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Greenbacks Über Gridlock

REACH Task Force Shows L.A. How to Save Billions
in Smog and Congestion Costs
(full version)

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Abstract

I: BACKGROUND: In recent years, air pollution and congestion have cost the average household in the Los Angeles Basin about \$4,000 a year -- about \$16 per workday. Since 1990 the average household in the South Coast Basin has lost four 40-hour workweeks a year to traffic delay. By 2010, if official models are right, smog costs could stay the same or decline, but congestion costs will rise to \$2,850 a year per household, roughly \$11 per workday. The average household in the Basin would then lose ten workweeks a year in traffic delay. California smog control planners have run low on cost-effective conventional controls for smog and congestion. In 1997, after two years of deliberation and \$1.5 million worth of study, REACH, a blue-ribbon California policy Task Force, unanimously recommended that full-scale emissions charges and congestion charges be studied and developed for the long run, and HOT lane demonstration projects for the short run. Subsequently both recommendations were unanimously adopted by the Southern California Association of Governments, the area's regional planning agency. This article represents the author's analysis of the Task Force's studies and findings.

REACH's models suggest that a combination of high-resolution emissions charges averaging a penny or so a mile, and congestion charges of 10-30-cents per peak-traffic mile could produce smog reductions worth more than \$200 million a year. Depending on coverage and modeling assumptions, congestion charges could also save up to three or four billion dollars a year by reducing travel delays. This could save the average household in the Basin about \$2-3 per workday, \$6-700 per

work year. Appendix One. In the process, it appears that some of the combinations would generate more than enough revenues to replace all 1991 transportation taxes, fares and fees, or, alternatively, to replace two-thirds of 1991 property or sales taxes. 90% or more of the benefits would be from congestion relief.

Until the late 1990's emission, and especially congestion charges have not been popular with the general public, but, if the models and the Task Force's attitude surveys are right, adopting some combination of the two seems to be a "no-brainer" compared to all other alternatives, including doing nothing.

I. The Costs of Smog and Congestion: about \$4,000 per household per year and rising?

Southern Californians have been struggling for more than 50 years to control smog and congestion. On smog they have been gaining, but they still have a long way to go. The Los Angeles Air Basin has long had the worst air and the highest pollution costs in the country.

For many years, smog cost estimates for the South Coast Air Basin have tended to range between \$10,000 and \$20,000 per ton; so have the South Coast Air Quality Management District's (SCAQMD's) cost cutoffs for regulatory pollution controls (Appendix One). The South Coast (Los Angeles Basin) Air Quality Management District's estimates still seem to be in this range, but more recent USEPA estimates are much higher (Appendix Fourteen). The REACH Task Force's Strategy Committee, which did not have access to the USEPA estimates (because they had not been published), used estimates of \$9,000 per ton of Volatile Organic Compounds (VOC), \$10,000 per ton of Oxides of Nitrogen (NO_x), and \$21,000 per ton of Particulate Matter (PM₁₀), based primarily on cost cutoffs in the 1994 South Coast Air Quality Management Plan. Regulatory cost cutoffs in the 1999 AQMP, the most recent, are somewhat higher, but these older estimates, though necessarily tentative, still seem as serviceable as any others available. If every ton of VOC, NO_x, SO_x, and PM₁₀ in the Task Force's 1993 baseline inventory did \$10,000 worth of damage, total 1993 smog costs in the Basin would have been about \$11.5 billion a year, or about \$2,200 per household per year. Under these assumptions, smog costs would be about six dollars per household per calendar day, six cents per average vehicle mile traveled. By several different reckonings, about 80 percent of the damage costs from mobile sources in the South Coast Basin were from ozone and its precursors (Appendix One).

As for congestion, Southern California was already in the slow lane when the Task Force met-- and it has been getting much slower if measured by the growing traffic density on city streets and freeways, and somewhat slower if measured by trends in average trip time. Average travel time to work in the Basin, after holding steady for many years (Meyer, 1994; Gordon and Richardson, 1994), started rising in the mid-1980's, increasing from 23.6 minutes in 1980, 26.4 minutes in 1990 (*L.A. Times*, Nov. 27, 1996, p. A5 c. 4). Before, during, and, no doubt after this slight increase, the commuting public managed to offset much of the catastrophic, density-based gridlock projected by transportation professionals by moving farther into the suburbs, often drawing jobs with them. Some may continue this sprawling process in the future -- as long as there is room for them to do so.

