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:

- How to set transportation prices
- Effectiveness
  - transportation impacts
  - environmental impacts
  - energy impacts
  - land use and locational impacts
  - revenue generation
- Unintended consequences
- Fairness/distribution of impacts
- Use of revenues
- Political acceptability
- Legal barriers
- 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:

- How would transportation pricing affect the transportation system, in terms of travel time, travel cost, mode shares, and overall travel patterns?
- 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:

- Who will benefit and who will not?
- 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 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 accepted, 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 bottlenecks 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:

- assignment of responsibility for implementation
- monitoring and enforcement
- 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 ticket-ing-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*(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:

- **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 locations.[1] 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 areas.[2] 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.

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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

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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 vehicles[9] 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.

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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 CO_2 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 (.0364 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]

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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 167 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.

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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 .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 .05 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

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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, NOx, 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:

- 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;
  - 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;
  - 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.

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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.

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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 STEP.[22]

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	• 1981 MTC Travel Survey • 1990 MTC Travel Survey (DHS Corrected Versions) • 1991 Caltrans Travel Survey	• 1991 SCAG Travel Survey (DHS Corrected Version) • 1991 Caltrans Travel Survey	• 1991 SACOG Travel Survey w/ Caltrans Travel Survey (DHS Corrected Version)	• 1985 SANDAG Travel Survey • 1991 Caltrans Travel Survey
US Census Data	• 1990 Public Use Microdata Sample	• 1990 Public Use Microdata Sample	• 1990 Public Use Microdata Sample	• 1990 Public Use Microdata Sample
Base Year (1990/91) Zonal Demographic Data	• Current ABAG/MTC Zonal Data File for 1990 as of 2/95	• Current SCAG Zonal and Tract Data File for 1990 as of 10/94	• Current SACOG Zonal Data File for 1990 as of 6/94	• Current SANDAG Zonal Data File for 1990 as of 10/93
Transportation Networks; Travel Time and Cost Data	• MTC 1990 Network (zones, superdistricts)	• SCAG 1990 network - final runs using DHS corrected version March 95	• SACOG network (zones, superdistricts)	• SANDAG network provided by Cambridge Systematics, Inc.
Parking costs	• MTC 1990	• SCAG 1990	• SACOG 1990	• SANDAG 1991
Vehicle fuel efficiency	• modeled based on vehicle type (known from 1990 survey)	• modeled based on vehicle type (using 1991 Caltrans data)	• modeled based on vehicle type (known from 1991 survey)	• modeled based on vehicle type (using 1991 Caltrans data)
Emissions data	• EMFAC 7F	• EMFAC 7F	• EMFAC 7F	• 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, CO_2, ROG, CO and NOx emissions, and annual gross revenues[1], for the years 1991 (the base year[2]) 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 (NOx). 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/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:

- 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.

- 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.

- An extensive program of HOV lanes for the Bay Area, proposed as part of Phase 2 of the Air Plan, was estimated to produce .41 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 CO_2 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 VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx	Annual Revenue
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	$0.09	-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 Price	Change From 1991 Base								Annual Revenue
			VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	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% -2.6%	-0.8% -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%	-1.2% -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%	-1.0% -2.8%	-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% -2.9%	-1.0% -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: VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx	Annual Revenue
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 (.0364 gallons per mile). Base fuel cost is about $1.20 per gallon, or 5.45 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 tp 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.	Bay Area	$0.50	-0.13	-3.9%	-3.6%	-5.4%	-7.5%	-9.1%	-3.7%	-3.6%	-3.4%	954
		$2.00	-0.13	-12.6%	-12.1%	-17.0%	-22.0%	-31.3%	-12.5%	-12.2%	-11.8%	2884
		$2.00	-0.05	-16.6%	-15.8%	-21.8%	-26.0%	-23.6%	-16.3%	-16.0%	-15.6%	3207
		$2.00	-0.22	-7.7%	-7.1%	-10.1%	-12.0%	-42.3%	-7.5%	-7.3%	-7.0%	2422
	Sacramento	$0.50	-0.13	-4.3%	-4.0%	-5.6%	-6.5%	-9.5%	-4.1%	-4.0%	-3.7%	264
		$2.00	-0.13	-13.9%	-13.3%	-17.6%	-18.5%	-32.4%	-13.7%	-13.5%	-12.6%	790
		$2.00	-0.05	-18.4%	-17.6%	-23.0%	-23.0%	-25.2%	-18.2%	-17.8%	-17.3%	874
		$2.00	-0.22	-8.5%	-7.8%	-10.9%	-12.0%	-42.8%	-8.3%	-8.1%	-7.7%	668
	San Diego	$0.50	-0.13	-4.1%	-3.8%	-5.5%	-7.0%	-9.2%	-3.9%	-3.8%	-3.6%	497
		$2.00	-0.13	-13.2%	-12.7%	-17.3%	-20.5%	-31.8%	-13.0%	-12.8%	-12.5%	1494
		$2.00	-0.05	-17.4%	-16.5%	-22.4%	-25.0%	-24.3%	-17.2%	-16.9%	-16.3%	1658
		$2.00	-0.22	-8.0%	-7.4%	-10.8%	-14.0%	-42.5%	-7.7%	-7.5%	-7.2%	1259
	South Coast	$0.50	-0.13	-4.1%	-4.0%	-5.4%	-6.5%	-9.1%	-3.8%	-3.7%	-3.5%	2405
		$2.00	-0.13	-13.3%	-12.8%	-17.5%	-21.0%	-31.8%	-13.2%	-13.0%	-12.2%	7219
		$2.00	-0.05	-17.6%	-16.7%	-23.4%	-29.0%	-24.5%	-17.4%	-17.1%	-16.4%	7992
		$2.00	-0.22	-8.1%	-7.5%	-10.6%	-12.5%	-42.5%	-7.9%	-7.8%	-7.4%	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; CO_2 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
		VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx	Revenue
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.	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: VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx	Annual Revenue
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).	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%	-5.7% -16.7%	320 284
	Sacramento	EMFAC In-Use	-2.7% -2.2%	-2.3% -1.8%	-3.1% -2.5%	-2.0% -1.5%	-5.2% -7.9%	-8.1% -20.7%	-8.0% -20.4%	-7.4% -18.8%	77 68
	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%	-7.6% -20.1%	-7.4% -19.7%	-6.8% -17.5%	148 131
	South Coast	EMFAC In-Use	-2.2% -1.8%	-1.9% -1.6%	-2.8% -2.1%	-3.0% -1.5%	-4.4% -7.2%	-7.0% -19.4%	-6.9% -19.0%	-6.2% -17.1%	743 658

