of Health, Safety, and Environmental Regulation", Volume 2 **Handbooks in Economics**, no 10 Elsevier Science, New York

Harvey, G (1978) **STEP: Short-Range Transportation Evaluation Program**, Metropolitan Transportation Commission, Oakland

Harvey, G (1983) **Methodology for Incorporating Transportation System Effects into Regional Transportation Energy Demand Forecasts** Report prepared for the California Energy Commission under Contract No 400-82-023 September

Harvey, G (1990) "Residential Location and the Journey to Work in Suburban Households " Paper presented at the Annual Meeting of the Transportation Research Board, Washington, D C

Harvey, G and E Deakin (1991) **Transportation Control Measures for the San Francisco Bay Area: Analyses of Effectiveness and Costs**, prepared for the BAAQMD, October

Hau, Timothy D (1992) **Congestion Charging Mechanisms for Roads: An Evaluation of Current Practice**, The World Bank, December

Hau, Timothy D (1992) **Economic Fundamentals of Road Pricing: A Diagrammatic Analysis**, The World Bank, December

Hoeller Dean, and Nicolaisen (1991) **Macroeconomic Implications of Reducing Greenhouse Gas Emissions: A Survey of Empirical Studies**, OECD Economic Studies, 0(16), pp 45-78

Harrison, Bill (1986) "Electronic Road Pricing in Hong Kong " **Traffic Engineering and Control**, January

Higgins, Thomas (1986) "Road Pricing Attempts in the United States " **Transportation Research** Vol 20A, No 2

Higgins, Thomas (1977) "Road Pricing Managing the Risks " **Policy Analysis** Vol 3

Jones, Peter (1989) **Traffic Restraint and Road Pricing in European Cities: The Current Situation** Transport Studies Unit, Oxford University, Oxford

Kain, John (1994) "Impacts of Congestion Pricing on Transit and Carpool Demand and Supply " in Transportation Research Board Special Report 242 **Curbing Gridlock: Peak-Period Fees to Relieve Traffic Congestion** National Academy Press, Washington, DC

Kirby, Ron (1973) "Road User Charges Some Practical Considerations " Urban Institute Report 1212-5, Washington D C

Krueger, Richard A (1994) **Focus Groups: A Practical Guide for Applied Research** 2d ed Sage Publications, Thousand Oaks, CA

Larsen, Odd I "The Toll Ring in Bergen, Norway - The First Year of Operation " **Traffic Engineering & Control**, April pp 216 - 222

May, Anthony (1983) "Making Progress With Traffic Restraint The Role Of Research " University of Leeds, England

Metropolitan Transportation Commission (1996) **Developing a Congestion Pricing Demonstration Program for the San Francisco-Oakland Bay Bridge: Status Report**, Oakland, California, March

Nossaman, Guthner, Knox & Elliott (1993a) "Intellectual Property Issues and the National IVHS Program", report prepared by the Federal Highway Administration, Washington, DC, Dec

Nossaman, Guthner, Knox & Elliott (1993b) "Advanced Vehicle Control Systems Potential Tort Liability for Developers," report prepared for the Federal Highway Administration, Washington, DC, Dec

Nossaman, Guthner, Knox & Elliott (1993c) "Intelligent Vehicle Highway Systems and State Sovereign Immunity for Torts," report prepared for the Federal Highway Administration, WashingtonDC, Dec

Nossaman, Guthner, Knox & Elliott (1993d) "Possible Impediments to Development of Advanced Traveler Information Systems An Analysis of Potential Tort Liability," report prepared for the Federal Highway Administration, Washington, DC, Dec

Nossaman, Guthner, Knox & Elliott (1993e) "Advanced Traffic Management Systems Tort Liability Issues" report prepared for the Federal Highway Administration, Washington, DC, Dec

O'Byrne, Nelson, and Seneca, (1985) "Housing Values, Census Estimates, Disequilibrium, and the Environmental Cost of Airport Noise A Case Study of Atlanta " **Journal of Environmental Economics and Management**, 12(2), pp 169-78 June

Olson, David (1994) "Pricing Urban Roadways Administrative and Institutional Issues", in Transportation Research Board Special Report 242. **Curbing Gridlock: Peak-Period Fees to Relieve Traffic Congestion** National Academy Press, Washington, DC

Orcutt, G (1976) (2d Ed) **Policy Evaluation through Discrete Microsimulation** Brookings, Washington, D C

Peterson, Bo E (1989) " Review of Traffic and Environmental Questions in Major Urban Areas in Sweden " **PTRC Proceedings of Seminar B**.

Pickrell, D (1993) ""What Gasoline Taxes Can - and Can't - Do", paper presented at the Graduate School of Architecture and Urban Planning, UCLA, Los Angeles, March 16

Pickrell, D (1995) "VMT and Vehicle Fuel Economy Elasticities", Memorandum, Volpe National Transportation Systems Center, Cambridge, MA, Feb 14

Pozdena, R (1994) "Notes on the Economics of Congestion Pricing," ECONorthwest, Portland, OR, February

Pozdena, R (1994) personal communication

Puget Sound Council of Governments (1990) **Transportation Demand Management Report** Seattle

Ramjerdi, Farideh (1989) **Evaluation of The Combination of Area Licensing Scheme in Stokholm County** Office of Planning and Urban Transportation, Stockholm County Council

Reinke, David (1988) "Recent Changes in BART Patronage: Some Findings on Fare Elasticities" **Transportation Research Record 1165**, National Research Council, Washington, pp 115-121

Richards, Martin (1992) "Road Pricing International Experience " Presented at Congestion Pricing Symposium sponsored by U S DOT, Washington, D C

M Roddin and D Andersen (1976) **Highway Research Record**

Saaty, T (1980) **The Analytic Hierarchy Process**, New York, McGraw-Hill

Sawyer, Robert (1995) personal communication

Sawyer, Robert (1996) personal communication

Schipper, Lee, E Deakin, and D Sperling (1994) **Transportation, Energy, and the Environment: International Comparisons**, Lawrence Berkeley Laboratory and University of California, Berkeley

Shefer, Daniel and Peter Nijkamp, (1996) **Urban Transport Externalities and Pigouvian Taxes: A Network Approach**, Technion - Israel Institute of Technology, Haifa, February

Skabardonis, Alex (1995) personal communication

Small, Kenneth (1992) **Urban Transportation Economics**, Harwood Academic Publishers, Chur, Switzerland

Small, Kenneth (1992) "Using Revenues From Congestion Pricing " Presented at the FHWA/FTA Congestion Pricing Symposium, Arlington, VA

Small, Kenneth (1976) "Bus Priority, Differential Pricing, and Investment in Urban Highways," PhD Dissertation, Department of Economics, University of California, Berkeley

SMS Research (1983) **Road Pricing Demonstration Project for the State of Hawaii** Hawaii

Spielberg, Franklin (1978) "Transportation Improvements in Madison, Wisconsin " Urban Institute Report 5050-3-7, Washington D C

Stoelhorst, H J , and A J Zandbergen (1990) "The Development of a Road Pricing System in The Netherlands " **Traffic Engineering & Control**, February

Traffic Eng & Control (1986) "Bergen Introduces Cordon Pricing " **Traffic Engineering & Control** 83, February.

Train, K and D McFadden, (1978) "The Goods/Leisure Tradeoff and Disaggregate Work Trip Mode Choice Models," **Transportation Research**, Vol. 12, pp 349-53

Transportation Research Board Special Report 242 (1994) **Curbing Gridlock: Peak-Period Fees to Relieve Traffic Congestion** National Academy Press, Washington, DC

Urban Transportation Monitor (1991) "Oklahoma's Automatic Toll Collection System Expands " November

Viton, P (1982) "Privately-provided Urban Transport Services Entry Deterrence and Welfare," **Journal of Transport Economics and Policy**, Vol 16, pp 85-94

Urban Institute and K T Analytics, Inc (1991) "Congestion Pricing Final Report " Prepared for the Southern California Association of Governments Los Angeles, CA

Wardrop, J D (1952) "Some Theoretical Aspects of Road Traffic Research", Proceedings of the Institution of Civil Engineers 2(1), pp 325-378

Watson, Peter and Edward Holland (1978) "Relieving Traffic Congestion The Singapore Area Licensing Scheme " World Bank Staff Paper No 281, Washington D C

Wilbur Smith Associates, Strgar - Roscoe - Fausch, Inc and K T Analytics, Inc , (1994) **Congestion/Road Pricing Study: Metropolitan Area of Minneapolis and St. Paul**, Wilbur Smith Associates, New Haven, June

Wilson, P "Scheduling Costs and the Value of Travel Time," **Urban Studies**, Vol 26, No 3, pp 356-66

Zupan, Jeffrey (1994) "The New York Region First in Tolls, Last in Road Pricing? " in Transportation Research Board Special Report 242 **Curbing Gridlock: Peak-Period Fees to Relieve Traffic Congestion** National Academy Press, Washington, DC

List of Inventions Reported and Published

None

Appendix A: Glossary

AASHTO - American Association of State Highway and Transit Officials
ABAG - Association of Bay Area Governments (sister agency to MTC)
ATSAC - automatic traffic surveillance and control
AVI - automatic vehicle identification
BART - Bay Area Rapid Transit
BPR - Bureau of Public Roads
BAAQMD - Bay Area Air Quality Management District
CarTalk - Policy Dialog Advisory Committee to Assist in the Development of Measures to Significantly Reduce Greenhouse Gas Emissions from Personal Motor Vehicles
Caltrans - California Department of Transportation
CARB - California Air Resources Board
CBD - central business district
CEC - California Energy Commission
CPI - Consumer Price Index
CO - carbon monoxide
CO₂ - carbon dioxide (a greenhouse gas)
CEQA - California Environmental Quality Act
CS - Cambridge Systematics
EDF - Environmental Defense Fund
EMFAC7F - California Air Resources Board's emissions model
EPA - Environmental Protection Agency
ETC - electronic toll collection
DOE - Department of Energy
DRAM/EMPAL - Direct Residential Allocation Model / Employment Allocation components of a land use model used in several metropolitan areas
FHWA - Federal Highway Administration
FTA - Federal Transit Administration (formerly UMTA)
HCM - Highway Capacity Manual
HOV - high occupancy vehicle
ISTEA - Intermodal Surface Transportation Efficiency Act of 1991
LOS - level of service
MEPLAN - a land use model used primarily outside the U S
MPO - metropolitan transportation organization
MTC - Metropolitan Transportation Commission (for the San Francisco Bay Area)
MTCFCAST - MTC's travel modeling package
NEPA - National Environmental Policy Act
NO_x - oxides of nitrogen
OECD - Organization for Economic Cooperation and Development
PM₁₀ - Particulate matter with a diameter of 10 microns or smaller
POLIS - land use model used in the San Francisco Bay Area
PPM - parts per million
PUMS - public use microdata sample of the U S Census

PUMA - public use microdata area defined by the U S Census
ROG - reactive organic gases
SACOG - Sacramento Area Council of Governments
SANDAG - San Diego Association of Governments
SCAG - Southern California Association of Governments
SCAQMD - South Coast Air Quality Management District
SIC - Standard Industrial Classification
SOV - single occupancy vehicle
SR - state route
STEP - a computer package for microsimulation of travel demand
SRGP - Short-Range Generalized Policy Analysis Program
SYNSAM - a computer package for the generation of synthetic samples
TCM - transportation control measure
TRANUS - a land use model used primarily outside the U S
TRB - Transportation Research Board
TRIP - version of STEP used for EDF work in Los Angeles
UCB - University of California at Berkeley
UTPS - Urban Transportation Planning System (regional transportation modeling package)
UMTA - Urban Mass Transportation Administration (now FTA)
VOC - volatile organic compound
VKT - vehicle kilometers of travel
VMT - vehicle miles of travel

Appendix B: Description of the STEP Analysis Package

B.1 Overview

This appendix discusses STEP, a travel demand modeling package designed for planning applications and policy analysis. STEP is composed of an integrated set of travel demand and activity analysis models, supplemented by a variety of impact analysis capabilities and a simple model of transportation supply. STEP is based on microsimulation - a modeling technique which uses the individual or household as the basic unit of analysis rather than dealing with population averages (cf. Orcutt, 1976). STEP results are aggregated only after the individual or household analyses are completed, allowing the user great flexibility in specifying output categories.

STEP's models use actual or forecast data on household socioeconomic characteristics, the spatial distribution of population and employment ("land use"), and transportation system characteristics for the selected analysis year(s). The socioeconomic characteristics of a sample of households and its members are usually taken from a regional travel survey or from the U.S. Census Public Use Microdata Sample (PUMS). Population, number of households, and employment by category (type) are taken from the regional "land use" data base. Transportation level-of-service data (times and costs) are derived from the region's travel model system. The land use data are provided to STEP for subareas (which could be zones, districts, or corridors) and for the region as a whole, the level-of-service data are provided in the form of large matrices of interzonal times and costs. STEP then reads through the household sample, attaching level-of-service and land use data to each household record as necessary. For each household, STEP uses its models to predict a daily travel and activity pattern for each individual in the household. Finally, household travel is summed up and household totals are expanded to represent the population as a whole.