But, for a sizeable minority of 1990's commuters, maybe a third, commuting already involved billions of dollars worth of delay, and most planners expect the situation to get steadily worse. Measured by traffic density, Los Angeles has had the worst congestion in the country for more than fifteen years. In 1991, according to Cameron (1994), the average household in the Southern California Association of Governments (SCAG) area lost the equivalent of four 40-hour workweeks a year to congestion delay of private autos only -- plus more weeks if you count delay for commercial traffic. At an assumed time value of \$6.80 per person hour, the resultant costs in delay and lost productivity have been estimated at about \$7.7 billion for 1991 -- \$9.4 billion, if you also count the extra cost in fuel, maintenance, and accidents (Calculated from 1996 SCAG Draft RTIP, Table II-12, for cars, and, for all traffic, 1991 TRIPS Origin and Destination Survey, summarized in Cameron, 1994, p. 7; SCAG, 1988, Table B-5, cited, Cameron, 1994, p. 8, n. 22; see Hanks and Lomax, 1990).

These imply 1990's congestion costs on the order of \$26 million per calendar day, and of nine cents per average mile, 23 cents per peak-hour vehicle mile, and two cents per off-peak mile, assuming that 36% of the VMT and 85% of the congestion delay take place during peak hours. For the average household in the Basin, total congestion costs in recent years would be about \$1,800 per year, \$7 per workday. Half of the congestion is recurrent, half varies with weather and "incidents," (though "non-recurrent" congestion is still overwhelmingly concentrated in peak hours) and could be somewhat harder than recurrent congestion to control with economic incentives of the type discussed here. But recurrent congestion alone cost the average family in the Basin \$900 a year in the 1990's, and "non-recurrent" peak-hour congestion another \$630 or so. Both could be substantially reduced with congestion charges.

By 2010, most studies project two- to threefold increases in auto traffic delay even if tens of billions of dollars worth of additional roads and rail lines are built by cash-strapped Los Angeles and Orange Counties (Wilbur Smith Associates, 1996, p. 8; SCAG 1996 Draft RTIP, Table II-12). If the new facilities are not built, traffic delay would increase by three- or fourfold. (SCAG 1996 Draft RTIP, Table II-12). The average round-trip commute -- now about 53 minutes -- could easily be an hour and a half longer a few years later in this century. If auto delays increase by, say, threefold, the average household, which now loses the equivalent of four workweeks a year to traffic delay would lose 12 workweeks a year to traffic delay, a loss exceeding \$3,200 a year with no allowance for additional fuel, maintenance, accident costs, or time loss costs for commercial traffic.

These numbers are approximate because planning documents do not always make it clear whether they are counting calendar days or workdays, private traffic only, or all traffic, freeways only, or all roads, how they define peak hours, and so on. Many of these conversion problems, and some field-expedient ways of coping with them, are discussed in the notes to Appendix Two. There is much room for debate about the projections -- whether and when the tens of billions of dollars of assumed expansion will take place, and whether people will continue to find ways to sprawl and adjust their way out of the worst forms of gridlock. And, as we have seen, there always has been much room for debate about smog costs.

It is one thing to acknowledge that there is room for debate at the margins, but quite another to ignore the massive, undeniable problems at the core. By the best available midrange estimates, the average household in the Los Angeles Basin seems to lose about \$4,000 a year in life, health time, and productivity, and no one thinks that the losses, to congestion at least, will decrease in the foreseeable future. These losses are not far from what the average household now pays in yearly property and sales taxes combined, but with one big difference. You do get something back for your taxes. But you get nothing at all back for your lost hours of time, life, health, and productivity.

With such high stakes, it is not surprising that the SCAG, the SCAQMD, and an industry consortium called COALESCE set up a 75-person community task force to Reduce Emissions and Congestion on Highways (REACH), and that the task force spent two years of research and deliberation, and a million and a half dollars of research funds, looking for better ways to reduce this heavy burden.

