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Authors
Rodier, Caroline
Johnston, Robert

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INCENTIVES FOR LOCAL GOVERNMENTS TO IMPLEMENT TRAVEL DEMAND MANAGEMENT MEASURES

CAROLINE J. RODIER* and ROBERT A. JOHNSTON
Division of Environmental Studies and Institute of Transportation Studies, University of California, Davis, 95616, U.S.A.

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Abstract—Regulatory agencies in the energy field have successfully used incentives to encourage electric and gas utilities to implement conservation measures. We develop a method for allocating federal and state funds to reward local governments that adopt effective travel demand management measures and reduce the need for expenditures on expanded roadway capacity. This method is applied to Sacramento using the region's travel demand models to forecast, for twenty and fifty year time horizons, the effects of two travel demand management scenarios: a congestion pricing scenario and a comprehensive scenario that includes congestion pricing, parking pricing, and a fuel tax. Estimates of the capital, operation, and maintenance costs were obtained from local data and are used in the financial analysis of cost savings. We found that in the Sacramento region travel demand management implementation could defer roadway projects for a minimum of 7 yr and a maximum of 24 yr, resulting in a total savings to federal and state agencies of least $100 million and at most $223 million in 1992 $, which could be used to make annual payments of at least $16 million or at most $31 million a year to local governments. Issues surrounding the technical and political feasibility of funding incentives to local governments are addressed and further research is suggested. © 1997 Elsevier Science Ltd

INTRODUCTION

Travel demand management strategies, particularly road pricing and land use measures, are widely believed to be highly effective in reducing auto use and thus congestion and air pollution. Road pricing studies in the Bay Area and Southern California project reductions of daily vehicle miles traveled (VMT) by 10–15% and roughly equivalent reductions in vehicle emissions in a five year period (Cameron, 1991; Harvey and Deakin, 1991). Studies of land use measures in the Seattle region (Watterson, 1991) and in Montgomery County, Maryland (Replogle, 1990) project a 10% reduction in VMT; however, such measures take up to 20 yr to become truly effective. Similar results were obtained in studies by Webster *et al.* (1988), which used several urban land use and transportation models, and by Johnston and Ceerla (1995) in the Sacramento region.

Road pricing and land use measures have not been successfully implemented in the U.S. The downtown area pricing demonstration projects promoted by the U.S. Urban Mass Transportation Administration in the 1970s and the pricing component in California's 1976 proposed long-range plan both failed to be implemented (Guiliano, 1992). The San Francisco Bay Area air district has recommended travel pricing measures; however, they have not been well received by the state legislature. Proposals in the Bay Area to increase land use densities near to Bay Area Rapid Transit rail stations have, for the most part, not been instituted. The Southern California Association of Governments' plan to balance employment and housing has also proved unpalatable.

Electric and gas utilities in California were also reluctant to implement energy conservation measures until the Public Utilities Commission (PUC) began a program, commonly known as 'shared savings,' that rewarded utilities for adopting energy conservation measures. Now, numerous utilities in at least ten states have in place similar incentive mechanisms. Energy analyst Amory Lovins has suggested that this concept be applied to the transportation field: federal and state transportation funding agencies should reward local governments for reducing travel demand. Lovins, however, does not specify how this should be done.

*Author for correspondence.

In this study, we develop just such a method of application. First, we review the literature on conservation incentives for electric and gas utilities. Next, we develop a method for allocating federal and state funds to local governments that adopt effective travel demand management (TDM) measures and reduce the need for expenditures on expanded roadway capacity. This method is then applied to the Sacramento region. The region's travel demand model is used to forecast the effects of two TDM scenarios: a congestion pricing scenario and a pricing scenario that includes congestion pricing, parking pricing, and a fuel tax. Estimates of the capital, operation, and maintenance costs of roadway projects included in the region's transportation plan were obtained from local data and are used in the financial analysis of cost savings. Issues of uncertainty in the method developed and its application, particularly issues surrounding travel demand modeling and funding projections, are addressed. Future research regarding the political feasibility of the concept is outlined.

CONSERVATION INCENTIVES FOR ELECTRIC AND GAS UTILITIES

Since the early 1990s, PUCs across the U.S. have been increasingly adopting programs that provide financial incentives for utilities to implement demand side management (DSM) programs (Chamberlin and Hanser, 1991). Incentive programs are in place on the East Coast (New York, Rhode Island, New Hampshire, Massachusetts, and Maine) and West Coast (Washington, Oregon, and California), as well as in the Mid-West (Wisconsin and Michigan).

Hirst (1992) reports that the shared saving mechanisms, "in which the utility keeps part of the net benefit provided by its DSM programs," are the most popular type of incentive program because "they encourage the utility to minimize costs and to maximize the net benefit created by its DSM programs." Estimation of energy demand reduction is critical to the computation of net benefits in the shared savings programs and, as a result, much emphasis is placed on program evaluation (Hirst, 1992). There is general consensus in the literature that, initially, engineering estimates can be used to establish the incentive system and that, later, an evaluation of results should follow and be reconciled with initial estimates (Hirst, 1992; Cummings, 1992; Messenger, 1992). For example, "the California Collaborative (1990), which includes utilities, government agencies, and other groups, agreed to an incentive system based on prior engineering estimates of savings for individual DSM measures. These estimates will be revised on the basis of evaluations, but only after the programs (and associated incentives) have been in place for 3 years" (Hirst, 1992). There is also significant concern in the literature about the potential for fudged evaluations that favor the utilities (Cummings, 1992; Messenger, 1992).

One of the first comprehensive evaluations of DSM incentives was performed for the California PUC. The study examined four California utilities. According to the report, "five types of incentive mechanisms, including two shared-savings methods, were used at the utilities, resulting in total incentives of $170 million (pre-tax) during the period from 1989 through 1992." They found that "shareholder incentives were major contributors to the observed turnaround and increase in utility DSM activities and commitment during this time period" (Schlegel *et al.*, 1993).