STEP can analyze any change in the population or in the transportation system that 1) can be represented in terms of the variables in its models and 2) can be associated with a specific geographic area or grouping of households. Testing the effect of a change in conditions or policies is a simple matter of re-analyzing the household sample using the new data values, and comparing the results with previous outputs. For example, a new highway or new transit service can be represented by changed travel times and costs for the areas served, a parking price increase can be represented by an increase in out-of-pocket costs,

an increase in income in a particular area or for a particular population subgroup can be represented by editing the household file to incorporate the revised incomes. Along similar lines, future years can be represented through proportional factoring and reweighting of survey observations to reflect expected regional trends, or can be based upon a more sophisticated microsimulation of household changes based on cohort survival and other methods of demographic forecasting.

The sampling framework preserves the richness of the underlying distribution of population characteristics and permits tabulation by any subgroup with sufficient observations to be statistically significant. For example, the results can be disaggregated by income level and age, which would allow an assessment of effects for, say, various income quintiles among the retired population. This is a significant advantage over an aggregate model, which uses zonal averages for most socio-economic data.

STEP maintains its quick response capability while achieving great detail in representing behavior in part by reducing its detail in representing transportation networks. STEP does not have an internal transportation network representation and traffic assignment model, so changes in level of service resulting from changes in demand must be calculated in another way.

To approximate the effects of changes in demand on network performance and vice versa, a simple routine for estimating level-of-service was incorporated into STEP in the early 1980s (Harvey, 1983). The simplified level of service model uses peak and off-peak travel times and base case demand estimates to calibrate a supply function for appropriate spatial groupings of trips (i.e., trips in broadly-defined "corridors"). For each change in demand, the calibrated function can be used to compute a new "equilibrium" in the corridor. While this simplified level of service model is useful for many analyses, it is intended only as an approximation of changes in network performance and is likely to be inadequate in cases where large network perturbations could occur or where specific route choice changes are at issue. When network questions are critical, STEP must be used in conjunction with a more detailed network model. Procedures for "interfacing" STEP with conventional network models have been developed for this purpose.

Several features of STEP make it useful as modeling tool for policy analyses. STEP's regional, subarea, and corridor-level analysis capabilities fit well with the scope and scale of

many policies proposed for urban areas. Its model formulations display linkages consistent with travel behavior theory and represent key time and cost variables as well as demographic variables. Its use of microsimulation makes it possible to address many of the questions about equity and the distribution of impacts that frequently arise in policy pricing. Finally, it is far faster and less expensive to run STEP than to apply a conventional regional model system.

STEP's data analysis capability is another important asset. STEP's microsimulation formulation permits the package to be used as a survey tabulation technique employing sophisticated data transforms and linkages. For example, many travel surveys contain detailed information about the vehicles each household owns and indicate which vehicle was used for each trip made on the survey day(s). Using STEP, these vehicle data can be tabulated so that exact usage patterns by model year or vehicle type can be determined. They also can be related to personal and household characteristics to yield useful information about, e.g., low-income households' dependence on old vehicles and their contributions to vehicular emissions.

STEP itself was originally developed for sketch planning analyses in the San Francisco Bay Area and in its initial versions used the Bay Area's travel models developed in the 1970s (Harvey, 1978). Since that time, all of the models in STEP have been completely reestimated and additional models addressing location choice, time-of-day of travel choice, and congestion effects have been added. The most recent formulations are nested logit. A number of versions of STEP are currently available, including options that permit the analysis of activity data as well as travel data, and versions that use either MOBILE or California EMFAC emissions data.

STEP has been utilized in a number of Bay Area studies over the years, and has been adapted for use in studies in Los Angeles, Sacramento, Chicago, and the Puget Sound region (Seattle). Applications can proceed with model reestimation specifically for the region - essentially, by creating a completely set of new models for STEP - but to date applications outside the Bay Area have relied on extensive recalibration of the default (Bay Area) models plus a limited amount of re-estimation as needed to match local conditions.

The basic structure of the STEP model system is shown in Figure B-1. The basic data requirements of the STEP model are summarized in Figure B-2, and a typical sequence of activities for a STEP application is shown in Figure B-3.

In the remainder of this document, the analysis concepts used in STEP and the basic features of the STEP models are presented. Because STEP was developed over a long period and several versions are in current use, the document provides a brief history of the modeling package and describes key applications.

B.2 The STEP Analysis Concept: Microsimulation

STEP is based on the concept of microsimulation, which was pioneered by the economist Guy Orcutt in the late 1950s. Orcutt created a method for analyzing prospective social welfare policies by applying an ensemble of models depicting relevant individual and household behavior to a set of households drawn from survey data. Simply put, Orcutt's method was to process one household at a time, using the models to estimate how the behavior of the household and its members would change given some adjustment in social policy. Overall estimates were developed by summing up the results for individuals and households, using appropriate population weights.

This method, sometimes called sample enumeration, has at least two powerful advantages. First, it allows all of the information known about households and individuals to be used in the behavioral models. In contrast, a conventional modeling approach typically relies on what can be summarized at an aggregate level, say for census tracts or traffic analysis zones. Much of the information content of a survey database can be lost in this way.

Second, the microsimulation approach supports broad flexibility in output tabulations, because of the detail that is known about each household and individual. In particular, behavioral changes can be compared among subgroups of the population - such as by income, age, household structure, and race - that are more difficult to isolate in an aggregate modeling framework.

With microsimulation, in order to report statistically valid results for a geographic subarea, there have to be enough households or individuals in the sample to represent that subarea.

If one is interested in flows between subareas - as in a typical transportation analysis - the typical travel survey's sample size can be a constraint. However, recent computer and software advances, along with now proven methods of generating good synthetic household samples based on the US Census Public Use Microdata Sample (PUMS), have made it possible to attain any desired level of spatial detail by performing microsimulation with up to a full population of the region.

The Orcutt microsimulation approach had been around for some time when disaggregate models of household and individual travel choice (especially for mode of travel) were first developed in the early 1970s. Microsimulation was widely used by researchers to test their specifications and to exercise their models "in-house", but none of the field applications of these models involved microsimulation, partly because of its heavy computational demands and partly because practitioners preferred incremental improvements to their aggregate models over the wholesale model system reconfiguration microsimulation would have entailed.

B.3 Microsimulation as an Application of the MTC Model System: SRGP and STEP

The first practical planning application of microsimulation in travel demand analysis was developed as a quick-response method of applying an innovative set of models developed for the San Francisco Bay Area in the mid-1970s. By that time, disaggregate travel demand modeling had advanced enough to suggest that a full demand model system covering all elements of traveler behavior could be developed with disaggregate techniques. A consortium of consultants and academics from Cambridge Systematics (CS) and the University of California at Berkeley (UCB) was asked to develop such a model system for the Bay Area under contract to the Metropolitan Transportation Commission (MTC).

The models were specified with one eye toward conventional infrastructure planning and another toward emerging proposals for travel demand management. Both travel time (in its various forms) and travel cost appeared as variables throughout the new models, whereas cost had not been acknowledged previously as a potentially important policy lever. The resulting models were innovative yet constrained by conventional approaches to the

representation of travel behavior. The model system in effect generates a weekday travel pattern for a specific household, as a function of the level-of-service characteristics of available modes (both peak and off-peak), the location of the household's residence, and key socio-economic characteristics of the household (such as income and number of workers). Standard trip purpose categories were used (home-based work, home-based social-recreational, home-based other, and non-home-based). But within each trip purpose there was a tight hierarchical relationship among 1) the quality of modal alternatives connecting trip origins and destinations, 2) the choice among potential trip destinations, and 3) household and individual decisions about how much to travel. Both choice of destination and number of daily trips (by motorized means) were found to be highly dependent on measures of accessibility. Household auto ownership also was found to vary directly with highway accessibility and inversely with transit accessibility.

MTC wanted the full model system to function in a conventional network- and zone-based framework, because infrastructure planning remained their most important model application. The CS/UCB team accomplished this by stratifying households in each traffic analysis zone by the most important household characteristic - income - then using census data to calculate average values of other household characteristics for each zone and income stratum and applying the household models to each zone and income stratum as if they were conventional aggregate formulations. The resulting large-scale model system was cumbersome, but innovative in its treatment of accessibility.

Recognizing the difficulty of using such a model system for screening myriad demand management (or infrastructure) proposals, the CS/UCB team also produced a microsimulation package for MTC based on the original disaggregate formulation of the models. Because the Bay Area's most recent travel survey dated from 1965, they also developed a method for synthesizing a household sample from census data (Coslett, 1977).

The microsimulation program, developed by G. Harvey (then at UCB) and J. MacMann and R. Nestle (then at CS), was initially named SRGP- Short-Range Generalized Policy Analysis Program (Cambridge Systematics, 1976). It drew on five streams of data to carry out a microsimulation using the new MTC model structure.

1. A file of household survey records, synthetically-generated for the Bay Area prototype, but potentially from an actual household travel survey.

2. A file of zone-to-zone travel times and costs, representing AM peak and off-peak conditions and highway and transit options
3. A file of zonal characteristics, including population, households by dwelling unit type, labor force, employment by job category, land area by use category, and average all-day and hourly (mid-day) parking costs. The zonal file also allowed two aggregations of zones for use in the remaining inputs and outputs: 1) a zone-to-county definition, for reporting by easily-recognizable jurisdictional boundaries, and 2) a zone-to-district definition, where districts were intended to be the smallest possible sub-county areas for which statistically-valid samples were present
4. A file of model coefficients, with an allowance for additional adjustments to constant terms on a county-to-county or district-to-district basis
5. A file based on a simple script language to allow quick transforms of variables on a district-to-district or global basis. For example, the script language could be used to add \$3.00 to the all-day parking charge for a specific district or group of districts

Once the ensemble of data was set up and the model calibrations were refined (to produce acceptably accurate flows, shares, etc. on a district-to-district basis), SRGP could be used to scan quickly among a variety of demand management strategies. Other, more complex, land use and infrastructure changes also could be tested by modifying the input files directly, but relatively little emphasis was placed on such applications initially.

The first major change to the microsimulation software was the addition of auto emissions models, carried out by Harvey and Atherton in 1978 (Cambridge Systematics, 1978). The revised software was used to investigate how regional emissions burdens might be affected by transportation policy levers. The microsimulation models were used to provide a first-order estimate of the number, time of day (through crude trip purpose correlations), length, and average speed of trips by each household under different policy scenarios. Emissions data taken from EMFAC in California and MOBILE outside California were used to estimate trip emissions as a function of average trip speed and vehicle condition (cold or hot) at start-up. By summing the transportation emissions estimates over a sample of households, total transportation emissions and changes from the "base case" were estimated.

CS also added a fuel consumption calculation and applied the SRGP microsimulation software in several studies for the Department of Energy (DOE) (Cambridge Systematics, 1978) and others. However, applications of SRGP ended in the early 1980s, in part because of a general decline in funding for transportation planning studies in that period and in part because the SRGP software, optimized for the computer capabilities of the mid-1970s, became increasingly in need of an overhaul.

During this same period, MTC took over its own version of the microsimulation software. Working directly for MTC, Harvey expanded the outputs, added calculations of "expected utility" (a direct and rigorous benefit measure), and produced a manual (Harvey, 1979). The MTC software was renamed STEP at the request of CS, to avoid confusion about divergence from SRGP.

After a flurry of exploratory activity with STEP, MTC lost interest in it, in the early 1980s. MTC's modeling efforts focused on making use of its new, high quality household travel survey (Crain & Associates, 1981), and data preparation and reestimation of the main, large-scale model system were given priority over the microsimulation software. However, Harvey continued to refine the STEP microsimulation software for use as a teaching tool in classes on transportation policy and travel demand. Between 1982 and 1989, he made a number of significant changes, including a total re-write of the software for the microcomputer, based on a structured approach designed to ensure ease of maintenance as well as to optimize speed. He also added a number of models and analysis modules, discussed in the following sections.

B.4 STEP Enhancements, 1982-1989

The key enhancements added to STEP in the 1980s included a simple supply model, a fuel consumption model, survey analysis capabilities, stated preference / expert system analysis capabilities, a residential location choice and land supply model, a work location choice model, a time of travel model, and an estimation data set generator routine. Each of these enhancements is discussed below.