The Task Force considered a wide range of incentive alternatives, ranging from simple, low-resolution ones like gas taxes or dirty-car ownership fees, to more

complex, high-resolution ones like time- and place-specific congestion charges and emissions charges based on each vehicle's actual emissions characteristics (see below).

In the end, it recommended the highest-resolution strategies available -- emissions charges and congestion charges -- for mid- and long-term implementation throughout the Basin. It also recommended HOT lanes, a high-resolution congestion-charge variant, for early study and adoption in selected corridors (REACH Task Force, 1997, pp. 3-4).

II. Why Resolution Matters

Strong incentives and tight targeting of harmful behavior are much more likely to change the behavior fairly and efficiently than weak incentives and loose targeting.

The REACH Task Force was not the first group to do a serious comparative study of smog and congestion reduction strategies for Southern California. Caltech's Environmental Quality Lab did some pioneering studies in the 1960's (Caltech EQL, 1972). The California Transportation Commission did a multi-volume study in the 1970's (Eckert, 1979; Elliott, 1986). The South Coast AQMD Advisory Committee, with the help of three major conferences co-sponsored by the AQMD, the California Air Resources Board, and UCLA, and paralleled by a blue-ribbon study panel of environmentalists organized by the Coalition for Clean Air, spent most of the early 1980's studying economic-incentive strategies to control congestion and smog. Among the outcomes were RECLAIM, the AQMD's tradable emissions permit market; California Assembly Bill 680, authorizing what is now the Route 91 HOT-lane project; and provisions in the Federal Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the Clean Air Act Amendments of 1990 encouraging the use of pricing incentives for transportation and smog control. In 1994 the National Research Council's Transportation Research Board published a two-volume study of congestion charges (NRC, 1994), and the Environmental Defense Fund published an analysis of strategies for unsnarling traffic in Southern California (Cameron, 1994). Since then, the California Air Resources Board has commissioned a very ambitious study of transportation pricing strategies for California, advance copies of which (CARB, 1995) were made available to the REACH Task Force.

More often than not the study groups started out with a strong bias in favor of simple, low-resolution strategies (such as taxing dirty cars or setting up a clean-air trust fund) which looked politically palatable at first glance. But in every case they wound up recommending more complex, high-resolution strategies (such as emissions or congestion charges) which seemed much less palatable at first glance, but offered far more long-run workability at lower cost. The REACH Task Force followed just this course, leaving many lower-resolution strategies -- flat gas taxes; flat VMT (vehicle-

miles-traveled) charges; parking charges; dirty car sales or ownership charges, and Rule 2202, the South Coast AQMD's employer rideshare mandate -- on the cutting room floor. It settled ultimately on emission and congestion charges as the most inviting strategies for further action because these are tightly targeted on the most harmful behavior and don't put unnecessary burdens on harmless behavior. Even a mid-resolution strategy of emissions-weighted, pay-at-the-pump imputed VMT charge, though carefully researched and evaluated by consultants Wilbur Smith Associates (WSA), did not make it to the Task Force's final recommendations because its charges could not be made time-specific, and, hence, could offer almost no help in congestion relief.

III. Smog and congestion impacts of different congestion- and emission-charge strategies

Appendices One through Nine compare estimated yields and costs of 16 different congestion- and emission-charge strategies under assumptions described in Section I above and in the long set of notes to Appendix One. Their cost and yield estimates are drawn from three sources: (1) the Wilbur Smith Associates/Comsis studies performed for the REACH Task Force, applying congestion charges to freeways only; (2) the author's extrapolations of WSA estimates to include surface streets, as well as freeways; and (3) estimates by Elizabeth Deakin and Grieg Harvey for the California Air Resources Board (CARB) (CARB, 1995; see also Cameron, 1994, Harvey, 1994).