Kushler (1993) reports on the "electric DSM incentive/penalty structure for Consumers Power Company, a utility with a history of minimal involvement (and little apparent interest) in DSM," which was established in 1992 by the Michigan Public Service Commission. According to Kushler, this program established a "substantial incentive: a potential 1% increase in rate of return (applied to the total company rate base, not just to DSM spending) for good performance." Based on a relatively qualitative evaluation, Kushler found a dramatic increase in the electric DSM activity since the 1991 incentive mechanism was put in place: a tenfold increase in electric DSM expenditures, dramatic increases in DSM staffing, and a projected average annual savings of 123 GWh and 20 MW, representing an eightfold increase over prior levels (Kushler, 1993).

Irvin and Peters (1992) report on the New England Electric System (NEES), which has conservation incentive programs in New Hampshire, Rhode Island, and Massachusetts. Shared savings programs are in place in New Hampshire and Rhode Island that allow the utility to "earn 5% of avoided costs plus 10% of DSM's net value (avoided costs less program costs)." A bounty incentive structure is in place in Massachusetts that gives the utility "$8 per kw and 3 mills per kw-h for permanent savings" (Irvin and Peters, 1992). They report that "largely in response to these incentives, NEES' DSM programs were implemented more aggressively and peak demand

and energy sales savings in 1990 exceeded targets by 10 and 30% respectively" and that "incentive payments to NEES were nearly 40% above expectations" (Irvin and Peters, 1992).

The literature suggests that incentives in the energy field can be very effective if they are structured properly. Problems arise, however, in the projection and evaluation of the effects of conservation policies and their cost savings. In the transportation field, evaluations may have to rely more heavily on less exact *ex-ante* engineering projections than *ex-post* evaluations, because regional governments may need firm commitments to adopt politically unpopular TDM measures. Electric and gas utilities do not face the same political pressures in adopting DSMs that local governments do in adopting TDM policies. To complicate the matter, travel demand models are inexact and may underestimate the effects of TDM policies. Fudging of the *ex-ante* estimates has been a problem in the transportation field in the past and could be a problem in projecting the effectiveness of TDM measures.

METHODS OF ANALYSIS

Conservation incentives in the transportation field would offer incentives for local governments to adopt effective TDM policies. The incentives would be derived from estimated cost savings of deferred roadway projects that result from the implementation of the TDM policies. The method developed to estimate these cost savings and disburse them to local governments consists of the following: (1) determine when the levels of congestion on roadways would require capacity expansions with and without the TDM policies; (2) project the cost of expanding roadways with and without the TDM policies and the amount of that cost federal and state governments would pay; (3) calculate the difference between the costs incurred by federal and state governments for the two scenarios to estimate cost savings; and (4) annualize cost savings to calculate yearly payments to local governments.

Implicit in the method outlined above is the assumption of a level of service investment rule; that is, local and regional governments base their decisions to expand roadway capacity primarily on the level of roadway congestion. This investment rule is typically employed by local and regional governments in the United States. However, if a benefit–cost analysis were used instead of the level of service investment rule, the imposition of TDM measures would not necessarily lead to the adoption of the delay- or no-build option. For example, the purpose of road pricing TDM measures is to seek to charge the marginal cost of congestion (i.e. delay and air pollution) and to signal decision makers about travelers' willingness to pay for the full costs of expanding a congested facility. The benefits of expansion will continue to justify the costs, if the volume of traffic and charges paid generate sufficient revenue to finance new capacity. Hence, road pricing TDM policies would not necessarily lead to reductions in roadway capacity expansions.

Currently, almost no regional government in the U.S. conducts a benefit-cost analysis of transportation policies. The true marginal cost of roadway congestion is extremely difficult to project with current travel and emissions data and modeling technology. Moreover, a benefit–cost analysis that places a monetary value on *all* the social costs and benefits of transportation expansion is virtually impossible. The method illustrated in this paper helps local governments identify a clearly suboptimal policy choice as well as identify more beneficial alternatives. TDM measures that begin to approach the true marginal costs of congestion should help move the transportation system toward increased efficiency and pricing charges can be refunded in ways that avoid equity problems.

Travel demand forecasts

Travel demand models. Regional travel demand models can be used to project travel demand on existing facilities in a region with and without TDM measures. These models can also predict the year in which travel demand will exceed capacity. Approximate forecasts of travel demand can be obtained up to 50 yr into the future. Ideally, databases for 30, 40, and 50 yr into the future should be available, in addition to the usual 10 and 20 yr databases.

Level of service rule. Level of service refers to the ratio of the actual volume of traffic during peak hours on a roadway to the amount of traffic a roadway can accommodate. When the volume-to-capacity ratio reaches levels of service E or F on a substantial portion of the roadways, expanded capacity will be assumed to be necessary. Levels of service E and F are the worst ratings a roadway can receive. Level of service F on roadways is interpreted as stop and go conditions with average speeds of less than 10 mph. Level of service E is interpreted as interrupted traffic flow with speeds under 35 mph.

Types of TDM policies. Because of their perceived effectiveness in reducing auto travel, the types of TDM policies tentatively envisioned for this program are pricing policies. However, any TDM measure or any combination of TDM measures could be used in the program, as long as its effects are significant enough to defer capacity expansion. TDM policies required by the federal Clean Air Act and the California Clean Air Act or other legislation (e.g. Congestion Management Plan statutes) should be counted in this program.

Financial forecasts

Costs. Capital outlays and operation and maintenance costs incurred by federal and state agencies for roadway expansion should be included in the calculation of financial cost savings. Federal and state funding (if any) of TDM measure costs should be subtracted from the federal and state costs of the deferred roadway expansion projects. Other costs related to these modes that are paid by the federal and state government, such as auto-related services (including highway patrol and court services), fuel subsidies, and fuel-related defense costs, will not be considered in the calculations, because they are external to the transportation agencies. In addition, local government costs related to TDM policies should not be considered in the calculation of financial cost savings for the federal and state funding agencies. Local governments can conduct their own projections of net costs to determine whether applying for TDM money is financially beneficial.