-- Supply Model

With support from the California Energy Commission, a simple supply equilibration routine was added to give a first-order indication of how a large change in demand might be diminished by compensatory changes in travel time (Harvey, 1983). An equation generalized from the well-known Bureau of Public Roads (BPR) formula was adapted for this purpose

$$t = t_0 * (1 + (v/c)^b)$$

where

t is the travel time per mile at volume v

t₀ is the "free-flow" travel time per mile

v is the peak VMT

c is - conceptually - the peak capacity in VMT

b is a parameter of the function

Two options for applying the formula are provided. The first involves equilibrating for each individual peak period trip without regard for what is happening to other travelers. An initial demand model calculation is made for the base conditions represented by peak and off-peak highway travel times in the STEP inputs. The resulting "personal peak VMT" becomes v in the above equation. The variables t and t₀ are just the original peak and off-peak travel times per mile, derived from the STEP inputs. Given a value for b, a "pseudo" capacity (c) can be computed. Values of b of about 2 seem to give the best indication of real network performance. The resulting equation then can be used to estimate how the peak travel time for this traveler might change when the demand (again measured in "personal peak VMT") changes as the result of some policy. For example, suppose that daily parking costs are raised by \$3.00. The "personal peak VMT" for a given traveler will drop by some amount. But a lower v will yield a lower t in the above equation, which translates into a lower peak travel time. In turn, the new time - when used in the demand models - produces a somewhat higher estimate of "personal peak VMT". So it goes back and forth until the change in peak travel time and the revised "personal peak VMT" stabilize. Careful programming minimizes the number of steps in this "equilibration". Generally, the change in regional aggregate peak VMT due to the policy in question is about 20 percent smaller after accounting for the highway supply effect than from a pure demand response.

A second, superficially more plausible method of equilibration applies the same formula in basically the same way to logical groupings of travelers. The districts defined in the STEP zonal data file are used to approximate major corridors in the region. Each inter-district movement is assigned to such a "pseudo corridor". Then the base case values of v , t , t_0 , and c are calculated for each pseudo corridor by enumerating the full sample once without applying any policy changes. Values of b around 2.1 seem to work best in this case (probably reflecting the presence of more extreme values of v/c in the "personal peak VMT" approach). Using the supply equation for each "pseudo corridor", the demand effects of proposed policies then are "equilibrated" through repeated enumeration of the sample, with an appropriate adjustment to the average corridor peak rate of travel (t) at each step. Again, careful programming minimizes the number of steps in this "equilibration", and the process is aided by the fact that the functions involved are quite well behaved in this context.

The "pseudo corridor" approach yields about the same attenuation of policy effects on regional VMT as the "personal peak VMT" approach (i.e., about 20 percent in the congested networks of the Bay Area and Los Angeles). The results appear to be consistent enough for a given network that it may not be necessary to equilibrate the results for every STEP run - a consistent x percent reduction (once x has been determined) can be applied to the pure demand outputs. However, the appropriate x value in this shortcut must be determined for each set of base network conditions (not only from region-to-region, but for different time periods within each region).

--Fuel Consumption Model:

Again with support from the California Energy Commission, a trip-based fuel consumption model was synthesized from the literature and implemented in STEP (Harvey, 1983). The model consists of two equations. The first gives the average gallons per mile for a reference speed as a function of vehicle weight and vehicle idling fuel consumption

$$f(v_0) = a_1 * W + a_2 * i$$

while the second yields a multiplicative adjustment for speeds above the reference speed

$$f = f(v_0) * (b_0 + b_1 * v + b_2 * v^2 + b_3 * v^3)$$

where

$f(v_0)$ is the fuel consumption in gallons per mile at speed v_0

v_0 is the base vehicle speed

W is the vehicle weight (lbs)

I is the vehicle fuel flow rate at idle, in gallons per minute

f is the fuel consumption in gallons per mile at speed v

a_1 , a_2 , b_0 , b_1 , b_2 , and b_3 are coefficients

Some of the household samples used with STEP have included information about the make, model, and year of each household vehicle (and occasionally an average mpg for each vehicle as estimated by the respondent). More generally (as when the STEP auto ownership model is used), specific data are not available that would enable an independent estimate of fuel economy for each vehicle. In these cases, the first equation above is replaced with an estimate of average fuel economy for the fleet, and the second equation is re-normalized to provide an appropriate adjustment above and below the reference speed.

-- Survey Analysis Capabilities:

An option was added to STEP for obtaining base case information by interpreting and tabulating a household survey rather than applying travel demand models (Harvey, 1987). In effect, the models are replaced with actual daily travel patterns, which still can be correlated with the zonal- and network-based data present in STEP's database. The software uses trip or activity diary records to build daily activity sequences for each individual and daily trip chains for each vehicle. If there is specific information about the make, model, and year of the vehicles, then the program can produce a highly accurate accounting of the emissions and fuel consumption characteristics of each trip.

"Handles" also were provided in the software for special tabulations beyond the normal STEP outputs. Typically, these must be programmed specially for each survey.

--Stated Preference and Expert System Analysis Capabilities:

In conjunction with the survey tabulation feature of STEP, software handles were provided for a rules-based (or more formal) method of representing policy effects directly through changes in activity/travel patterns. For example, stated preference surveys might be used to explore how respondents to a trip diary think they would alter their travel patterns in response to some policy change. Then, either the specific changes described by the respondents, a set of expert system-type rules generalized from the responses, or a mathematical model estimated from the responses can be programmed into the STEP code.

STEP has been used in this way only to carry out some "what if" analyses of proposed transportation measures. In the Bay Bridge congestion pricing study, for example, we tested different levels of time-of-day shift and mode shift in response to higher peak tolls, in order to assess the implications of errors in the models. (A more formal activity change module is planned for STEP based on the outcome of the Bay Area stated preference survey planned for 1996.)

-- Residential Location Choice and Land Supply Model:

A residential location choice model (Harvey, 1989), enhanced by a simple land supply procedure, was added to STEP to capture the changes in location that might occur in response to changes in transportation investments and policies. The model uses districts based on the Census Public Use Microdata Areas (PUMAs) rather than on the more detailed traffic analysis zones. Each PUMA is considered a potential residential location. A different choice model was developed for each of several household types, defined by

- type of dwelling unit (single family vs multi unit)
- type of financial arrangement (own vs rent)
- number of employed adults (1, 2, or 3)
- presence of minor children (yes or no)
- ethnicity (Hispanic, black, Asian, other)

A specific location choice model has the following form

$$P_i = \exp[U_i] / (\exp[U_1] + \dots + \exp[U_n])$$

$$U_i = b_1 * (\text{price}\{i\} / f(\text{inc})) + b_2 * \text{eth}\{i\} + b_3 * \text{crime}\{i\} + b_4 * \text{tax}\{i\} + b_5 * \text{sch}\{i\} \\ + b_6 * \text{sum}(\ln[\text{mode choice denominator}\{ij\}])$$

where.

i indicates a potential PUMA of residence

j indicates the zone of work

n is the number of PUMAs in the system

P_i is the probability this household will choose to live in i

U is the perceived utility of a PUMA as a residence

$\text{price}\{i\}$ is the mean monthly price at i of the household's current type (rent, own, single, multi)

$f(\text{inc})$ is a non-linear transform of the household's income

$\text{eth}\{i\}$ is the percent at i with this household's ethnicity

$\text{crime}\{i\}$ is the rate per 100,000 of serious and violent crime at location i

$\text{tax}\{i\}$ is the property tax on a home of average value at i (homeowners only)

$\text{sch}\{i\}$ is the average per pupil expenditure in location i (households with children only)

$\text{sum}(\ln[\text{mode choice denominator}\{ij\}])$ is the sum of the log of the denominator of the mode choice model for each worker in the household

$\exp[\]$ indicates "e" to the power denoted in brackets

\ln indicates the natural log

b_1, \dots, b_6 are parameters fit by estimation

The parameters are different for each household type and region. For example, single worker, single person households do not place much importance on work trip accessibility (measured by the mode choice denominator), while the location behavior of two worker, two person households is well explained by work trip accessibility alone. In general, price, crime,

and work trip accessibility are the most important variables, and the models can be run plausibly with those alone

In a typical analysis, the residential location choice model is run first on the base case data, in order to develop a set of location- and household-type-specific dummy variables to replicate the base distribution of households. Future zone characteristics (other than accessibility) can be taken from available sources or explored through scenario testing.

The exogenous specification of prices in the location choice model would be problematic if things change enough, because large shifts in location preferences would surely alter these prices. To approximate this effect, a simple land supply response procedure was added. The supply response depends on information about the remaining land area available for development at each location, and about the amount of land consumed on average by a unit of each housing type. Basically, the location choice models are not allowed to violate the cap on developable land in a location or drop below the number of occupied units present in the most recent (actual) base year (other rules of this sort would be possible). Rather than simply imposing boundary constraints on the allocations, however, price adjustments are used to shift allocations through the residential location models. At the upper end (over-allocation), prices of all housing types in the location are shifted up by a single factor. At the lower end (under-allocation), the price of each housing type is reduced in proportion to the degree of under-allocation (but by no more than 50 percent, so that instances of under-allocation in some extreme cases cannot be avoided). A reasonably efficient search routine is used to "equilibrate" the prices and location choices.

Information on the remaining development potential of each location was readily available in the Bay Area, where these models were initially developed. Some metropolitan areas do not produce such data routinely. In these cases, it is necessary to either 1) estimate the developable land area from, say, gross land area and approximate density assumptions or 2) simply assume a cap on the percentage change (up and down) that can occur in each location, and test the sensitivity of results to the caps. In the extreme case, one can assume that the housing stock will stay the same at each location, and allow prices to adjust accordingly. Though such a tightly-constrained analysis may be valid in some circumstances, the results would imply a very high impact on low income households.

Modeling results for residential location would improve if a more detailed picture of the housing stock by subarea were available. But the approach described here is sufficient to provide a first-order understanding of the circumstances under which location might be sensitive to transportation conditions.

-- Work Location Choice Model:

A work location choice model was added to STEP.¹ This work location choice model is simply the work trip distribution model from the full MTC model system.

$$P_j = \exp[U_j] / (\exp[U_1] + \dots + \exp[U_n])$$

$$U_j = \ln[A_j] + b \cdot \ln[\text{mode choice denominator}\{ij\}]$$

where

i indicates the zone of residence

j indicates the zone of work

n is the number of zones in the system

P_j is the probability that a worker living in i works in j

U is the perceived utility for a zone as a workplace

A_j is the attractiveness of zone j as a workplace

$\exp[\]$ indicates "e" to the power denoted in brackets

\ln indicates the natural log

b is a parameter fit by estimation

The mode choice denominator contains all of the information from the work mode choice model for a trip between zones i and j . While the model could be construed as a conventional gravity type, it was in fact estimated from disaggregate data using multi-modal accessibility factors drawn from the work mode choice model.

¹ The original version of STEP did not address workplace location, the number of workers in a household and the location of each primary workplace was assumed to be known from the household file.

Because this model presents a fairly crude picture of work location choice (e.g., it is not internally constrained to match workplaces with available jobs), we have tended to use it mainly for longer-term studies, and to interpret the results primarily as an indication of where labor market pressure might arise for a different spatial arrangement of commercial and manufacturing activities than indicated by the official zonal forecasts. For studies of near-term policy effects, we have tended to keep the status quo arrangement of workplaces as embodied in the survey.

STEP can be run to force the work trip attractions to match the employment in each zone. This is achieved by creating "pseudo" attraction factors that are allowed to rise or fall until the "true" attractions are matched.

For compatibility when both the residential and workplace location models are in use, an alternate version of the residential location model was estimated using the workplace location denominator for each worker rather than the mode choice denominator.

--Time of Travel Model:

A simple time-of-travel for AM Peak work trips was added to STEP.² The model focuses on work starting time for auto drivers, as indicated by work trips reported in the survey data. We assumed that the morning departure time from home (which arguably is of greatest interest to transportation planners because of its tendency to be sharply peaked) stems from two partially-related behaviors: a determination of the desired work start time and a decision about when to begin traveling in order to satisfy the desired start time. Put differently, given the work start time, departure time is determined largely by the performance of available travel modes. (Of course there will be exceptions to this, as when a parent must time the work trip to match the start of daycare or school.)

The model asks first whether the worker is likely to have a "regular" schedule, defined as a work start time between 5:30 am and 10:30 am. This is treated as a binary probability of following a regular schedule, as a function of household income, household size, and the

² As of this writing, time of travel for other trip purposes is based on distributions drawn from travel survey data.

ratio between am peak and off-peak highway travel time. Then, the model computes the probability of starting in each of the five peak hours, as a function of household size and, again, the ratio of am peak to off-peak travel (coefficients are allowed to vary by time period). The result is a simple placement of each worker in an hour of the peak period or off-peak.

Response to the am peak/off peak ratio is not linear. In fact, the ratio does not make much difference until it reaches about 1.8, but by about 2.0 it has become a very strong explanatory factor. This indicates that congestion may not have much influence on activity scheduling until it becomes quite severe. To put this finding into perspective, as of 1990 only about 5 percent of the work trips in Los Angeles and the Bay Area are exposed to routine peak travel time ratios of 2.0 or higher, less than 1 percent of San Diego work trips are exposed to this level of congestion, and no Sacramento work trips are.