The WSA estimates modeled traffic specifically on every freeway, but globally on surface streets, none of which were charged in the model. The Deakin-Harvey estimates modeled traffic globally for all roads in the Basin but, unlike WSA, applied congestion charges both to freeways and surface streets. Thus, the two basic models, WSA and Deakin-Harvey, had contrasting strengths and weaknesses. WSA looked stronger and more detailed on freeways, but weaker on surface streets, and weaker in its inability to model for charges on surface streets. Deakin-Harvey was broader, much less detailed about freeways, much more detailed about impacts on different economic classes, and able to model globally for charges on surface streets. Deakin and especially Harvey were reticent about their modeling assumptions, and Harvey died shortly after the Task Force shut down, leaving many loose ends. But some of the missing assumptions could be gleaned from earlier, more explicit Harvey studies, such as Harvey, 1994, and Cameron, 1994. Others have been borrowed or adapted from WSA and other sources. The notes to Appendix One discuss a number of such borrowings and adaptations, attempting to make the two studies as comparable with each other, and with available planning documents, such as the AQMP and the SCAG RTIP, as circumstances would permit. Though the comparisons and adaptations are far

from perfect, the two main studies are generally consistent with each other and with the planning documents. They and the two landmark 1994 studies, by Cameron and by the Transportation Research Board, put transportation planners far ahead of where they were prior to 1994. They do present a valuable, coherent, instructive set of approximations of the most probable impacts of emissions, congestion, and mileage charges of varying levels.

Appendix One gives an overview of all the impacts, costs and yields, with most impacts presented both in percentage variation from baseline and in dollar values. These are: \$9,000 per average ton for TOG; \$10,000 per average ton for NOx; \$21,000 per average ton for PM10; and \$6.80 per average person hour for travel time. Readers are free to experiment with different figures, but these are as close to the "going rates" as are likely to be found, and they are, for the most part, the same rates currently in use for regulatory cost cutoffs (See Section I above, Appendix Fourteen).

Appendix Two breaks out the estimated smog reduction yields of seven of the 16 strategies. A penny-per-average-mile emissions charge, variable by the emission level of each car, is about as high as the current "going rate" cost cutoffs for industrial polluters. By itself it would control more than \$100 million worth of smog per workyear. So would a 15/30-cents a-mile peak-hour congestion charge on all roads, also by itself, assuming the charges had the same impact on surface streets as WSA calculated for freeways (See notes to Appendix One). A lower, freeways-only congestion charge would control just under \$100 million worth of smog per workyear. Conclusion: either reasonable, "going-rate" emissions charges or reasonable congestion charges could cut smog damage by at least about \$100 million a workyear. Deakin and Harvey say the control yield could be more than twice that figure for a 1-cent/mile emissions charge (Appendix One), but let us leave that aside for the moment and suppose that \$100 million is a conservative, round-number guess for the yield of either strategy by itself.