Percentage of federal and state contribution. The percentage of the contribution of federal and state governments to the cost of the project should be determined. For example, the federal government might fund 80% of the project and the state government might fund 20% of the project. The percentage should be based on existing federal and state funding rules [e.g. Intermodal Surface Transportation Act (ISTEA), 1991 and, for our case study, California's Streets and Highway Code section 164 (a) (5) and 164.2].

Estimating financial cost savings. To estimate the federal and state cost savings due to the implementation of TDM measures, the present value of the cost of the roadway project with the TDM measures should be subtracted from the present value of the cost without the TDM measures:

$$\text{Cost savings} = \text{PV of cost without TDM} - \text{PV of cost with TDM} \qquad (1)$$

The present value formula should be used to calculate the capital cost of the roadway project without the TDM policies where n is equal to the number of years from the reference point of the present value calculation to the time at which the capital costs would be incurred and r is equal to the discount rate:

$$\text{PV of capital cost without TDM} = \sum \text{capital costs}_n/(1+r)^n \qquad (2)$$

In our analysis, we identify the year in which the present value is calculated by the label "PV 1992." For example, if all the costs of a project were expected to be incurred in 2008 and the present value was calculated as of 1992, the costs would be discounted 16 yr back to 1992. It is assumed that capital, operation, and maintenance costs will inflate at the general price level, and thus they can be expressed in real constant dollars.

To estimate the present value of the capital cost with the TDM measures, the present value formula should be applied to the present value of the capital costs without the TDM measures where nd is equal to the number of years the project is delayed:

$$\text{PV of capital cost with TDM} = \text{PV of capital cost without TDM}/(1+r)^{nd} \qquad (3)$$

For example, if the project planned for 2008 (mentioned above) was deferred 7 yr to 2015 with the TDM measures, the present value of the project's capital cost would be discounted by 7 yr (the number of years that the project is delayed).

The maintenance and operation costs for new roadway capacity are assumed to be avoided during the deferment period. The present value of the maintenance and operation costs should be calculated and added to the present value of the capital cost of the project without TDM measures.

Thus, the present value of the cost of the project without TDM measures is equal to the sum of the present value of the capital cost without TDM measures plus the present value of the maintenance and operation costs. The present value of the cost of the project with TDM measures is equal to the present value of the capital cost of the project with TDM measures only. The difference between the present value of the costs with and without the TDM measures yields the present value of cost savings.

Cost savings should be disbursed to local governments annually, beginning when the roadways would have been expanded without the TDM measures and ending when the expansion is projected to be necessary with the TDM measures. Annual payments will be calculated in nominal dollars in the year they will be paid out. The uniform capital recovery formula can be applied to the present value of cost savings to calculate annual payments to the local governments:

$$\text{Annual payment} = \text{PV of cost savings } [r(1 + r^n)]/[(1 + r)^n - 1] \quad (4)$$

Disbursement. The disbursement of the funds should be contingent upon local governments' implementation of the TDM programs to which they commit themselves. If local governments do not fully implement the proposed TDM measures, the federal and state agencies will stop the funds.

Once the local governments receive the funds from deferred roadway capacity expansion, they should then pass on the benefits to the public through, for example, lower municipal taxes. For pricing TDM measures, all pricing charges should also be refunded to the public through lower taxes.

UNCERTAINTY IN THE METHODS OF ANALYSIS

The accuracy of model projections. Travel demand models were originally designed to project traffic volumes to plan for the construction of new highway and freeway capacity. The models generally performed this function adequately, because it did not require a high degree of absolute accuracy. However, many travel demand models in use today lack sensitivity to travel time and cost variables and to transit, walk, and bike accessibility variables and thus are relatively insensitive to the effects of many TDM policies. Travel demand models that incorporate these variables are used by only a few metropolitan planning organizations today (Johnston and Rodier, 1994). Because of the strict modeling requirements of the Clean Air Act [40 CFR, 51.452b(1)], Metropolitan Planning Organizations (MPOs) across the nation are updating their travel demand models to increase their sensitivity to TDM policies. Even with these improvements the effects of TDM policies are really only reasonably projected at the regional level and not at the road or link level. The federal government is currently funding the development of new travel demand models that will be specifically designed to project more accurately the effects of TDM measures at the link level. Some transportation planners predict that these models will be available for MPO use within the next 5–10 yr.

Still, travel demand models in their current form are the best travel forecasting tools available. Federal and state transportation agencies currently view projections from travel demand models as credible in determining the need for expanding roadway capacity. Thus, the use of state-of-the-practice models for this program (until more advanced models become available) is justified. It should be made clear that the effects of TDM polices will be realized roughly as predicted by the travel demand model at the regional level; however, the reductions in travel demand predicted on specific links may vary considerably.

Another modeling uncertainty is the difficulty of projecting travel demand beyond 20 yr into the future. Fifty-year studies have been performed in Portland, Oregon, and in Sacramento. Politically negotiated demographic estimates are frequently used in such studies, but their accuracy is questionable for obvious reasons. Demographic projections derived from regional employment and residential location models and population models are preferable. However, even with the use of these models, projecting demographic variables and relationships becomes more and more difficult farther into the future. In addition, the stability of coefficients in the model also decline farther into the future. Thus the credibility of forecasts beyond 20 yr is questionable.

Even within the twenty year forecasts, many variables are uncertain. For example, many pricing policies have not been implemented in the U.S.; thus, their precise effects on demand for auto travel in the U.S. are not known, and it is difficult to test models fully. However, better data may become available from demonstration road pricing projects proposed in the San Francisco Bay Area and the San Diego region.