Occupation and industry variables have been omitted from the standard model formulation because these variables are not always available from household travel surveys. However, exploratory tests in the Bay Area indicate that even a crude indicator of industry, such as the first digit of the SIC (Standard Industrial Classification) code, greatly improves the predictive ability of the time of day models. Whereas the average work start time for all "regular" workers in a place like the Bay Area is almost exactly 8 am, with a skewed distribution toward later start times, start times for individual industries peak anywhere from 7:00 am (financial sector) to 9:30 am (retail sector). Travel time ratios and household characteristics remain important in the presence of these industry/occupation variables, but overall model performance is greatly improved. The more advanced versions of the time of travel models currently can be added to STEP with some programming.

-- Sampling of Alternatives Capabilities:

The models dealing with spatial allocation (trip distribution, workplace location, residential location) were altered to allow sampling of alternatives from the full universe of spatial choices, with weighting of results according to the sampling rate. These sampling options offer a clear tradeoff between speed and accuracy (although it should be noted that when large numbers of alternatives are available, sampling is nearly as accurate as full enumeration of the alternatives.)

-- Estimation Data Set Routines:

The survey analysis routines in STEP were augmented to produce estimation data sets for each type of model included in the overall package. These routines have become an integral part of STEP, so that when a new survey is configured for use in STEP (with appropriate zonal and level-of-service data), it is a relatively simple matter to estimate new models (STEP applications drawing on synthesized household data clearly cannot yield estimation data sets)

--Summary:

By the end of 1989, STEP was available in four principal formats

- 1 A travel demand microsimulation module, based on the original MTC disaggregate model system
- 2 A travel demand microsimulation module with the original MTC disaggregate model system at its core, augmented by a supply response routine, a work trip time-of-day model, a work location choice model, and a residential location choice model
- 3 A household travel survey analysis module, for linking survey data with spatial (zone) and network data, for estimating the emissions and fuel consumption implications of survey trips, for producing survey tabulations, and for generating new estimation data sets for travel and location models
- 4 A travel demand microsimulation module, based on the original pattern of trips documented in each household survey response, allowing the use of rules, a formal model, or stated preference survey results in depicting policy-driven changes to each household's travel pattern

This ensemble was supported by a library of ancillary software for estimating models, converting to and from binary file formats, pre-processing surveys to correct or remove

obvious errors, and creating synthetic household data from Census and other survey sources

B.5 Recent Applications and Modifications of STEP

Beginning in 1989, STEP was applied in a number of policy studies and forecasting efforts, several of which led to significant enhancements of the STEP package. These are discussed in this section

-- Bay Area Air Quality Conformity Analyses:

When the San Francisco Bay Area failed to attain the federal air quality standards by 1987, MTC was required to implement a previously-devised contingency plan. Part of the contingency plan called for a review of the air quality impacts of each new highway investment in the region, and for the delay until attainment of any highway found to increase emissions. MTC was sued for not carrying out this portion of the contingency plan, and, after an unsuccessful effort to apply a qualitative rating scheme to each proposed highway, agreed to perform a model-based emissions assessment of the highway program as a whole (by comparing with emissions under a no-build scenario). A consensus typology of potential travel and land use differences between the build and no-build alternatives was developed by both sides of the case (ranging from different route choices all the way through changes in trip generation, auto ownership, and location). MTC found that its model system was capable of capturing most of the hypothesized effects, but feedback through the model hierarchy above trip distribution was not usually carried out because of high resource requirements (both computer time and personnel).

Noting that STEP had preserved the original model hierarchy and feedbacks and was cheaper and faster to use than the full model system, MTC proposed to carry out the analysis of feedback effects by passing to STEP inter-zonal travel time matrices representing the highway alternatives and receiving from STEP inter-district trip tables depicting differences in origin-destination trip patterns. If the differences exceeded certain threshold values, the district-level trip tables then were to be used to factor MTC's inter-zonal trip tables for reassignment to the networks and reassessment of emissions.

differences (emissions outputs from STEP were not used for this purpose, though they could have been)

Procedures were developed for passing trip tables from STEP to a large-scale network model, by distributing the trip total from each specific STEP district-to-district cell among all of the affected zone-to-zone combinations, proportional to the pattern present in a prototypical zone-to-zone trip table. STEP itself takes the zone-to-zone trip table - which ideally should represent a "closely comparable" run of the large-scale network model - and carries out the translation from district to zonal flows. This capability makes it now routinely possible to use STEP in conjunction with a network analysis package. Note that by expanding the size of the STEP sample - synthesizing additional observations, if necessary - it is possible to increase the number of inter-district cells that STEP can support statistically - to the point that synthetic replication of the total population would support a full zone-to-zone trip table (actually, about 20 percent of the population would be enough for most zonal systems).

STEP has now been used in five cycles of highway program analysis. It has never indicated shifts in trip patterns sufficient to warrant a change in the large-scale model results.

-- Bay Area TCM Studies:

The State of California passed a new Clean Air Act in 1988 with a one-hour ozone standard (allowing zero exceedences) of 09 ppm (parts per million), far more stringent than the applicable federal standard. A companion piece of legislation instructed the San Francisco Bay Area to take the lead in exploring whether transportation control measures (TCMs) could be used to attain this standard. The region was asked to carry out an analysis without considering changes to automotive technology beyond what the California Air Resources Board (ARB) had mandated already. One purpose of the exercise was to instruct the legislature on what the policy alternatives to further regulation of automotive technology might be.

A quick analysis of ambient air quality measurements and previous dispersion model runs indicated that a reduction of about 30 percent below expected levels of ozone precursors

would be necessary. MTC and the Bay Area Air Quality Management District (BAAQMD; "Air District") convened a broadly representative task force and set about scanning, categorizing, analyzing, and prioritizing a comprehensive set of measures brought to the table by all involved parties. The result was a three-tier strategy:

- 1 Measures that entail little additional public cost and are unlikely to generate intense political opposition (i.e., "traditional" transportation control measures such as ridesharing promotion, voluntary employer-based trip reduction, and increased telecommuting). These measures together were found to yield a 3-5 percent reduction in reactive organics (ROG).
- 2 Measures that entail substantial additional public cost but whose political opposition would be likely to focus only on the need for additional revenue (i.e., transit infrastructure and service expansions, and perhaps high-occupancy vehicle [HOV] lanes). Investments that could be funded with a 10 cent additional fuel tax were considered, because that level of additional taxation was deemed ultimately acceptable to the public for environmental and congestion reduction purposes. These measures together were found to yield a 4-7 percent reduction in reactive organics (ROG).
- 3 Measures whose actual implementation would be likely to generate political opposition. These included an array of pricing options (VMT fees, large increments to fuel taxes, parking fees, congestion pricing, and emissions-based registration fees - the latter obviously treading on the Legislature's prohibition) and land use measures (higher densities around transit stations, incentives for mixed-use development, transit and pedestrian friendly designs, etc.). Several groupings of these measures that could yield 15-25 percent reductions in reactive organics (ROG) were developed.

STEP played a role in analyzing measures for each tier. The simple measures at level 1 mostly were not amenable to travel behavior modeling, so STEP was used to test the implications of various levels of effectiveness found in the literature by imposing appropriate changes on the survey trip pattern and computing emissions reductions. The infrastructure measures at level 2 were analyzed with STEP by running interzonal level of service tables for each alternative, derived from the large-scale network model, through the STEP

enhanced demand module. The pricing measures at level 3 were analyzed directly by imposing various configurations of new prices on the STEP database.

Most of this work could be carried out with only minor improvements to the STEP ensemble of programs. But the pricing measures entailed a more significant change. A subtle advantage of the original MTC model system was the presence of travel price in all of the individual model specifications - accessibility derived from the mode choice models appears in each of the trip distribution, trip generation, and auto ownership models. The location models added to the basic MTC package also incorporated price in this manner, but the worker time-of-day model did not. This made it impossible to test congestion pricing and other time-dependent pricing policy options. Without any precedent for time-variant prices, either in the Bay Area or in a closely-comparable city, it also was not possible to estimate a new time-of-day model incorporating price.

In this situation, we revised the STEP time of day model to reflect price effects using the data on hand, by assuming that price could be converted to an equivalent amount of time using the value of time from each worker's mode choice utility. The effect of different peak and off-peak prices on time of travel then could be tested by: 1) expressing each price (peak and off-peak) in minutes, using the mode choice value of time as a conversion factor, 2) adding the peak time equivalent to the numerator and the off-peak time equivalent to the denominator of the ratio used in the time-of-day model, and 3) applying the time-of-day model in the normal way. (Any prior differences that may have existed between peak and off-peak prices are ignored.) Note that this method does not assume a single value of time for all workers, because STEP's microsimulation entails a separate calculation for each worker, based on a value of time that depends on the worker's household income.

It is clear that a more empirically-based treatment of price-dependent time-of-day choice would make STEP a stronger model for pricing studies. Data from CA State Route 91 surveys or from stated preference surveys collected in Portland, San Francisco, and Dallas/Fort Worth may provide a basis for further model development in the near future.

-- Los Angeles Pricing Studies:

Soon after completion of the Bay Area TCM work, the Environmental Defense Fund (EDF) raised the possibility of carrying out a similar study for the Los Angeles region, with a focus on pricing measures. The ideal approach would have been to adapt a suitable set of LA models to the STEP microsimulation framework. However, the existing models for the region did not incorporate the necessary feedbacks of price and time through the behavioral hierarchy. Furthermore, model estimation was made difficult by the vintage of the region's survey data. At the time (1990-91) the most recent estimation-quality data set was from 1967. Probably no metropolitan area in the US had experienced greater social, economic, or spatial change over that period, making it difficult to argue convincingly for the representativeness of the older data. In addition, models of transit choice - central to the STEP ensemble and critical to a appraisal of future LA transportation policy - were impossible to estimate because of the small number of transit trips present in the 1967 survey data and the generally low quality of transit service available at the time. (Our experience has been that reliable mode choice coefficients for a full set of time and price variables - in-vehicle time, walk time, initial wait time, transfer wait time, and fare - are possible only when the estimation data reflect considerable transit service that is competitive with highway travel, through some combination of transit quality and highway congestion. Thus, data from Boston, Chicago, New York, and San Francisco tend to yield strong mode choice specifications, while data from cities such as Los Angeles and Sacramento often have difficulty resolving any effect of time or price on mode choice.)

The two critical problems in applying STEP to LA thus concerned vintage and local content. Vintage was an issue in any event because most of the STEP models had been developed on 1965 Bay Area data. So, for the EDF Los Angeles application, we first updated some of the coefficients based on the Bay Area's high quality 1981 household travel survey (primarily constant terms, scaling factors, and affects of aggregate zonal characteristics). We did not develop entirely new specifications at this time due to resource limitations (mode choice specifications were tested and found to replicate 1965 values reasonably well).

Local content was a more difficult issue. We took a relatively small household survey that had been conducted in 1976 (about 7000 observations, the completeness of its trip diaries had always been questioned, so we could not consider the survey for model estimation),

and "grew" it to 1990 using district-level demographic and income data (the 1990 PUMS for LA was not available at the time) Then, we added 1990 network and zonal databases provided by the Southern California Association of Governments (SCAG) and ran the models with their Bay Area coefficient values For comparison, we judged that the best source of data on local travel patterns was the current "base case" from the regional model system, as embodied in the home-based work, home-based other, and non-home-based trip tables (and the rearrangement of those tables into peak and off-peak flows) While these tables were produced by the region's large-scale model system, as a calibrated base case they also contained substantial information from exogenous sources such as the US Census journey-to-work tables, transit counts, and measured highway link flows (which, of course, is the reason why it is possible to use interzonal travel times from the large scale model to run a STEP base case)

STEP outputs and SCAG trip tables were each configured to be comparable at the district-to-district level Then, STEP constant terms and factors were adjusted to achieve basic agreement with the SCAG outputs at the district/mode/time trip table level A prototypical adjustment sequence involved

- Adjusting mode choice constants, first at the county-to-county level, then for a small number of district-to-district interchanges, to achieve comparable mode shares for each district pair ("comparable" is a term of art in this usage)
- Adjusting the time-of-day constants to achieve about the same prediction of peak hour flows In most cases, because peaking in large-scale models does not vary significantly among district-to-district pairs only a handful of time-of-day adjustments are necessary
- Adjusting trip distribution constants, first at the county level, then for a small number of district-to-district interchanges, to achieve about the right shares to each destination from each origin. Where more than one STEP model contributes to a trip type, both models are adjusted in tandem
- Adjusting auto ownership constants, so that available district (or county) data for households by auto ownership level are matched

- Adjusting trip generation constants, so that about the "right" number of trips per household is produced in each district
- Adjusting residential location constants so that about the right number of households is placed in each district

When the adjustments are made by moving up the hierarchy in this way, only one pass through the modeling sequence is required (though repeated runs are necessary to develop the adjustments at each level)

The Los Angeles models were applied in two studies published by EDF (Cameron, 1991, and Cameron, 1994) The first study examined a series of pricing strategies, and the second focused on the equity issues raised by such measures

-- Examination of Modeling Uncertainties:

As part of the first EDF Los Angeles study, there was a great deal of interest in characterizing the "confidence interval" around each policy forecast, given the statistical variability of the STEP models Two sources of uncertainty were investigated

- The uncertainty associated with coefficient estimates STEP was modified to allow coefficients to vary according to a normal distribution whose mean is the value of the coefficient and whose variance is derived from the coefficient's t-statistic With this option selected, STEP begins a run by selecting new coefficient values randomly from the normal distributions, then it carries out one microsimulation pass to create a "base case" with the new coefficients and a second pass to test a policy with the same coefficients If this process is repeated a large number of times (using a different random number seed each time), the result is a simulated distribution of the change in each STEP output measure predicted to result from the policy
- The uncertainty implied by the probabilistic nature of the STEP models Up to this point in its development, STEP used choice probabilities exactly as they are applied in the large-scale travel models For example, if the mode choice calculation for a

particular worker yields 2 for the transit probability and 8 for the auto probability, and if this worker in the STEP sample represents 100 workers in the population, then the worker's morning trip is counted as twenty transit trips and eighty auto trips. In reality, the worker is making a single trip that has a 20 percent chance of being by transit and an 80 percent chance of being by auto. An alternate way to interpret the probabilistic outcome is to pick randomly from the model-generated distribution and assign all 100 people for whom the worker is a proxy to that option. Over many repetitions of the process, the 100 people would be assigned to transit about 20 percent of the time and to auto about 80 percent of the time.