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 7.6

Analysis Results for Congestion Pricing - 2010

Description	Region	Average Price	Change From 2010 Baseline								Annual Revenue
			VMT/VKT/PM	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%	-8.2%	-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 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%	-1.6% -3.9%	-2.6% -6.5%	-1.1% -2.7%	-1.1% -2.8%	-1.1% -2.8%	-0.9% -2.6%	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% -2.6%	-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% -8.6%	-1.1% -2.7%	-1.0% -2.6%	-1.0% -2.7%	-0.9% -2.6%	1408 4161

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; CO_2 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: VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx	Annual Revenue
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 (.0364 gallons per mile). Base fuel cost is about $1.20 per gallon, or 5.45 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 tp 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.	Bay Area	$0.50	-0.13	-3.6%	-3.4%	-5.3%	-8.5%	-8.8%	-3.5%	-3.5%	-3.3%	1332
		$2.00	-0.13	-11.7%	-11.3%	-16.8%	-25.5%	-30.6%	-11.6%	-11.5%	-11.1%	4053
		$2.00	-0.05	-15.5%	-14.8%	-22.8%	-36.5%	-22.5%	-15.3%	-15.2%	-14.5%	4526
		$2.00	-0.22	-7.1%	-6.8%	-10.1%	-15.0%	-42.0%	-7.0%	-6.9%	-6.4%	3387
	Sacramento	$0.50	-0.13	-4.1%	-3.9%	-5.5%	-7.0%	-9.3%	-4.0%	-3.9%	-3.7%	414
		$2.00	-0.13	-13.2%	-12.7%	-17.6%	-22.0%	-31.8%	-13.0%	-12.9%	-12.5%	1245
		$2.00	-0.05	-17.4%	-16.7%	-23.1%	-28.5%	-24.3%	-17.2%	-17.0%	-16.3%	1382
		$2.00	-0.22	-8.0%	-7.7%	-11.4%	-17.0%	-42.5%	-8.0%	-7.9%	-7.5%	1049
	San Diego	$0.50	-0.13	-3.9%	-3.5%	-5.5%	-8.0%	-9.1%	-3.8%	-3.6%	-3.3%	747
		$2.00	-0.13	-12.5%	-12.0%	-17.1%	-23.0%	-31.3%	-12.3%	-12.2%	-11.8%	2257
		$2.00	-0.05	-16.5%	-15.7%	-22.6%	-30.5%	-23.5%	-16.3%	-16.2%	-15.4%	2513
		$2.00	-0.22	-7.6%	-7.3%	-10.6%	-16.0%	-42.3%	-7.5%	-7.3%	-6.8%	1895
	South Coast	$0.50	-0.13	-4.2%	-3.9%	-6.1%	-9.5%	-9.3%	-4.1%	-4.0%	-3.8%	3724
		$2.00	-0.13	-13.0%	-12.5%	-18.7%	-28.5%	-31.6%	-12.8%	-12.7%	-12.4%	11235
		$2.00	-0.05	-17.1%	-16.4%	-24.8%	-38.5%	-24.0%	-16.9%	-16.8%	-16.0%	12483
		$2.00	-0.22	-8.2%	-7.8%	-11.7%	-17.5%	-42.6%	-8.0%	-8.0%	-7.1%	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
		VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx	Revenue
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.	Bay Area	-3.9%	-3.7%	-5.7%	-9.0%	-4.1%	-3.8%	-3.7%	-3.6%	1122
	Sacrament	-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; CO_2 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	
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).	Bay Area	EMFAC In-Use	-2.2% -1.6%	-1.9% -1.4%	-2.9% -2.1%	-3.5% -2.5%	-3.9% -6.6%	-6.4% -17.7%	-6.3% -17.5%	-4.5% -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%	-6.7% -20.2%	-6.6% -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%	-6.4% -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%	-5.6% -6.0%	-3.9% -7.2%	-6.5% -18.9%	-6.4% -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
			VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx	Revenue
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	-1.8%	-1.7%	-5.7%	-19.5%	-5.8%	-4.5%	-4.7%	-2.1%	1143
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%	-1.0%	-1.3%	-2.3%	-1.1%	-0.9%	-0.9%	-0.8%	405
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.	-2.3%	-2.6%	-3.7%	-7.0%	-2.6%	-2.5%	-2.6%	-2.4%	1196
3a	Fuel Tax Increase by $0.60 (1991)	Fees would be paid at the pump.	-3.9%	-3.6%	-5.4%	-7.5%	-9.1%	-3.7%	-3.6%	-3.4%	964
3b	Fuel Tax Increase by $2.00 (1991)		-12.6%	-12.1%	-17.0%	-22.0%	-31.3%	-12.5%	-12.2%	-11.8%	2884
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.	-2.0%	-1.7%	-2.7%	-3.6%	-4.1%	-6.5%	-6.5%	-5.7%	320
4b	Mileage- and Emissions-Based Fee (Range Approx. 10-1000/yr)		-1.6%	-1.4%	-1.9%	-1.5%	-6.9%	-18.2%	-17.9%	-15.7%	284
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%	-5.8%	-8.0%	-4.2%	-4.1%	-4.0%	-3.9%	804
	Example of Combined Effects: Moderate Impact	1, 2a, 3a, and 4a with maintenance of current transit service.	-8.1%	-7.5%	-13.9%	-28.9%	-18.3%	-14.4%	-14.6%	-11.3%	2589
	Example of Combined Effects: High Impact	1, 2b, 3b, and 4b with extensive transit investment. (Revenue not reduced to reflect cost of new transit.)	-19.7%	-19.0%	-29.1%	-46.8%	-46.3%	-37.4%	-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
			VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx	Revenue
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%	-6.0%	-1.8%	-1.5%	-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%	-2.6%	-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%	-3.1%	-3.1%	-2.8%	290
3a	Fuel Tax Increase by $0.60 (1991)	Fees would be paid at the pump.	-4.3%	-4.0%	-6.6%	-6.6%	-9.6%	-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%	-13.6%	-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. In alternative 4a, the fee would be based on	-2.7%	-2.3%	-3.1%	-2.0%	-5.2%	-8.1%	-8.0%	-7.4%	77
4b	Mileage- and Emissions-Based Fee (Range Approx. 10-1000/yr)	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%	-1.8%	-2.5%	-1.5%	-7.9%	-20.7%	-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%	-4.3%	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%	-12.1%	536