The uncertainty surrounding model projections raises questions about monitoring TDM measure implementation. Local governments will be required to implement the TDM measures they agreed to implement (e.g. congestion tolls or certain land use densities around transit stations). Given current modeling inaccuracy, it is unreasonable to expect regions to achieve reductions in travel exactly as projected by their models. However, local governments should be able to relate gross failures to achieve projected travel reductions to unexpected events such as a dramatic drop in fuel prices.

Almost all models provide opportunities to fudge projections, particularly in calibration. Martin Wachs (1989) has commented on this problem in transportation planning. Past procedural requirements applied to new rail projects and current requirements for air quality conformity analysis could be applied to TDM policy projections to reduce the problem of fudging.

Accuracy of funding projections. There is also some uncertainty surrounding the shares of federal and state funding. As discussed above, current funding rules will have to be used. However, funding for roadway projects has increasingly shifted from the federal and state governments to local governments. In states like California, where local governments bid for federal and state project funds (i.e. local governments that come up with more money on their own have a better chance of getting funding), estimating the share of federal and state contributions will be difficult. In addition, the construction dates of new projects as listed in regional transportation plans are frequently subject to change, depending on funding availability.

APPLICATION OF THE METHOD TO THE SACRAMENTO REGION

Travel demand modeling

Model description. The Sacramento Area Council of Governments' (SACOG) 1990 Systems Planning Study four-step travel demand model (1990 SACMET model) was used for this analysis. This model has several limitations that should be kept in mind when interpreting its projections. The model generally suffers from a lack of current local data. Friction factors and logit coefficients are borrowed from other regions. The factoring for peak hour trips and the application of those travel times to all work trips probably exaggerates the transit share for work trips and perhaps may overestimate transit shares for all trips. The model lacks an auto ownership step and the trip generation step is not sensitive to level of service variables such as time and cost. Thus, time and cost impedances cannot be fed back to these steps. Peak spreading is not simulated in the model. These limitations make the model insensitive to policies that change the time and cost of travel. For example, the model may overpredict auto trips under conditions of congestion and underpredict transit trips due to lower fares. The trip generation step also lacks some important demographic variables, for example, age and income of the head of the household. The trip assignment step uses the equilibrium assignment method, which has a limited behavioral basis. Thus, level of service projections on specific links may be very inaccurate. The model is not used in conjunction with a land allocation model, and thus the effect of major system changes on land use cannot be adequately simulated.

Despite the limitations of the Sacramento region's travel demand model, it is representative of those in use in many medium-sized urban regions, so the simulations should be taken to represent what would happen if agencies with similar models performed these analyses. The borrowed friction factors and logit coefficients make this model set somewhat abstract, that is, not necessarily accurate for this region but arguably useful for policy evaluation in general.

Operation. The assignment step in the Sacramento model estimates speeds and travel times for all peak hour and daily trips. A loop is built into the model to feed these congested speeds and travel times back to the mode choice step. This feedback loop simulates the effect of congestion on mode choice but not on trip distribution. Therefore, in operating the model for this study, congested speeds and travel times were also fed back to trip distribution to simulate the effects of congestion on trip lengths. The Environmental Protection Agency now requires feedback to trip distribution for air quality conformity analyses in nonattainment regions.

The model's VMT output and level of service (LOS) output for each iteration indicated that in general VMT did oscillate with each iteration in a dampening fashion as convergence was approached. The first three iterations converged rapidly and the last two iterations converged more slowly. The results also indicate that the LOS output generally follows the oscillating and dampening pattern of VMT. The final model projection was obtained by averaging the results of the last two model runs.

Data files. Zonal land use files for the years 2015 and 2040 created for use in the Sacramento regional model were obtained from the California Department of Transportation (Caltrans) Southeast Area Transportation Study (JHK and Associates, 1993). Mundie and Associates (1993) developed the population and retail and non-retail employment projections used in the 2040 zonal land use files. These projections rely heavily on SACOG's defined holding capacities for minor zones, which are based on existing land use plans and zoning and current development patterns. We found that these projections reasonably matched the California Department of Finance 2040 population projections (1993).

Network files. From SACOG's (1993) updated 1992 Metropolitan Transportation Plan, 21 freeway, expressway, and highway projects expected to receive state and federal funding were identified for possible deferral. The network files for these two model years included most of the projects. Thus, these 21 projects were deleted from the network files. Table 1 provides a detailed description of these projects.

Build year. Because projections from state-of-the-practice travel demand models are considered reasonable only at the regional level and not at the roadway link level, a micro-examination of the effects of TDM policies on specific roadway links was not considered feasible. As a result, a more aggregate approach was taken: the number of lane-miles for freeways, expressways, and highways at levels of service E and F, minus the 21 planned projects, was obtained from the SACOG model for a year that was the weighted average of the build date for the projects, which was estimated to be approx. 2008. These projections serve as the level of service benchmark that triggers the need for the capacity additions. If the lane-miles of congestion for freeways, expressways, and highways fall below this figure in the TDM scenarios, then the projects will be considered deferred past that year.

A 2008 model year was not available from the Southeast Area Transportation Study (SATS). Thus, the results from SACOG's 2005 model year and the SATS 2015 model year were used to interpolate, using a semi-log graph, the lane-miles of congestion at levels of service E and F for the average build year, 2008. The benchmark was found to be 570 lane-miles at levels of service E and F.

TDM alternatives. To illustrate the method, we chose two different scenarios: a congestion pricing scenario, and a pricing policy scenario that included parking pricing, congestion pricing, and a fuel tax. These TDM measures were chosen for a number of practical, methodological reasons.