STEP was modified to allow this discrete interpretation of travel and location probabilities as an option. For each household in the microsimulation, the full hierarchy of probabilities is computed - residential location, auto ownership, destination (for multiple trip types), mode, and time-of-day (continuous functions such as trip generation are left as deterministic values). Then, moving from the top (residential location) down, a specific option is chosen randomly at each level according to the calculated probability distribution. These selections move down the hierarchy, creating a path through the tree of alternatives. Finally, all of the sample weight for the household is assigned to the identified sequence of outcomes rather than being split among all possible outcomes according to the calculated probabilities.

Uncertainties stemming from both the imprecision of coefficient estimates and the use of discrete sampling were explored systematically for the EDF Los Angeles work. (A third potential source of statistically measurable error - sample size - was ignored, because with the 5000+ households that STEP routinely uses sample size is not important to the accuracy of regional-level forecasts.) After 100 runs, we found that about 80 percent of the outcomes were clustered within 10 percent of the original forecasts of change in VMT, vehicle trips, etc. Moreover the variation due to the two sources of error taken together never exceeded 30 percent on either side of the original forecasts. About 5/6 of this variation was attributable to coefficient imprecision.

The effect of coefficient imprecision in this analysis is highly dependent on the *t* values for variables most strongly influenced by the proposed policies (i.e., cost, and secondarily time). In general, the cost and time coefficients in the STEP models have asymptotic *t*

values ranging from [2.5] to [6.0], which might be classified as "moderate" statistical significance. These t values could be raised easily by increasing the size of the estimation data sets - an easy matter, since the original ones were held to about 1000 observations to reduce the time required for each run of the estimation software. A doubling of the sample size probably would decrease the width of the interval by about 30 percent (i.e., from +/- 25 percent to about +/- 18 percent).

The small additional contribution of discrete sampling to uncertainty is explained by the number of households in STEP's LA database (about 5000). With such a large number of observations contributing to the regional total for each output measure, it really doesn't make much difference whether households are apportioned across all choice outcomes or assigned to a specific set of outcomes. This source of uncertainty would be of greater concern in assessing the small sample properties of a microsimulation such as STEP.

Despite the effort involved, the outcome of this exploration of uncertainty was not entirely satisfactory, because it did not address what most people would recognize as the largest potential sources of uncertainty: future values of factors such as fuel price, household income, and population and job growth. All of these are critical factors in travel and location behavior. To cite one example that lies outside our immediate focus but nevertheless is quite instructive, aggregate non-business air travel (passengers enplaned per annum) appears to be proportional to real income raised to the power of 4. Thus, predicting a 5 percent increase in real income when it instead drops by 5 percent could result in nearly a 50 percent over-prediction of air traffic (i.e., $1.05^4 / 0.95^4 = 1.49$).

For the most part, urban travel behavior models are not quite that sensitive to income, but a number of parallels can be drawn. For example, when significant congestion (and associated delay) begins to appear in a metropolitan highway system, the non-linearities of traffic flow make the delay increase roughly geometrically with population. Thus, in a region such as Los Angeles, already experiencing much highway congestion, a mistake in the assumed growth rate can have huge implications for the long-run impact of a policy such as congestion pricing. An analysis of LA congestion pricing in 2010 with a 2.5 percent growth rate versus a 1.5 percent growth rate (current "official" forecasts foresee a 2 percent growth rate) indicated that congestion pricing would be more than two times as effective at the higher rate (in hours of delay reduced), given the same infrastructure assumptions for both cases.

Congestion pricing is something of an extreme example, because highway delay is so much a phenomenon of marginal traffic growth. To be more systematic about major sources of uncertainty, we picked plausible ranges for three key variables and ran STEP for different regionwide transportation policies to gauge the effects on analysis results for LA in 2010. The variables and their ranges were

Fuel Price (1991 dollars per gallon)	1.00-2.00
Real Household Income (Percent of 1991 Mean)	95-120
Population Growth (Annual % Change From 1991)	1-2.5

STEP was run for combinations of the extreme values of these variables. The results of the analysis can be summarized through the example of one output measure - regional total VMT - and one policy - a VMT fee, tested for values from 1 to 10 cents per mile. The estimated percent change in total VMT ranged from 25 percent below to 15 percent above the original predictions using default 2010 assumptions. In other words, if the original STEP run for 2010 conditions indicated a 5 percent decrease in VMT, then errors in the key input variables might raise that estimate to 5.75 percent or lower it to 3.75 percent.

The story seemed to be the same when we predicted total VMT in 2010, but the implications were quite different. The extremes in the above example yielded future VMT projections that were 30 percent above and below VMT at the "official" forecast values (i.e., from about 300 million to about 550 million daily VMT in the LA region). In other words, uncertainty in the future baseline was at least as large as the change in VMT predicted for the largest VMT fee.

Another source of uncertainty concerns the specifications and structure of the travel demand models. What if important variables with a bearing on travel responses are omitted? What if the basic behavioral structure embodied in the models turn out to be wrong? What if the impact models (such as for emissions) are inaccurate? It was not possible to explore these issues in any detail as part of the EDF work, but the questions certainly should be kept in mind. For example

- The major system variables used to model travel behavior are time (several categories) and cost, yet safety, reliability, and comfort are known to be important considerations as well. Are we confident that the effects of these non-standard variables will be neutral in the face of price changes, or would population subgroups respond differently to price changes depending on their sensitivity to the changes (e.g., women more likely to pay higher prices when alternate modes are perceived as unsafe, airport access travelers more likely to pay higher prices when alternate modes are perceived as unreliable)?
- The validity of conventional models has been questioned by many researchers, both for the decision calculus attributed to tripmakers and for the high level of abstraction with which the components of the daily trip pattern are treated. For example, the continuous, compensatory relationships of time and cost in linear utility equations, widely used in economics, are viewed with skepticism by psychologists, whose empirical work points to hierarchical treatment of attributes and other less-analytically-convenient patterns of cognition. As another example, travel demand modeling as now practiced has been challenged by those who favor a method that explicitly treats travel as a by-product of the total household activity pattern viewed holistically.
- The validity of current emissions factor models is under intense challenge, both for understating the level of emissions by as much as a factor of two and for treating the process by which vehicular travel produces emissions in an overly simplified way. For example, while published factors do not provide clear evidence about what happens to emissions on freeway segments under forced flow, these conditions are precisely what a well-designed congestion pricing scheme would ameliorate.

A prudent course of action in the face of such uncertainty is to adopt the most robust analysis style possible and to be honest about the conclusions. This means being explicit about imprecision in the data, the model coefficients, and the forecasts. It also may mean exploring alternate ways of eliciting information about behavior and even examining other plausible behavioral paradigms. Exploration of alternate data collection methods is the rationale for the stated preference surveys recently conducted or now underway in Portland (OR), Washington (DC), San Francisco, and Dallas/Fort Worth. Examining the implications of different behavioral paradigms was the motivation for the model development described

in the next section (and also is the rationale for the Los Alamos model development effort funded by the Federal Highway Administration)

-- Applications of STEP in Other Regions:

STEP has been used in a number of other studies in the last five years, including a project to analyze packages of pricing measures for California's four largest metropolitan areas (Los Angeles, the Bay Area, San Diego, and Sacramento) and smaller efforts to investigate pricing policies for the Puget Sound Region and Chicago. As part of these studies, STEP was not only transferred to new regions, but was re-estimated for Los Angeles and the Bay Area using new travel surveys and new network data.

It turns out to be most practical to undertake a partial, rather than full, reestimation of the STEP models in the typical case, because of the problem with transit quality cited earlier. The rich detail of travel time coefficient estimates that is possible in a region like San Francisco, where for some trips transit actually competes with auto in door-to-door time, cannot be inferred from data in a less transit-oriented city. There, transit dependency, based on low auto availability, is the dominant mode choice phenomenon. Good mode choice models require both of these behavioral processes to be present in the estimation data. When there is only transit dependency, time plays almost no role in mode choice (i.e., drive alone vs. HOV time differences usually are small and not well measured). Where time is not a factor in choice, the argument for using the mode choice denominator as an accessibility measure disappears, and the logic of the hierarchical, accessibility-driven model structure falls apart. This problem is so serious and so prevalent that it has become common to carry out transit investment studies with transferred coefficients for key mode choice variables.

A partial model transfer for STEP is carried out by preserving a core of time and cost of coefficients from the original specification and re-estimating the remainder of the models using appropriate statistical software. It is necessary to exercise extreme caution to make certain that level-of-service variable definitions are reasonably consistent between the donor region (say, San Francisco) and the recipient region (say, Sacramento). In several applications we have found it prudent to re-estimate the "original" models using adjusted variable definitions, in order to match data available from the recipient region.

-- STEP Model Re-Estimations:

While the original MTC specifications performed (and continue to perform) plausibly in policy studies, the desirability of making a number of improvements was increasingly apparent as STEP was applied in new regions and to new policy issues. The following changes were identified as the most needed:

- Re-estimation of the models on new survey data
- Re-estimation of the models using rigorous nested logit procedures and linkages among levels of the model hierarchy
- Re-estimation of the models to cover non-motorized modes of travel, and to recognize trip interdependencies and trip chaining
- Re-estimation of the models to address activities instead of trips per se

Elements of each of these changes has been carried out. First, the STEP models were reestimated using 1981 Bay Area data, with changes to introduce a modern treatment of the nested logit relationships. Second, an entirely new set of travel models based on a reclassification of daily activities was developed, initially using the 1981 Bay Area travel survey. The goal of this exploratory effort was to incorporate more information about trip chaining and time of travel in STEP, by organizing the prediction of the daily trip pattern around schedule-constrained activities such as work and school, and directly integrating decisions about the less time-specific activities which tend to be associated with these

The new models address five types of urban travelers:

- Full-Time Workers
- Part-Time Workers
- Students
- Non-Employed Working-Age Adults
- Non-Employed Retired Adults

As different as these new models may seem from older formulations, they still produce the same basic types of outputs for policy assessment and for input to a large-scale network analysis. In comparison with the more conventional MTC specifications (as augmented for STEP), activity-oriented models tend to show somewhat greater effects from policies that focus on work travel, because of the association of so many non-work activities with the work trip chain. Other differences appear as well, but in general it is more remarkable how closely policy assessments from the new activity models parallel ones from the older STEP formulations. In retrospect it seems that the initial concept and subsequent modifications of the MTC models must have captured many of the implications of activity-travel interrelationships without attempting to do so explicitly.

Both the revised version of the STEP travel models and the new activity-oriented models for STEP were developed within the STEP ensemble of software, so that reestimation of either structure for a new database is automatically possible once the data have been set up to run with STEP. Using this capability, either partial or complete reestimation was carried out for each of the regions modeled with STEP in the past five years - Chicago, Los Angeles, Sacramento, San Diego, Seattle, and the San Francisco Bay Area.

-- Bay Bridge Congestion Pricing Demonstration Project Application:

The most recent extension of STEP occurred for the San Francisco Bay Bridge Congestion Pricing Demonstration Project, funded by FHWA under the Intermodal Surface Transportation Efficiency Act of 1991. The focus of the Bay Bridge analysis was on time-of-day tolls in a specific corridor. STEP's revised travel and activity-oriented models were viewed as capturing enough of the relevant behavior to be usable without significant modification. However, two issues arose during the application of STEP in this very different spatial context: 1) the available household travel survey sample (about 8000 clean observations for the Bay Area) was too sparse to support detailed inferences about the Bay Bridge corridor, at least without abandoning fixed workplaces from the sample in favor of the workplace location model, and 2) a much more detailed treatment of traffic operations on the Bridge was desirable, in order to address the concerns of policy-makers.