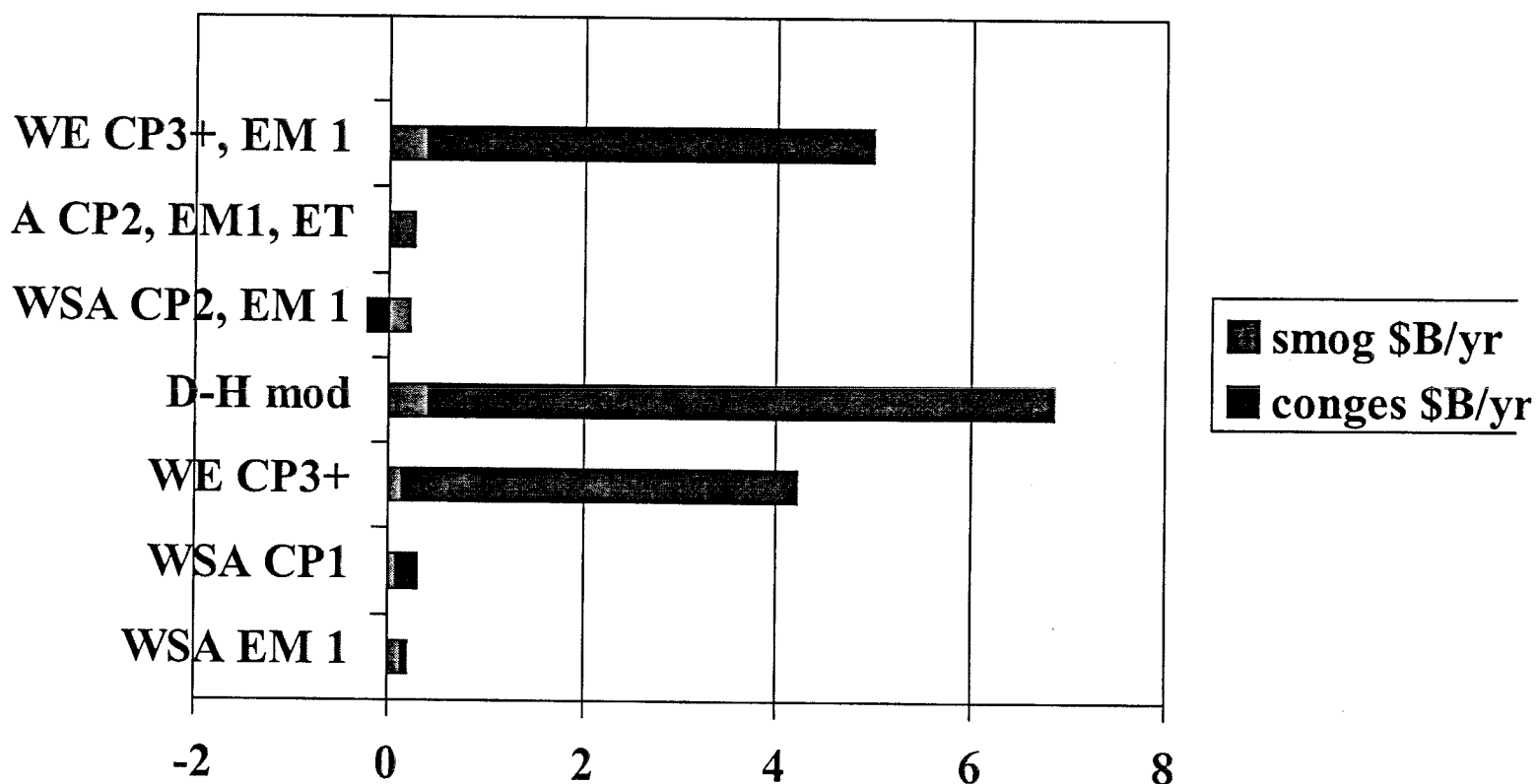
Appendix Two also says that a combination of reasonable-rate emissions charges and congestion charges would produce at least \$200 million worth of annual smog savings, and maybe well over \$300 million. \$200 million is about equal to the officially-estimated control yield of mandatory ridesharing.

Appendix Three is in some ways the most plainly revealing of the appendices. Alone among the appendices, it appears twice, once in its proper, logical place among the appendices, once in the main body of the text to make sure the reader does not miss it. See Glossary, below, for definitions of the various strategies. *WSA* means "Wilbur Smith Associates." *EMI* means "first emissions-charge variant." *CPI* means "first

congestion pricing variant,” freeways only. *WE* means “Ward Elliott.” *CP3+* means “third WSA congestion-pricing variant, extended to surface streets.” *D-H Mod Combo* means “Deakin-Harvey ‘moderate-impact’ combination.” *ET* means \$12.5 billion worth of “enhanced transit.”

Appendix Three

Gross Smog, Congestion Benefits, 2010, Selected Strategies



Appendix Three: The three modeled congestion-charge alternatives that cover freeways and surface streets could save billions of dollars a year in smog and congestion costs. In dollar value, at least 90% of the savings would be congestion costs. Even a penny-a-mile charge, aimed solely at smog, would save four times as much cost from congestion as it would save in costs from smog alone.

Appendix Three compares the yields of the same seven strategies as Appendix Two, but with congestion-control benefits included, as well as emission-control benefits. Two features stand out:

(1) none of the official WSA scenarios listed -- neither the reasonable, penny-a-mile emissions charge, which affects all roads, but is not time-specific, nor any of the congestion-charge combination scenarios, which are time-specific but affect freeways only -- has much effect on speed.