Table 1. List of roadway projects from SACOG's 1993 Metropolitan Transportation Plan

Project no.	Location	Description	Facility type	No. added lanes	Lane length (miles)	Build year
1	Route 99	Mack Rd to Elk Grove Blvd	HOV	4	3.75	1995
2	Route 99	Martin Luther King to L/Q Streets	HOV	2	3.75	1999
3	Route 99	Elk Grove Blvd to Grant Line Blvd	HOV	2	2.5	2015
4	I-5	Meadowview to J. St	HOV	4	6	2010
5	I-5	J. St to Metro Airport	HOV	4	17	2015
6	Route 50	Route 99 to El Dorado County Line	HOV	4	23	2010
7	Route 50	Route 99 to 15/16 St	HOV	2	0.75	2015
8	Route 51	L/Q St to I-80	HOV	2	7	2010
9	I-80	Route 51 to Placer County Line	HOV	4	6	2010
10	I-80	I-5 to Route 51	HOV	4	7	2010
11	I-5	Laguna Blvd to Meadowview Rd	FWY	2	6	1996
12	Route 16	South Watt Ave to Treeview Rd	HWY	2	5.5	2010
13	I-80	Richards Blvd to 50/I-80 in West Sac.	HOV	2	9.5	2010
14	Route 50	Jefferson to Pioneer Bridge West Sac.	FWY	2	0.5	2015
15	Route 84	Marshall Rd to Rte 50	HWY	2	3.5	1997
16	I-5	Build New Connection to Rte 113	EXP	4	2	2010
17	Route 99	Sac. County Line to Rte 70/99 upgrade	FWY	widen 4	13	2015
18	Route 70	From 70/99 to 1 mile north of Bear River	EXP	2	11	1999
19	Route 65	Blue Oaks to Sunset	EXP	2	1.5	2010
20	Route 65	Sunset to Industrial	HWY	2	3.5	2010
21	Route 65	Build Lincoln Bypass	HWY	4	11	2010

Pricing policies can have a more dramatic effect on travel demand reduction than many other TDM measures. Travel cost is represented reasonably well in travel demand models, and thus the effects of pricing policies can be simulated. This is not true for many TDM measures such as telecommuting and flextime policies. Further, pricing TDM measures involve few, if any, capital costs that would be financed by the federal and state governments (unlike TDM measures that improve transit service, for example), and thus the calculations of cost savings are more straightforward.

The effects of congestion pricing were modeled in the year 2015 by increasing the per-mile cost of travel on freeways, expressways, and highways with levels of service E and F in the future base case by 10 cents in 1992 \$. A congestion fee was not imposed on the high occupant vehicle (HOV) lanes. In year 2040 the congestion fee was increased to 15 cents per mile in 1992 \$.

For the comprehensive pricing policy scenario, an all-day parking charge of \$2.50 in 1992 \$ was added to the year 2015 zones that did not previously have parking charges, and in the zones with parking charges, the higher of either the existing charge or the \$2.50 charge was chosen. In the 2040 zone file, all-day parking charges were increased to \$5 in 1992 \$ for all zones. Only the work-trip mode choice model is sensitive to all-day parking charges. The congestion fee was the same as above.

The fuel tax policy was modeled with an increase in the per mile operating cost in the Sacramento regional model from 13 cents per-mile to 16 cents per mile in 1992 \$ for the year 2015, and to 19 cents per mile in 1992 \$ for the year 2040. Fleet mileage is assumed to be 20 mpg; thus, 60 cents per gallon is equivalent to 3 cents per mile. However, because the long-run elasticity of demand for fuel costs is roughly −0.3 (i.e. people shift to higher-mpg vehicles as fuel prices rise), the increase in fuel tax levied would actually be \$2 per gallon.

Results. Table 2 provides the model's projections of lane-miles of congestion at levels of service E and F for freeways, expressways, and highways for the congestion pricing and comprehensive pricing scenarios in the years 2015 and 2040.

The lane-miles of congestion at LOS E and F for freeways, expressways, and highways for the comprehensive pricing and congestion pricing scenario are below the 570 lane-miles benchmark in 2015 but not in 2040. Thus, the 21 projects in this study would be deferred by the congestion pricing or comprehensive pricing policies for at least 7 yr. Interpolation of the comprehensive pricing and congestion pricing results for the years 2015 and 2040, using a semi-log graph, indicates that projects may be deferred for approx. 21 yr (to 2029) with the congestion pricing policy, and for 24 yr (to 2032) with the comprehensive pricing policy. Using more model years would permit a more accurate determination of the deferral date.

Financial forecasts

Sources of cost data. The Sacramento regional transportation plan is the source of the capital costs of constructing the 21 roadway projects. The proportion of federal and state funds committed to capital costs is provided in the plan for some of the projects of interest. When this information was not available from the plan, it was assumed that the federal government would cover 88.53% of the project's capital cost and the state government would cover 11.47% of the cost. This assumption is based on existing funding rules, as described in Caltrans' *Transportation Financing Opportunities, State and Federal Funds Available for Local Agencies Capital Outlay Projects* (Caltrans, 1993), as well as on advice from Caltrans planners.

Estimates of the cost of maintenance for the 21 projects were obtained from county post mile reports for the fiscal year 1992–93 provided by the office of maintenance at Caltrans District 3, which contains the Sacramento Region. Post miles coincide with crossroads on a route and are used internally as markers by Caltrans. Reports were provided for the 21 projects of interest to the

Table 2. Lane-miles of congestion for the comprehensive pricing and congestion pricing scenarios

	Lane-miles of congestion at LOS E and F for FWY, EXP, and HWY	
Year	Comprehensive pricing	Congestion pricing
2015	325.5	369
2040	770	773.5

closest post mile. These reports provide maintenance cost figures for the route per mile, not per lane-mile. Thus, the per mile maintenance costs were divided by the number of lanes on the route segment. The post mile reports also broke down the per mile maintenance cost by type of maintenance cost. This allowed the elimination of the types of maintenance costs that would probably not change with the addition of lanes (e.g. landscaping, highway lighting, and signal maintenance).