The problem of sample size was addressed by adapting the entire Bay Area PUMS file (about 110,000 households) for use in STEP. This file contains all of the household data needed to run STEP's modeling options, with the exception of home and workplace traffic analysis zones. PUMS includes some location information, in the form of Public Use Microdata Area (PUMA) designations for each household's home and primary workplaces, but more specificity is required for travel behavior modeling (PUMA populations average about 125,000 in the Bay Area, compared with about 9000 per traffic zone). Home census tracts for the PUMS households were inferred based on the PUMA of residence (by correlating with available tract-level crosstabs for household size by income), work zones were added based on the PUMA of employment (using MTC's most recent work trip table as the basis for a probabilistic assignment). The resulting sample was run through STEP to make the required coefficient adjustments (i.e., to match base case regional travel patterns).

Details of highway operations at the Bay Bridge were addressed by adding a feature that allows the highway level-of-service for a specified set of district interchanges to be determined partly by a simple stochastic queuing model. The concept is tailored for a setting like the Bay Bridge, where a single facility can be isolated and treated separately. The facility is imagined as a downstream link fed by two upstream links. The first upstream link (an HOV bypass lane, in the Bay Bridge case) operates with sufficient capacity that a bottleneck will not form in the range of expected volumes, the second upstream link operates at an average service rate determined by the capacity of the downstream link minus the flow on the first upstream link. In other words, all the vehicles arriving on the first link (the HOV bypass) are served but only those vehicles on the second link (mixed-flow lanes) for which there is residual space downstream (on the Bridge) are served. The second link is treated as a simple Poisson queue whose average service rate equals the residual capacity in each time period (there is no provision for spillback to links further upstream).

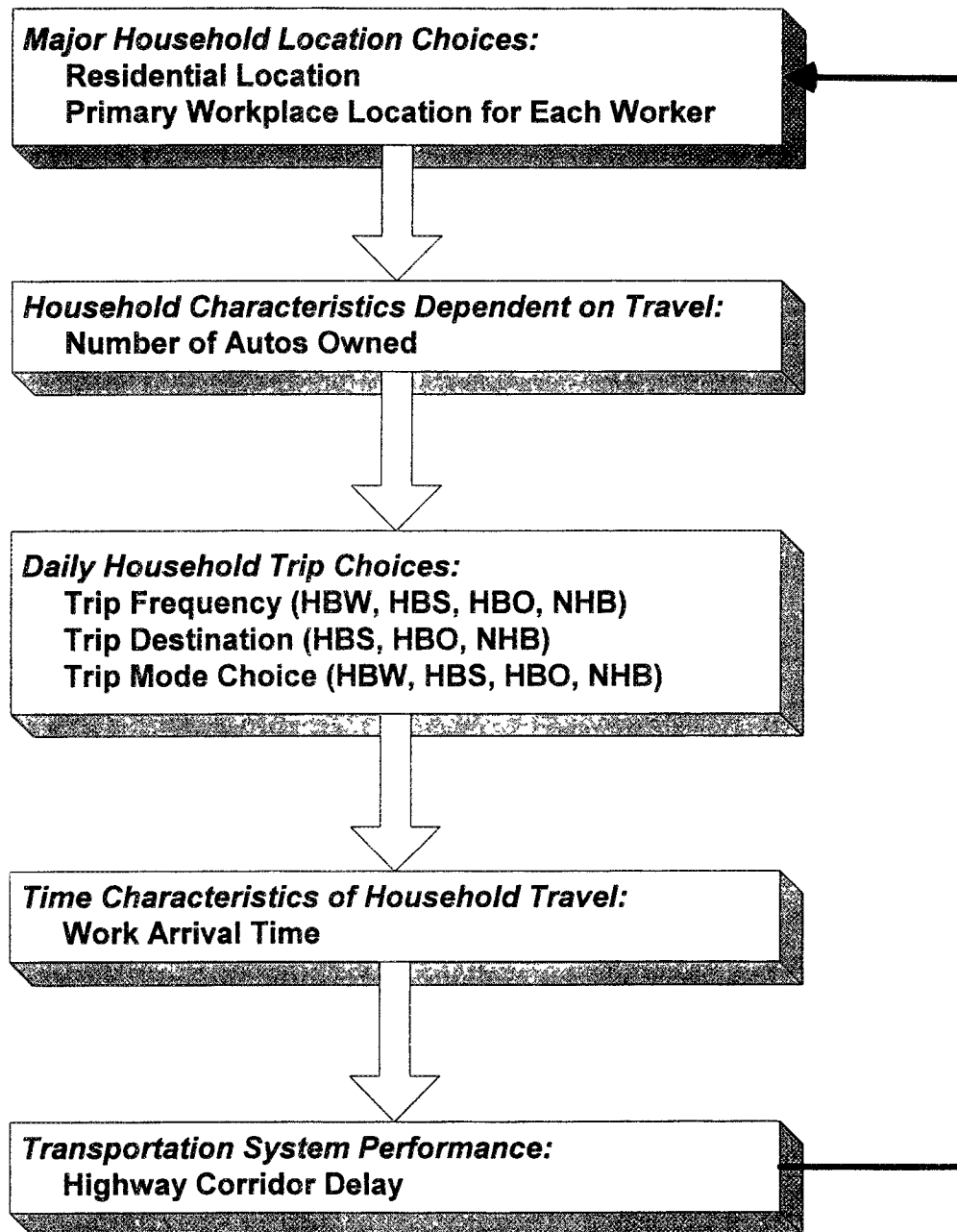
The links are tied into the broader highway system at nearby nodes in the regional highway network, and STEP is provided with access to tables containing network-based travel times and distances (in the usual STEP format) for trip segments leading to and following from the facility. STEP assembles the travel times as they are needed during sample enumeration. As required for the simpler supply models discussed earlier, STEP must go through several iterations of supply and demand calculations to reach a stable equilibrium. The first iteration works with facility queuing times approximated from the regional network times (peak and

off-peak) for the special facility links, using a linear approximation for the buildup and erosion of the peak. In each subsequent iteration, STEP provides a flow profile by hour (using the demand functions, based on travel times from the previous iteration) which are input to the internal supply functions (including the queuing model) to calculate hour-by-hour travel times. For the queuing model only, the STEP hour-by-hour demand predictions are smoothed to produce a continuously varying arrival rate (with care to conserve the total peak period demand).

The ability to focus supply calculations on a specific facility was formalized in a new version of STEP. This version allows up to five facilities in the highway system to be treated in detail, with each facility represented as a miniature network, and the performance of each link represented through a simple stochastic queuing process. Route choice outside each facility model still is not represented, so the detailed treatment may be applied only when route switching is made difficult or impossible by the topology of the network.

A feature allowing more detailed treatment of rapid transit also was added to this version of STEP, in order to provide a better treatment of rail transit access and egress and to make it easier for STEP to examine transit policies. Instead of drawing on the usual regional network tables for transit level-of-service, STEP can reference station-to-station tables of rail transit times and costs. Access is handled through mode choice sub-models that draw from tables of access times and costs covering each zone-to-station combination.

**Figure B.1:
STEP Model Structure with Enhanced MTC Models**



Note
HBW - Home-Based Work Trips
HBS - Home-Based Shopping Trips
HBO - Home-Based Other Trips
NHB - Non-Home-Based Trips

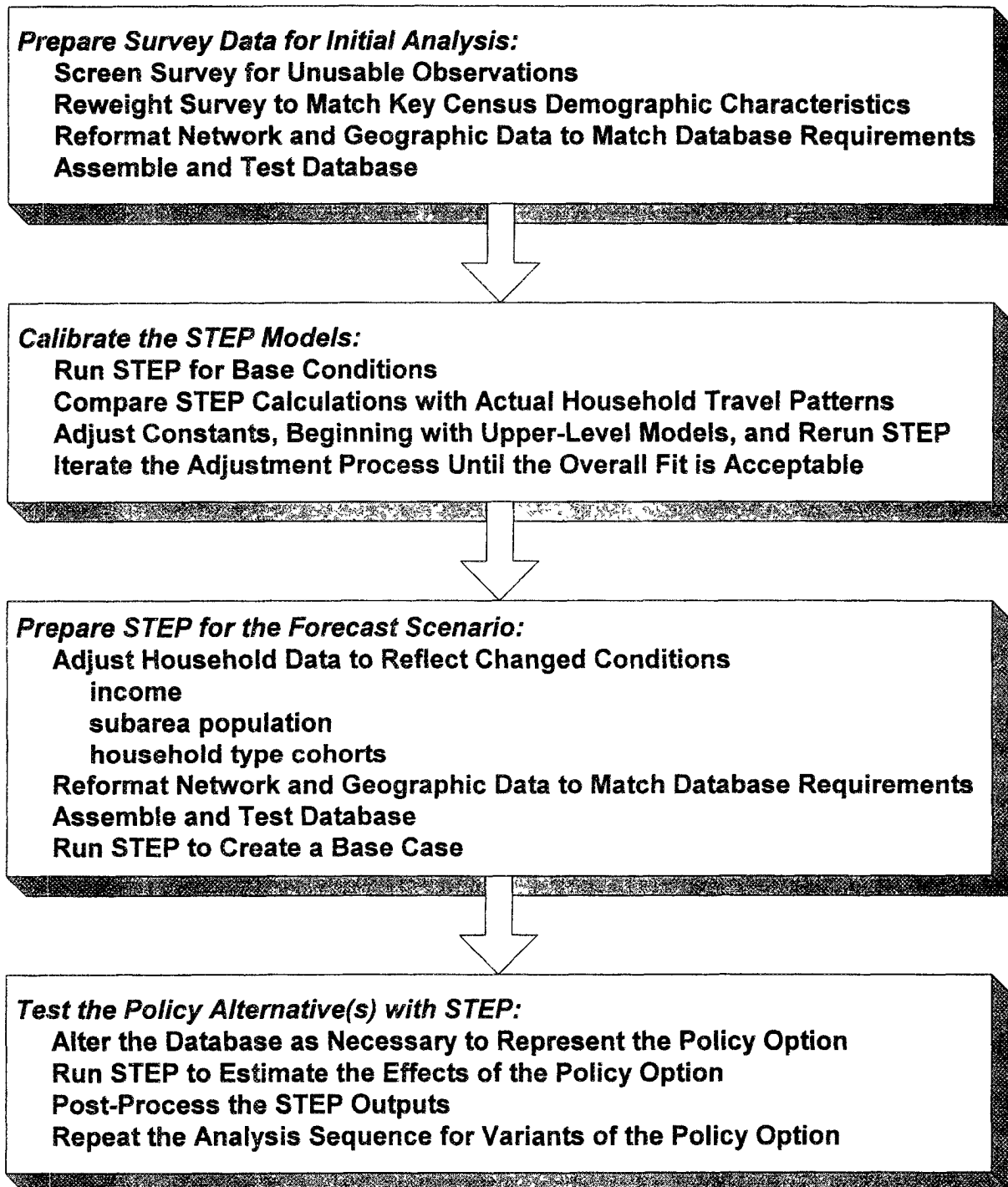
Figure B.2: Primary STEP Data Requirements

Basic Data:
Regional Household Travel Survey
1990 US Census Public Use Microdata Sample

For the Survey Year:
Geography
land area, population, housing stock
for tracts, zones, and/or districts
Network Level-of-Service
highway, transit
am peak, pm-peak, off-peak
times, costs

For Each Forecast Scenario:
Geography
land area, population, housing stock
for tracts, zones, and/or districts
Network Level-of-Service
highway, transit
am peak, pm-peak, off-peak
times, costs
Economics
expected real income growth
expected real fuel price growth

**Figure B.3:
Sequence of Activities for a STEP Application**



Appendix C: Basic STEP Equations in Detail¹

The following subsections provide a summary of the principal travel demand models used in the MTC version STEP. Detailed specifications are included for

- o Home-Based Work Mode Choice
- o Shared-Ride Occupancy
- o Home-Based Shop Trip Destination and Mode Choice
- o Home-Based Shop Trip Frequency Model
- o Home-Based Social/Recreational Trip Destination and Mode Choice
- o Home-Based Social/Recreational Trip Frequency Model
- o Worker-Household Vehicle Ownership
- o Non-Worker Household Vehicle Ownership
- o Home-Base Work Trip Distribution

These nine models were developed for the Metropolitan Transportation Commission (MTC) using data from the San Francisco Bay Area, and were part of the version of MTC's regional travel model known as MTCFCAST. Three additional models from MTCFCAST, covering non-home-based trips, are also included in the STEP software.²

C.1 Home-Based Work Mode Choice Model

The basic model form is multinomial logit

$$P_m = \frac{\exp(U_m)}{\sum_{i=a,s,t} \exp(U_i)}$$

where P_m is the probability of choosing mode m ,
 U_m is the traveler's utility for mode m ,
 i represents the set of available modes
 $i = a >$ drive alone
 $s >$ shared ride
 $t >$ transit