	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%	-38.7%	-35.5%	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: VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx	Annual Revenue
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%	-10.6%	-2.9%	-2.6%	-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.	-2.6%	-2.9%	-3.8%	-4.0%	-2.7%	-2.7%	-2.8%	-2.6%	668
3a	Fuel Tax Increase by $0.50 (1991)	Fees would be paid at the pump.	-4.1%	-3.8%	-5.6%	-7.0%	-9.2%	-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%	-12.6%	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 EMFAC7F. In alternative 4b, the fee would be based on actual odometer readings and in-use tailpipe measurements.	-2.4%	-2.1%	-2.9%	-2.6%	-4.9%	-7.6%	-7.4%	-6.8%	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%	-17.6%	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%	-7.6%	-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%	-7.6%	-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%	-36.4%	-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
			VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx	Revenue
1	Regionwide Congestion Pricing (level-of-service D/E) - 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%	-5.5%	-2.5%	3187
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%	-1.1%	-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%	-2.8%	-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%	-3.8%	-3.7%	-3.5%	2405
3b	Fuel Tax Increase by $2.00 (1991)		-13.3%	-12.8%	-17.5%	-21.0%	-31.8%	-13.2%	-13.0%	-12.2%	7219
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	-2.2%	-1.9%	-2.8%	-3.0%	-4.4%	-7.0%	-6.9%	-6.2%	743
4b	Mileage- and Emissions-Based Fee (Range Approx. 10-1000/yr)	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.	-1.8%	-1.6%	-2.1%	-1.5%	-7.2%	-19.4%	-19.0%	-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%	-4.3%	-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%	-15.9%	-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%	-39.8%	-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/VKT/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%	-3.6%	-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%	-3.5%	-3.9%	-5.4%	-5.3%	-4.5%	384
4b	Mileage- and Emissions-Based Fee (Range Approx. 10-1000/yr)		-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%	-16.3%	-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 VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx	Annual Revenue
1	Regionwide Congestion Pricing (level-of-service D/E) - Average $0.08 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	-1.5%	-1.4%	-4.8%	-16.5%	-4.8%	-3.7%	-3.9%	-1.7%	443
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%	-2.6%	-1.1%	-1.1%	-1.1%	-0.9%	142
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.	-2.6%	-2.8%	-3.9%	-6.5%	-2.7%	-2.8%	-2.8%	-2.5%	419
3a	Fuel Tax Increase by $0.50 (1991)	Fees would be paid at the pump.	-4.1%	-3.9%	-5.5%	-7.0%	-9.3%	-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%	-12.6%	1246
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.	-2.6%	-2.3%	-3.6%	-4.5%	-4.0%	-5.7%	-5.6%	-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	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%	-4.1%	-5.9%	-7.6%	-4.4%	-4.3%	-4.2%	-3.9%	349
	Example of Combined Effects: Moderate Impact	1, 2a, 3a, and 4a with maintenance of current transit service.	-8.7%	-8.2%	-14.1%	-26.6%	-17.6%	-13.4%	-13.5%	-9.9%	1016
	Example of Combined Effects: High Impact	1, 2b, 3b, and 4b with extensive transit investment. (Revenue not reduced to reflect cost of new transit.)	-21.0%	-20.2%	-30.2%	-46.1%	-46.5%	-39.3%	-39.1%	-34.5%	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
			VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx	Revenue
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%	898
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%	-12.3%	-12.2%	-11.8%	2257
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.	-2.5%	-2.2%	-3.2%	-3.6%	-4.1%	-6.5%	-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%	-19.5%	-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%	1940
	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
			VMT/VKT/PM	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx	Revenue
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%	-8.1%	-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	-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)	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.	-2.1%	-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%	-21.6%	-17.1%	-16.9%	-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 be 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 1	2	3	4	5	Total Households
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 1	2	3	4	5	Total Population
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 1	2	3	4	5	Total Autos
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 1	2	3	4	5	Total Workers
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 1	2	3	4	5	Regional Average
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 1	2	3	4	5	Regional Average
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 1	2	3	4	5	Regional Average
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 1	2	3	4	5	Regional Average
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-Alone
By PUMA of Residence and Household Income Quintile