The maintenance data is for one slice in time and thus may not reflect variations in maintenance costs over time. For example, pavement problems may be fewer in new lanes than in older lanes. This could lead to an overestimation of the cost of maintenance for new lanes in the first 5 yr after their construction. Additionally, a lot of maintenance work could have been done on a route the year before the 1992–1993 fiscal year. This could lower the maintenance cost figures in 1992–1993. Thus, these data should be viewed as a rough approximation of maintenance costs.

Operation cost data were only available in average per lane-mile figures from Caltrans District 3. The total operating cost for District 3 was divided by the number of lane-miles in the region, obtained from Caltrans' 1992–93 Route Segment Report (Caltrans, 1993), to calculate the average yearly operation cost per lane-mile. The result was approx. $552 per lane-mile. Operation costs for freeways, expressways, and highways tend to be higher than those for arterials. Because this calculation included all types of roadways, the figure probably underestimates the operation costs of the projects included in this study.

Calculation of cost savings. The transportation plan provided the projects' capital costs in 1992 $. Capital costs are summarized in Table 3. The total federal and state capital costs for the 21 projects were obtained by summing the product of the percentage of the federal and state contribution and the total capital cost for each project. The result is the 2008 future value of the projects' capital cost in 1992 $, without the TDM measures, totalling $635,320,000, with $535,430,000 in federal costs and $99,890,000 in state costs. To calculate the 1992 present value of the capital cost of the projects without the TDM measures, the present value formula (with Caltrans' discount rate of 6.25%) is applied to the capital cost of the projects in 2008 for a 16 yr period (from 1992 to 2008):

$$\begin{aligned}
&\text{PV 1992 federal capital costs}_{\text{w/oTDM}} = \$535{,}430{,}000/(1.0625)^{16} = \$202{,}973{,}700\\
&\text{PV 1992 state capital costs}_{\text{w/oTDM}} = \$99{,}890{,}000/(1.0625)^{16} = \$37{,}866{,}830 \qquad (5)\\
&\text{PV 1992 total capital costs}_{\text{w/oTDM}} = \$635{,}320{,}000/(1.0625)^{16} = \$240{,}840{,}500
\end{aligned}$$

Table 3. Federal and state capital costs

Project no.	Total capital cost millions	Federal funds (%)	Federal capital costs millions	State funds (%)	State capital costs millions
1	11.9	0.00	0.00	100.00	11.90
2	12.0	88.53	10.62	11.47	1.38
3	7.0	88.53	6.20	11.47	0.80
4	32.0	88.53	28.33	11.47	3.67
5	46.0	88.53	40.72	11.47	5.28
6	83.8	88.53	74.19	11.47	9.61
7	1.0	88.53	0.89	11.47	0.11
8	133.0	88.53	117.74	11.47	15.26
9	35.0	88.53	30.99	11.47	4.01
10	47.0	88.53	41.61	11.47	5.39
11	7.8	0.00	0.00	76.00	5.93
12	8.0	88.53	7.08	11.47	0.92
13	37.0	88.53	32.76	11.47	4.24
14	6.0	88.53	5.31	11.47	0.69
15	27.0	0.00	0.00	47.00	12.69
16	30.0	88.53	26.56	11.47	3.44
17	10.0	88.53	8.85	11.47	1.15
18	63.0	88.53	55.77	11.47	7.23
19	6.0	88.53	5.31	11.47	0.69
20	4.0	88.53	3.54	11.47	0.46
21	44.0	88.53	38.95	11.47	5.05
		SUM	535.43	SUM	99.89

To calculate the present value of the cost of the projects with the TDM measures, the present value formula is applied to the cost of the project without the TDM measures over the 7 yr deferment period (from 2008 to 2015):

$$\begin{aligned} &\text{PV 1992 federal capital costs}_{w/TDM} = \$202{,}973{,}700/(1.0625)^7 = \$132{,}781{,}400 \\ &\text{PV 1992 state capital costs}_{w/TDM} = \$37{,}866{,}830/(1.0625)^7 = \$24{,}771{,}730 \\ &\text{PV 1992 total capital costs}_{w/TDM} = \$240{,}840{,}500/(1.0625)^7 = \$157{,}553{,}100 \end{aligned} \tag{6}$$

Operation and maintenance cost figures were obtained for each project in annual per lane-mile values in 1992 \$. The operation and maintenance cost for each project was multiplied by the total number of lane-miles added by each project. These figures were summed to obtain the total annual operation and maintenance cost of the 21 projects in 1992 \$. This figure was estimated to be \$8,197,770. Operation and maintenance costs are summarized in Table 4.

Operation and maintenance costs are assumed to be avoided during the projects' deferment period. Thus, the present value of the operation and maintenance costs during the projects' deferment period is calculated and added to the present value of the capital cost of constructing the projects without the TDM measures.

To obtain the present value of the annual operation and maintenance costs, the present value formula (with the 6.25% discount rate) is applied over a period of sixteen years (from 1992 to 2008):

$$\text{PV 1992 Annual O\&M costs} = \$8{,}197{,}770/(1.0625)^{16} = \$3{,}107{,}654 \tag{7}$$

To calculate the total present value of the operation and maintenance costs without the TDM measures during the 7 yr deferment period, the uniform present worth formula is applied to the present value of the annual operation and maintenance costs in 1992 \$:

$$\text{PV 1992 O\&M} = \$3{,}107{,}654[(1.0625)^7 - 1]/[0.0625(1.0625)^7] = \$17{,}195{,}010 \tag{8}$$

To obtain the cost savings due to TDM measure implementation, the present value of the cost of the project with the TDM measures can be subtracted from the present value of the cost of the project without the TDM measures:

$$\text{PV 1992 cost savings} = (\text{PV capital cost}_{w/oTDM} + \text{PV O\&M}) - \text{PV capital cost}_{w/TDM} \tag{9}$$