¹ The models presented here are from the MTC version of STEP. STEP's models are updated periodically and new versions of the travel model ensemble are added (see Appendix B)

² For documentation of the non-home-based models in STEP, see Harvey, 1978

The utility equations are defined on the next page. It can be seen that, e.g., the utility for drive alone is

$$U_a = -2.512 - 0.0000714x_{dinc} - 1.067x_{cbd} - 0.244x_{ivt}_a - 0.77x_{walk}_a \\ - 21.43x_{(cost_a - inc)} + 1.958x_{autos} + 6.77x_{head}$$

	Coefficient Value	Variables in the Utility			Explanation
		a	s	t	
1	- 00000714	dinc	dinc		Household disposable income
2	-1 067	cbd			Constant for central business district
3	- 347		cbd		Constant for central business district
4	327		nwork		Number of workers in household
5	- 0244	ivtt(a)	ivtt(s)	ivtt(t)	In-vehicle travel time (minutes)
6	- 077	walk(a)	walk(s)	walk(t)	Walk time (minutes)
7	- 045			wait1	Transit initial wait (minutes)
8	- 0428			xferwait	Transit transfer wait (minutes)
9	-21 43	cost(a))inc	cost(s))inc	cost(t))inc	Cost (cents) / household income (\$)
10	1 958	autos			Number of autos in household
11	1 763		autos		Number of autos in household
12	1 389			autos aac	Number of autos for auto access
13	-1 237			aac	Constant for auto access to transit
14	677	head			Constant for head of household
15	-2 512	const			Drive alone constant
16	-3 473		const		Shared ride constant

Home-Based Work Mode Choice Model

C.2 Shared Ride Work Trip Auto Occupancy Model

The model is a simple linear regression, constrained to have a value greater than 2

$$srocc = \max(2, [2.542 - 0.0004717 \times dinc + 0.1116 \times ivtt_s])$$

where *srocc* is the shared ride occupancy,
dinc is the household disposable income,
ivtt(s) is the shared-ride in-vehicle time

C.3 Home-Based Shop Trip Destination and Mode Choice Model

The shopping destination/mode choice model is a logit probability equation with a set of choice alternatives encompassing the auto and transit modes and the full set of zones accessible to a household for the shopping trip purpose. Each specific mode and destination combination is a separate alternative. Thus, if ten destinations are available, each with two modes, there are twenty choice alternatives recognized by this model.

The basic model form is

$$P_{dm} = \frac{\exp(U_{dm})}{\sum_{j=i}^{nzones} \sum_{i=a,t} \exp(U_{ji})}$$

where P_{dm} is the probability of taking a shop trip to destination d by mode m ,
 U_{dm} is the traveler's utility for the destination d mode m combination,
 i represents the set of available destinations (defined as zones or districts),
 j represents the set of available modes (a or t)

The utility definitions for a given destination are given on the next page. E.g., the utility of the auto mode to a specific destination d is

$$U_{da} = -8631 + 2563 \times cbd_d + 5.053 \times (autos / hhsz) - 0.00202 \times (time_{da} \times inc) \\ - 0.2447 \times cost_{da} + 0.005995 \times rden_d + \ln(rjobs_d)$$

	Coefficient Value	Variables in the Utility		Explanation
		Auto	Transit	
1	- 8631	const		Auto constant
2	2563	cbd		Constant for central business district
3	8912		cbd	Constant for central business district
4	5 053	autos/hhsize		Autos per person in household
5	- 000202	time(a)*inc	time(t)*inc	Door-to-door travel time (minutes) weighted by income
6	- 02447	cost(a)		Cost (cents)
7	- 02299		fare*hhsize	Transit fare (cents) weighted by household size
8	0005995	rden	rden	Retail density (employees per population serving acre)
9	1 0	ln(rjobs)	ln(rjobs)	Natural log of retail workers in zone

Home-Based Shop Trip Destination and Mode Choice Model

C.4 Home-Based Shop Trip Frequency Model

The shop trip frequency model is a non-linear regression yielding an inverse function of household characteristics, home zone characteristics, and aggregate destination attractiveness (as embodied in the expected utility for shopping destination/mode choice). The exact model specification is

$$hbshop = \frac{8194}{07766 + \exp(-34174 \times hhsz - 051512 \times (inc - 100) - 052681 \times E[U_{dm}] + 1146 \times \ln(edn + 1))}$$

where

hbshop is the number of daily home-based shopping trips per household,
hhsz is the number of persons in the household,
inc is the household income (\$),
 $E[U_{dm}]$ is the expected utility from the shopping destination/mode choice model,
defined as the natural log of the denominator of that model's logit equation,
eden is the service and retail employment density, in workers per gross acre

C.5 Home-Based Social/Recreational Trip Destination and Mode Choice Model

The social/recreational destination/mode choice model is a logit probability equation with a set of choice alternatives encompassing the auto and transit modes and the full set of zones accessible to a household for the social/recreational trip purpose. Each specific mode and destination combination is a separate alternative. Thus, if ten destinations are available, each with two modes, there are twenty choice alternatives recognized by this model.

The basic model form is

$$P_{dm} = \frac{\exp(U_{dm})}{\sum_{j=1}^{nzones} \sum_{i=a,t} \exp(U_{ji})}$$

where: P_{dm} is the probability of taking a social/recreational trip to destination d by mode m ,
 U_{dm} is the traveler's utility for the destination d mode m combination,
 j represents the set of available destinations (defined as zones or districts),
 i represents the set of available modes (a or t)

The utility definitions for a given destination are shown on the next page. Based on this table, the utility of the auto mode to a specific destination d is

$$U_{da} = 1.844 - 215 \times cbd_d + 2.167 \times (autos - hhsz) + 3368 \times rautos - 0.001097 \times (time_{da} \times inc) \\ - 0.256 \times cost_{da} + 0.609 \times rden_d + 0.244 \times popden_d + 6998 \times \ln(pop_d - rjobs_d) + \ln(rjobs_d)$$

	Coefficient Value	Variables in the Utility		Explanation
		Auto	Transit	
1	1 844	const		Auto constant
2	- 215	cbd		Constant for central business district (destination)
3	1 19		cbd	Constant for central business district (destination)
4	2 167	autos/hhsize		Autos per person in household
5	3368	rautos		Autos not used for work trips
6	- 0001097	time(a)*inc	time(t)*inc	Door-to-door travel time (minutes) weighted by income
7	- 0256	cost(a)		Cost (cents)
8	- 0108		fare*hhsize	Transit fare (cents) weighted by household size
9	0609	rden	rden	Retail density at destination (employees per acre)
10	0244	popden	popden	Population density at destination (persons per acre)
11	6998	ln(pop/rjobs)	ln(pop/rjobs)	Natural log of population) retail jobs at the destination
12	1 0	ln(rjobs)	ln(rjobs)	Natural log of retail employment in the destination zone

Home-Based Social/Recreational Trip Destination and Mode Choice Model

C.6 Home-Based Social/Recreational Trip Frequency Model

The S/R trip frequency model also is a function of household characteristics, home zone characteristics, and destination characteristics (as embodied in the expected utility for social/recreational destination/mode choice). The exact model specification is

$$hbsr = 1398x \exp(4671x \ln(hhsize) + 005055x(hhsize - nwork) + 3963x \ln(inc - 100) + 06785xE[U_{dm}] - 3213x \ln(seden + 1))$$

where:

hbsr is the number of daily home-based social/recreational trips per household,

hhsize is the number of persons in the household,

nwork is the number of workers in the household,

inc is the household income (\$),

$E[U_{dm}]$ is the expected utility from the social/recreational destination/mode choice model, defined as the natural log of the denominator of that model's logit equation,

seden is the service employment density, in workers per gross acre

C.7 Worker-Household Vehicle Ownership Model

The worker-household vehicle ownership model is of the logit form with three ownership alternatives -- zero, one, and two or more vehicles

The basic equation is

$$P_v = \frac{\exp(U_v)}{\sum_{k=1}^{2+} \exp(U_k)}$$

where

P_v is the probability of choosing vehicle ownership level v ,

U_v is the household's utility for vehicle ownership level v ,

k represents the set of vehicle ownership levels

$k = 0$ > zero autos in household,

1 > one auto in household,

$2+$ > two or more autos in household

The utility definitions are shown on the next page. E.g., the utility of owning one auto is

$$U_1 = 4989 + 3935x\text{sinfam} - 05419x\text{eden} - \frac{2689}{\text{hhsz}} + 06814x\text{twork}_1 + 7919x\ln(\text{nnc}_1)$$

	Coefficient Value	Variables in the Utility			Explanation
		0 Vehicles	1 Vehicle	2 or More	
1	4 989		const		One vehicle ownership constant
2	5 689			const	2+ vehicle ownership constant
3	3935		sinfam		Constant for single family detached unit
4	1 342			sinfam	Constant for single family detached unit
5	- 05419		eden	eden	Workers per acre in the home zone
6	-2 689		autos)hhsiz	autos)hhsiz	Autos per person in household The variable "autos" has the value 1 for v=1 and 2 25 for v=2+
7	5608	tshop			A measure of the quality of transit service from the home zone for non-work trips, defined as the sum of transit utilities divided by the sum of auto utilities for the shopping destination/mode choice model
8	06814	twork0	twork1	twork2+	A measure of the quality of transit service from the home zone for work trips, defined as the household head's work trip transit utility divided by the sum of work trip drive and work trip shared ride utilities
9	7919	ln(rinc0)	ln(rinc1)	ln(rinc2+)	Natural log of the remaining income after housing, auto ownership, and commuting expenses are taken into account

Worker-Household Vehicle Ownership Model

C.8 Non-Worker-Household Vehicle Ownership Model

The non-worker household vehicle ownership model has the same form as the worker model. The utility specifications and coefficients are shown below.

	Coefficient Value	Variables in the Utility			Explanation
		0 Vehicle	1 Vehicle	2 or More	
1	- 8695		const		One vehicle ownership constant
2	-8 357			const	2+ vehicle ownership constant
3	- 0682			popden	Population density in home zone (persons per acre)
4	3188		$\ln(\frac{dinc}{hsize})$		Natural log of the household disposable income per person
5	1 227			$\ln(\frac{dinc}{hsize})$	Natural log of the household disposable income per person
7	5608	tshop			A measure of the quality of transit service from the home zone for non-work trips, defined as the sum of transit utilities divided by the sum of auto utilities for the shopping destination/mode choice model

e.g., the utility of owning one auto is

$$U_1 = - 8695 + 3188 \times \ln(\frac{dinc}{hsize})$$

C.9 Home-Based Work Trip Distribution

Effects of changes in accessibility on non-work trips are reflected in the shopping and social/recreational models described earlier. Work trip distribution also might be expected to change, though not in the same ways as non-work trips. The original work trip distribution model from MTCFCAST is a work "destination choice" model similar to (but simpler than) the shopping and social/recreational versions. The basic model form is

$$P_d = \frac{\exp \left[\ln(\text{workers}_d) + 1.811 \times \sum_{v=1}^{2+} (P_v \times E[U_{m|v,d}]) \right]}{\sum_{i=1}^{nzones} \exp \left[\ln(\text{workers}_i) + 1.811 \times \sum_{v=1}^{2+} (P_v \times E[U_{m|v,i}]) \right]}$$

where P_d is the probability of choosing destination d as the workplace,
 workers_i is the total number of workers in zone i ,
 $E[U_{m|v,i}]$ is the expected utility of work mode choice to destination i , given auto ownership level v ,
 P_v is the probability of choosing household auto ownership level v ,
 $nzones$ is the number of zones in the region

Appendix D: Baseline Transportation and Emissions Data

As the text of the report explains in some detail, we have presented most of our analysis results in terms of percent changes from a base case rather than in terms of absolute totals of VMT, trips, time, emissions, fuel consumption, and so on. One reason is that the kinds of models used for this study are more likely to yield robust estimates of changes in transportation system measures than of regional totals. A second, closely related, reason is that there can be a remarkable degree of disagreement among credible estimates of transportation system performance - especially for long-range forecasts, but even for current conditions.

Nevertheless, because many readers will be more accustomed to thinking in terms of absolute changes, we have assembled a set of estimates covering California's four large metropolitan areas for the two analysis years featured in the report - 1991 and 2010. These are shown in Table D 1 for eight key measures of system performance:

- Vehicle-miles traveled
- Vehicle trips
- Vehicle hours
- Reactive Organic Emissions
- Carbon Monoxide Emissions
- Oxides of Nitrogen Emissions
- Particulate Emissions
- Fuel Consumption

The estimates cover personal travel, defined approximately (in CARB terms) as the sum of light-duty auto, motorcycle, and a majority of light-duty truck travel. They are derived from STEP outputs, but correspond closely to MPO and CARB estimates current in January 1994 (when the majority of our analyses were initiated). The emissions estimates reflect the EMFAC7F emissions model then current.