PUMA Name	PUMA Number	PUMA Residents: Number of Workers Diverted by Income Quintile 1	2	3	4	5	All Quintiles
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 Increasefor Employees Working in PUMAs Marked ***

Table 8.6

Employee Parking Price Increase, $5.00 Regionwide

Sacramento Region - 1991

Number of Workers Diverted From Drive-Alone

By PUMA of Residence and Household Income Quintile

PUMA Name	PUMA Number	PUMA Residents: Number of Workers Diverted by Income Quintile					
		1	2	3	4	5	All Quintiles
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/Florin	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	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 1	2	3	4	5	Total
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	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

	Percent Change Resulting From:		Household Characteristics	
Ethnic Group	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

	Percent Change Resulting From:		Household Characteristics	
Gender	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 Impacts[1]

9.1 Overview

The land use impacts[2] 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

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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]

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[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.

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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:

- Specific "gateway" facilities with no significant alternative routes (for example, the San Francisco-Oakland Bay Bridge)

- Targeted limited-access facilities with comparable facilities not subject to congestion pricing (for example, Route 101 and I-280 on the San Francisco peninsula)

- Targeted limited-access facilities with alternative routes via surface streets (arterials) (for example, I-80 and San Pablo Avenue along the East Bay shore)

- 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 percent[9]). 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:

- Change work start and end times to avoid the peak,
- Change to a different shift (manufacturing jobs), or
- 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	- 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	- 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	- Unless implementation occurs differentially within the region, the main location and land use impacts will be the general ones described above.
VMT Fees	- Same as for fuel tax increases
Emission Fees	- Same as for fuel tax increases

Table 9.3: Transportation Pricing Impact Differences Among Case Study Regions

Location	Difference
Los Angeles	- 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	- 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	- This region has adopted land use plans focusing development on centers; the land use plans would be supported by pricing strategies.
Bay Area	- 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 more 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.