Table 4. Yearly operation and maintenance costs for the projects

Project no.	Added lanes	Length of lanes (miles)	Yearly operation costs \$92	Yearly maintenance costs \$92	Yearly O&M costs \$92
1	4	3.75	8276.92	303,393.75	311,670.67
2	2	3.75	4138.46	63,694.69	67,833.15
3	2	2.50	2483.08	32,421.38	34,904.45
4	4	6.00	13,243.07	726,840.00	740,083.07
5	4	17.00	37,522.03	1,418,885.96	1,456,407.99
6	4	23.00	50,765.09	2,813,802.52	2,864,567.61
7	2	0.75	827.69	8285.10	9112.79
8	2	7.00	7725.12	539,350.00	547,075.12
9	4	6.00	13,243.07	159,827.26	173,070.32
10	4	7.00	15,450.25	371,509.04	386,959.29
11	2	6.00	6621.53	135,378.00	141,999.53
12	2	5.50	6069.74	7507.50	13,577.24
13	2	9.50	10,484.10	291,219.27	301,703.37
14	2	0.50	551.79	10,570.33	11,122.12
15	2	3.50	3862.56	20,842.50	24,705.06
16	4	2.00	4414.36	N/A	4414.36
17	widen 4	13.00	14,346.66	374,244.00	388,590.66
18	2	11.00	12,139.48	159,313.00	171,452.48
19	2	1.50	1655.38	28,818.00	30,473.38
20	2	3.50	3862.56	67,242.00	71,104.56
21	4	11.00	24,278.96	422,664.00	446,942.96
		SUM	241,961.90	7,955,808.00	8,197,770.00

This calculation is applied separately for federal and state costs. Operation and maintenance costs are incurred by the state, and thus the present value of operation and maintenance costs are included in the state cost savings calculations but not in the federal cost savings calculations. Cost savings are in 1992 \$.

$$\begin{aligned} &\text{federal cost savings} = \$202{,}973{,}700 - \$132{,}781{,}400 = \$70{,}192{,}300 \\ &\text{state cost savings} = (\$37{,}866{,}830 + \$17{,}195{,}010) - \$24{,}771{,}730 = \$30{,}290{,}110 \\ &\text{total cost savings} = \$70{,}192{,}300 + \$30{,}290{,}110 = \$100{,}482{,}400 \end{aligned} \tag{10}$$

In the above calculations, cost savings were estimated in present value as of 1992, in 1992 \$, as opposed to the 2008 build year. The former base year was deemed preferable because it is easier for policy makers to relate to 1992 values than to 2008 values and thus to compare various methods of investing public funds with the proposed policy. For calculating annual payments for local governments, however, annual payments are estimated in the year that they would start. For example, if payments started in 1995, then they would be calculated in 1995 future value and in 1995 \$.

To obtain the annual payments to the local governments in 2008 for the 7 yr deferment period, the future value of the cost savings in 2008 and in 2008 \$ is estimated with the future value formula and Caltrans' nominal discount rate of 10% (which includes the real rate of 6.25% and the inflation rate of 3.75%):

$$\begin{aligned} &\text{FV 2008 federal cost savings} = \$70{,}192{,}300(1.1)^{16} = \$322{,}531{,}700 \\ &\text{FV 2008 state cost savings} = \$30{,}290{,}110(1.1)^{16} = \$139{,}182{,}200 \\ &\text{FV 2008 total cost savings} = \$100{,}482{,}400(1.1)^{16} = \$461{,}714{,}000 \end{aligned} \tag{11}$$

Then, the uniform capital recovery formula is applied to the estimated future value of federal, state, and total cost savings in 2008:

$$\begin{aligned} &\text{Federal annual payment} = \$322{,}531{,}700[0.1(1.1)^7]/[(1.1)^7 - 1] = \$66{,}249{,}790 \\ &\text{State annual payment} = \$1{,}392{,}200[0.1(1.1)^7]/[(1.1)^7 - 1] = \$28{,}588{,}800 \\ &\text{Total annual payment} = \$461{,}714{,}000[0.1(1.1)^7]/[(1.1)^7 - 1] = \$94{,}742{,}100 \end{aligned} \tag{12}$$

If a region would like annual payments to begin when the TDM policies were implemented (for example, 1995) as opposed to the beginning of the project deferment period (in this case, 2008), the future value of the cost savings in 1995 and in 1995 \$ would be estimated:

$$\begin{aligned} &\text{FV 1995 federal cost savings} = \$70{,}192{,}300(1.1)^3 = \$93{,}425{,}950 \\ &\text{FV 1995 state cost savings} = \$30{,}290{,}110(1.1)^3 = \$40{,}316{,}140 \\ &\text{FV 1995 total costsavings} = \$100{,}482{,}400(1.1)^3 = \$133{,}742{,}100 \end{aligned} \tag{13}$$

Then, the uniform capital recovery formula could be applied to the 1995 future value of cost savings over the 20 yr deferment period:

$$\begin{aligned} &\text{Federal annual payment} = \$93{,}425{,}950[0.1(1.1)^{20}]/[(1.1)^{20} - 1] = \$10{,}973{,}780 \\ &\text{State annual payment} = \$40{,}316{,}140[0.1(1.1)^{20}]/[(1.1)^{20} - 1] = \$4{,}735{,}518 \\ &\text{Total annual payment} = \$133{,}742{,}100[0.1(1.1)^{20}]/[(1.1)^{20} - 1] = \$15{,}709{,}300 \end{aligned} \tag{14}$$

Table 5 and Table 6 summarize the cost savings and the annual payments for the TDM alternatives. The results of this study indicate that sizable incentives could be derived from the estimated cost savings of deferred projects due to the implementation of either the congestion pricing or the comprehensive pricing scenario. In the Sacramento region, total cost savings in 1992 \$ to

Table 5. Cost savings in 1992 $ due to TDM implementation

	Cost savings in millions of 1992 $		
TDM Scenarios	Federal	State	Total
Congestion pricing and comprehensive pricing	$70	$30	$100

Table 6. Annual payments in 1995 future value and $ over 20 yr and in 2008 future value and $ over 7 yr due to TDM implementation

	Annual payments in 1995 FV over a 20 yr period in millions of 1995 $			Annual payments in 2008 FV over a 7 yr period in millions of 2008 $		
TDM scenarios	Federal	State	Total	Federal	State	Total
Congestion pricing and comprehensive pricing	$11	$5	$16	$66	$29	$95

the federal and state agencies were found to be $100 million. These savings could be used to provide incentives to local governments, which could total $16 million a year for 20 yr beginning in 1995 or $95 million a year for 7 yr beginning in 2008.