While some use of these data is made in the body of the report, notably to illustrate the application of percent changes produced by STEP (Chapter 7) and to investigate cost

effectiveness, we recommend that readers substitute up-to-date estimates from the local MPO, CARB, or other credible sources when pursuing their own calculations

Table D.1: Example Baseline Data for California Metropolitan Areas

Year Region	Area Type	Daily Totals - Personal Vehicles Only									
		Vehicle Miles (000)	Vehicle Trips (000)	Vehicle Hours (000)	Reactive Organics (tons)	Carbon Monoxide (tons)	Nitrogen Oxides (tons)	Particulates (tons)	Gallons of Fuel (000)		
1991 Bay Area	Air Basin	99100	14000	3600	251	1600	159	24	4670		
	Sacramento County	19800	3600	600	58	360	37	5	940		
	San Diego County	54400	7600	1800	151	1060	97	13	2580		
	South Coast	251500	30800	9100	559	3680	378	61	11810		
2010 Bay Area	Air Basin	141400	18800	5400	53	480	60	33	5100		
	Sacramento County	31100	4100	1100	11	105	13	7	1120		
	San Diego County	73900	9800	2600	40	330	39	17	2660		
	South Coast	360900	40700	13900	126	1130	158	84	13030		

Sources: STEP outputs; EMFAC7F (1/94)

Appendix E: Focus Group Information

E.1 Schedule

2 hours total per group

moderator with 10-12 participants

5 min opening statement and ground rules
20 min overview of the proposals
15 min overview discussion (Question 1)
40-60 min discussion of key strategy (Questions 2-5)
15-35 min comparison with other options (Question 6)
5 min open-ended question (Question 7), closing statement and wrap-up

E.2 Locations and Key Topics

Bay Area (San Jose)	Vehicle Registration Fees and Parking Charges
Bay Area (Berkeley)	Congestion Pricing - Bay Bridge
Sacramento	Vehicle Registration Fees and Parking Charges
Los Angeles (Encino)	Congestion Pricing and Parking Charges
San Diego	Congestion Pricing and Fuel Fees

E.3 Script

INTRODUCTIONS AND GROUND RULES (5 minutes)

Good evening My name is _____ and I will be your moderator for this evening's session

We thank you for joining us this evening, for a group discussion on transportation strategies to reduce congestion, air pollution, and fuel consumption. We will be spending the next two hours together in what we hope will be a lively discussion. We will begin by hearing about four strategies that are being considered by public policy-makers as possible ways to influence transportation choices, and then we will discuss one of the strategies in detail. Toward the end of the session we will come back to the other strategies and discuss how you would rank them in comparison to the others. I will present the strategies to you, pose

questions, help keep the discussion on track, and encourage everyone to participate, but I will not be a participant myself

There are some simple ground rules for this session. First, we want to assure you that we will treat any personal information you provide us as confidential. While your comments, views and suggestions are being recorded and you are being observed by members of our group from behind the one-way mirror over here, none of you will be identified individually in the reports. Your names and other information about you personally will not be reported.

Second, we want you to speak your minds about the strategies that you will hear about at this session. It is likely that there will be differences of opinion. Sometimes you may be in agreement, and other times you may not agree with one another. That's fine, we are anxious to hear the full range of viewpoints. You should feel free to say what you think. Also, let's make sure we hear from each of you.

Finally, we want to emphasize that the strategies that we are going to consider tonight are in the preliminary discussion stages. Because of this, not all of the details have been worked out on some of the proposals, and there may be several different ways to go. Your views will be important in helping policy-makers decide which ideas are worth pursuing and which are not, and will shape their thinking about how to proceed. Also, we may not have answers to some of the questions you raise. Don't let that stop you from asking the questions! Your questions will be used to guide the next steps in the studies and discussions.

So, with that said, let's begin.

OVERVIEW OF THE PROPOSALS (20 minutes)

Californians face a number of problems that are directly related to how much we travel and the transportation choices we make.

Show story boards

Traffic congestion is an irritating, stressful, and costly problem for many commuters, according to polls conducted in the state's major metropolitan areas. Congestion also increases the costs of doing business in the state and discourages some companies from making investments here.

Air pollution is a major environmental problem and a direct threat to the public's health. California has the dirtiest air in the United States, and every large city in the state violates federal and state health standards. Federal and state laws mandate improvements and the state could lose federal funds if we can't clean up the air. Businesses also could face constraints on growth.

Transportation's **dependence on petroleum** makes it the least flexible sector of the California economy from an energy perspective. Transportation's heavy dependence on oil not only puts the state at risk in the event of a disruption in overseas supplies, but makes transportation a major source of the emissions that are contributing to global warming.

Major efforts have been undertaken to reduce these problems, and some progress has been made. But for a variety of reasons the problems persist. For example, a new car emits only a fraction as much pollution as did the new car of 20 years ago. The vehicle fleet also is much more energy efficient than it used to be. But the growing number of cars on the road and increases in the amounts that people are driving offset some of the gains. Growth in traffic also has outstripped highway expansions, contributing to increased congestion in many areas. Stop-and-go driving in turn leads to increased fuel use and higher emissions.

State and local agencies have tried to entice travelers to reduce their driving by offering alternatives, such as transit services, preferential high-occupancy vehicle (HOV) lanes for carpools and vanpools, and bike and pedestrian facilities. While some travelers do make use of these options, voluntary programs and incentives to increase this use have been only partly successful. In most areas, seventy percent or more of the commute trips are made by driving alone - a percentage that actually is higher than it was ten years ago.

Today, federal and state requirements for air pollution reduction are increasing the pressure to do something about this situation. In some metropolitan areas, mandatory programs to reduce travel have been imposed. For example, large employers are now required to reduce the number of vehicles their employees bring to work. However, employers are having difficulty in meeting this requirement, because their employees don't think commute alternatives are competitive with the car. It is increasingly apparent that a different approach is needed if we are going to make headway.

In analyzing why it is so difficult to change people's driving habits, two factors are repeatedly uncovered. First, many people say the alternatives need to be much improved before they will be serious competition to the private automobile. And indeed, where there are good transportation alternatives (such as to downtown San Francisco) the number of people who use the alternatives greatly increases. But major transportation improvements are expensive, and the funding that is currently available for transportation falls short of identified needs.

A second factor is that drivers do not pay the full cost of driving their cars, particularly in areas where there is serious congestion or air pollution. In addition, many drivers are provided with parking free of charge, even though providing the parking is a major expense. As a result, driving alone appears to be much cheaper than it really is.

These two points have led some policy-makers to look for strategies that would make the price paid by drivers more fully reflect the costs of driving. Charging drivers more also would generate revenues, which could be used to improve alternatives, and perhaps to offset inequitable impacts. So far, four options have been proposed:

- congestion pricing
- vehicle registration fees which vary with pollution and energy use
- gas tax increases
- parking charges

Studies and experience indicate that these options could be quite effective in reducing auto use and providing the funds needed to improve travel alternatives. But their public acceptability remains an open question.

Here is an overview of how the strategies might work.

Congestion pricing refers to prices, or tolls, which are charged only at those times of day when congestion is a problem. The toll would be set high enough to induce some travelers to use other routes, switch to other modes, or travel at a less congested time of day. Congestion pricing might be implemented on a facility that already has a toll, such as the bridges in the Bay Area and the new toll roads in Orange County, or it might be installed when a new lane is added to a freeway (you'd pay the toll in order to use the additional lane). Some have suggested allowing solo drivers who pay a toll to use extra capacity in HOV lanes. New "smart card" technologies, already in use in Texas and on the new Orange County toll road, make it possible to pay the toll without stopping at a toll booth - an electronic reader detects whether the car has the required card, and if not, triggers enforcement. Over the long run, these new tolling technologies would allow any road equipped with toll card detectors to have congestion pricing. Congestion pricing not only would reduce congestion, but also would reduce fuel use and emissions somewhat. Revenues from the program could be used to improve the highways, improve transit and ridesharing programs, or perhaps to provide lifeline rates for low income people.

Vehicle registration fees currently are based on a flat fee charged to all vehicles, plus a license fee of two percent of the market value of the vehicle. This strategy would add a fee based on the total estimated emissions from the vehicle over the year, and perhaps based on the vehicle's fuel efficiency as well. The fee might be based on the vehicle's age, make, and model information, or might also take into account the odometer mileage and emissions measurements, read during the vehicle's emissions test. A car that is very clean and energy efficient would pay no fee, whereas the dirtiest, most gas-guzzling cars might pay several hundred dollars more than at present. Over time, car owners would take steps to clean up their cars, reduce their use, or replace them with cleaner, fuel efficient models. Super-polluters and gas guzzlers would be driven less and scrapped sooner. The funds generated from the higher fees could be used to improve transportation options, offset the

impact on low income people, or perhaps to give a discount to people whose cars are especially clean and efficient - actually lowering their fees from present levels

Gas tax increases would be the most direct way to reduce fuel consumption. Increased fuel prices also would reduce emissions and congestion, because some would drive less or shift to other travel modes. Fuel-efficient vehicles would be more popular and gas-guzzlers would be less so. Gas tax increases could range from a few cents a gallon, for example, to cover the costs of air pollution and fund energy conservation programs, to as much as several dollars per gallon if prices similar to those in Japan or Europe were introduced or if revenues were to pay for other major costs of auto use such as the costs of accidents. Another possibility would be to substitute a gas tax for other transportation funding sources which are less directly related to auto use, such as sales taxes and property taxes.

Parking charges would be designed to reduce the subsidy to motorists who now are provided with free parking. For example, at present about 85% of commuters park for free, although the parking space they occupy is a significant expense. A new state law requires certain employers who pay for commuter parking for their employees to offer the employees a cash equivalent. This policy could be extended or modified to make it apply to more broadly. One strategy would be to extend the cash-out policy to everyone, that is, require every employer who provides employee parking to offer all employees a cash payment of the equivalent amount. Another strategy would require employers either to charge for parking at its actual cost (typically \$25-50/mo. in industrial areas and the suburbs, and up to \$200/mo. in downtown areas), or to report the value of the parking space as income to the employee. Charging the actual cost for parking would reduce drive alone commuting by 10-15%, increase the use of alternative modes of travel, and potentially reduce fuel use, emissions, and congestion. On the other hand, revenues would not necessarily be available for other uses.

QUESTIONS (90 minutes)

1 (15 minutes)

To get the discussion started, I'd like to hear your general reactions to the problems that we are trying to solve - congestion, air pollution, dependence on petroleum.

- a) On a scale of one to ten, where one is not important at all and ten is very important, how important an issue is congestion, to you personally? How about to the public as a whole?

show scale - poll each participant - encourage participants to say why they feel the way they do

b) On the same scale of one to ten, where one is not important and ten is very important, how do you rate air pollution

- to you personally?

- and how important do you think it is as an issue for the public as a whole?

poll each participant using scale

c) And finally, how important an issue is dependence on petroleum

- to you personally?

- and how important do you think it is as an issue for the public as a whole?

poll each participant using scale

2 (60 minutes for questions 2-5)

Now I'd like to turn the discussion to the strategy on which we have been asked to focus our attention _____ Let's take another look at that option

Review story boards on the focus strategy - add detailed boards

What are your initial reactions to this strategy?

3 What do you see as the biggest benefits, if any, resulting from this strategy? What do you see as the biggest problems, if any?

4 Some variations on how the strategy might be implemented were presented

Review story boards on the options for the session's main strategy

- Which of these ways of proceeding do you think is preferable?

- Why?

5 Do you feel that this policy would lead you to change your behavior? If so, how and why? Or if not, why not?

6 (20 minutes for questions 6 and 7)

Let's now take another look at the four strategies we discussed initially

Review story board on all four strategies

How do you rate each of these strategies? On a scale of 1 to 10, where 1 is terrible, or unacceptable, and 10 is a great idea that should be strongly supported, how do you rate

Show scale - poll each participant for each strategy in turn

congestion pricing

vehicle registration fees

parking charges

gasoline taxes

7 If you could send a personal message to the policy makers concerning the ideas we have discussed here tonight, what would it be?

That concludes our discussion for the evening We thank you for coming

(Any housekeeping tasks go here)

E.4 List of Support Graphics

- 1 California Traffic Problems
- 2 Current strategies have helped .
- 3 but voluntary programs to change travel modes are only part of the answer
- 4 Driving Habits are Hard to Change
- 4a Mode Shares (CA Metro Areas)
- 5 Pricing Strategies Could Address These Concerns
- 6 Congestion Pricing
- 7 Congestion Pricing Options
- 7a New Toll Technologies (show toll tags etc)

- 7b How Big Would a Congestion Toll Be?
- 8. Vehicle Registration Fees
- 9 Registration Fee Options
 - 9a How Much Does a Dirty Car Pollute?
 - 9b How Much Fuel Does a Gas Guzzler Consume?
- 10 Gas Tax Increases
- 11. Gas Tax Options
 - 11a Current Gas Taxes in California
- 12 Parking Charges
- 13 Parking Charge Options
- 14 Importance Scale for Question 1
- 15 Desirability Scale for Question 6