The cost savings estimated above are very likely conservative because they are based on the assumption that the TDM measures defer the projects only to 2015. Model years between 2015 and 2040 were not available to test the effectiveness of the TDM measures in intervening years. However, interpolating the comprehensive pricing and congesting pricing results for the years 2015 and 2040 indicates that projects may be deferred for approx. 21 yr, or to 2029, with the congestion pricing policy and for 24 yr, or to 2032, with the comprehensive pricing policy. The deferment period for the congestion pricing scenario, interpolated in this way, would result in a total cost savings of $209 million in 1992 $ with annual payments of $111 million over 21 yr or $29 million over 34 yr. The deferment period for the comprehensive pricing scenario would result in a total cost savings of $223 million in 1992 $ with annual payments of $114 million over 34 yr or $31 million over 37 yr. See Table 7 below.

Given the uncertainty of travel demand model projections further into the future, basing calculations of cost savings on a model year that is within a 20 yr time horizon, as was done in this study, is recommended. If a local government wanted to defer projects further into the future, it could conduct new studies closer to the end of the deferment period. Estimates of cost savings and annual payments could then be revised. Interpolations of deferment years beyond a twenty year time horizon, such as the one performed above, could be used by local governments to make rough estimates of the total potential benefit of participating in the program.

FUTURE RESEARCH ON FEASIBILITY

The results of the literature review on conservation incentives for electric and gas utilities and our analysis of uncertainty raise a number of questions that are crucial to the potential feasibility of funding the proposed incentive program. Officials in the energy field report that utilities will

Table 7. Total cost saving and annual payments due to TDM implementation for years 2029 and 2032

	Projects deferred to 2029 with congestion pricing			Projects deferred to 2032 with comprehensive pricing		
	Federal	State	Total	Federal	State	Total
Cost savings (millions of 1992 $)	$146	$63	$209	$156	$67	$223
Annual payments beginning in 1995 (millions of 1995 $)	$20	$9	$29	$21	$9	$31
Annual payments beginning in 2008 (millions of 2008 $)	$76	$34	$111	$80	$34	$114

participate in conservation incentive programs only if incentives are large enough to outweigh the costs of implementing the demand side management programs. Regional governments that adopt TDM policies, particularly pricing and land use controls, are likely to incur much higher costs (at least politically) than utilities that adopt demand side management programs. For example, road pricing and increasing land use densities have traditionally been extremely unpopular with the public. In addition, significant concern has arisen in the energy field about how best to deal with the uncertainty inherent in the projection of energy savings due to demand side management programs. Programs in place today generally award utilities only some portion of the projected energy savings and/or require yearly monitoring of energy savings so that incentives can be adjusted accordingly. Travel demand model projections of reduced vehicle travel due to TDM policies are also subject to a considerable degree of uncertainty. To address fears of potential overpayment, incentives could be designed to comprise only a portion of projected travel savings and/or could be adjusted based on yearly monitoring.

A future examination of feasibility, then, should seek to answer essentially two questions. First, will the incentives calculated through the developed method be large enough to entice local governments to participate in the program? And second, how much leeway could federal and state policy makers have in adjusting the incentives to protect against potential overpayment? The results of this research will be useful for formulating not only this policy, but also other policies that attempt to alter the incentives faced by regional governments. The need for such policies is evident: regional governments are currently rewarded financially for demonstrating increased travel demand, not reduced travel demand.

The analysis of feasibility will take the form of decision trees. A decision tree is a flow diagram that illustrates the 'logical structure of a decision problem'. The diagram generally consists of four parts: (1) decision nodes that indicate all courses of action faced by the decision maker; (2) chance nodes that indicate intervening uncertain events and possible outcomes; (3) probabilities of possible outcomes; and (4) payoffs that sum the combinations of each decision and chance event (Stokey and Zeckhauser, 1978). Decision trees can incorporate a time dimension, the possibility of obtaining new information, and the effects of risk aversion (Stokey and Zeckhauser, 1978).

Interviews and surveys will be conducted with key officials in the regional governments of Sacramento and the San Francisco Bay Area to develop decision trees that describe the value and probability of future events and choices that would influence regional governments' decisions to adopt TDM policies.

CONCLUSIONS

The results of this study indicate that sizeable incentives could be derived from the estimated cost savings of deferred projects due to TDM measure implementation. In the Sacramento region travel demand management implementation could defer roadway projects for a minimum of 7 yr and a maximum of 24 yr. This would result in a minimum total savings to federal and state agencies of $100 million and a maximum total savings of $223 million in 1992 $, which could be used to make annual payments of least $16 million or at most $31 million a year to local governments. However, the travel demand projections on which these estimates are based are uncertain and may under- or over-estimate the effect of TDM measures and the resulting cost savings. Federal and state government officials are not likely to grant incentives to local governments for project deferrals if there is a high risk of overpayment. On the other hand, local governments are not likely to participate in the program and take the political risks potentially involved in adopting pricing TDM measures unless incentives are sizable. Because this initial analysis indicates that incentives would be relatively large, one solution may be to develop incentives that comprise only a portion of the projected cost savings. We have proposed a second study that attempts to determine whether the levels of incentives projected in the present study would garner local government participation and whether the incentives could be reduced (to give state and federal agencies comfort) and still gain participation by local officials.

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