(2) the two scenarios combining reasonable penny-a-mile emissions charges with reasonable 10-30-cents-per-peak-mile systemwide congestion charges show enormous time savings, about 15 times greater in dollar value (at \$6.80 per person hour per Section 1 above) than the very sizeable smog savings (at \$9,000 to \$21,000 per ton per Section 1) also produced. The lower estimate, WE CP3+, EM1, would save 680 million person hours a year, the higher, D-H mod, would save 950 million person hours a year (calculated from Appendix One). A third scenario, with 15-30-cents systemwide congestion charges, but no emissions charge at all, equals the WSA penny-a-mile emissions charge in smog reduction *and* produces 30 times as much savings from congestion relief. In each case, the higher figure (e.g., 30 cents a mile) is the charge for currently crowded links, the lower (10 cents a mile) is a "balancing" charge to keep traffic in charged crowded links from simply shifting to uncrowded links.

IV. Costs and benefits of different strategies

Why the three billion-dollar difference in benefits between comprehensive, high-resolution and partial, low-resolution strategies? The short answers are that reasonable emissions charges are too broad and diffuse, too low-resolution, and too low to divert much peak-hour traffic; and that freeways-only congestion charges are too narrow to increase speeds systemwide. Penny-a-mile-average emission charges are too loosely targeted to affect congestion. They fall lightly on all mileage, rather than heavily on the peak-hour 36% of the mileage which produces 85% of the delay. Freeways-only peak-hour congestion charges, by contrast, are targeted tightly enough to increase speeds on freeways drastically, by as much as a third. But, since surface streets are not charged in the official WSA models, only half of the diversion is to ride-sharing and off-peak hours (Appendix Twelve). The other half is to surface streets, where traffic runs at 14 mph, on average, three or four times slower than on freeways. Even if the extra traffic does not slow down existing surface-street speeds, as WSA's model

improbably assumed, the projected slowdown of the diverted traffic equaled or exceeded the speedup of traffic on priced freeways. Where the charge was close to optimal for freeways -- that is, about equal to the 20-30 cents per peak mile average delay cost actually imposed per peak-hour vehicle mile -- the slowdown from diversion to surface streets more than counterbalanced the speedup on the freeways and the systemwide average speed actually declined!

Conversely, very light freeways-only congestion charges made a small enough diversion to surface streets that average systemwide speed remained about the same. See WSA "Travel and Emissions Modelling Summary, Final Draft, Dec. 12, 1996, Table 5. Thus, two combinations of "reasonable" emissions charges with low, freeways-only congestion charges, did make substantial emissions reductions without slowing down the system. WSA "Travel and Emissions Modelling Summary, Final Draft, Dec. 12, 1996, Table 7. These were the combinations most favored by WSA and recommended by the Task Force's Strategy Subcommittee. They would make a worthwhile improvement over the baseline, cutting smog emissions by 5-15% without reducing average speed systemwide.

V. Congestion charges should ultimately apply to every crowded or crowdable road, including surface streets.

But freeways-only charges could not save the three or four billion dollars of travel time projected in the three scenarios in Appendices One and Three with a systemwide congestion-charge component, thanks to the massive, self-defeating exemption of surface streets from charges in all WSA model runs. WSA was sophisticated enough to foresee diversion from charged, crowded freeway segments to uncharged, uncrowded freeway segments. They appropriately added "balancing" charges to the uncrowded freeway segments, thereby preventing harmful diversion and keeping them uncrowded. But they did not add balancing charges to prevent harmful diversion to surface streets, and, hence, cancelled out most of the time savings from charging freeways. There were two reasons for this: WSA's model was not coded for surface streets and could not model for surface-street charges even if asked to; and the Task Force's higher-ups expressly ruled surface streets out of the model. They argued that surface streets were outside of SCAG's jurisdiction and that congestion charges on surface streets were not only technically impossible to simulate with WSA models, but also politically unthinkable.

Congestion-charge advocates on the Task Force objected to this exclusion and asked for at least an educated guess as to what would happen if surface streets were also charged. They argued that congestion charges make sense only if they are not self-

cancelling; that they are no more unthinkable for surface streets than for freeways, either politically or technically; that they have been successfully used in Singapore for 20 years; and that SCAG should not act as though the public's need for knowledge of smog and congestion impacts stopped at the edge of SCAG's political jurisdiction. Many of these issues are discussed at greater length in Appendix Thirteen. WSA, however, declared it impossible to make an educated guess about systemwide charge impacts without destroying their professional reputation, leaving congestion-charge advocates with three options: rely on Deakin-Harvey's estimates; make estimates of their own; or forget the whole thing.

They – or should I say we, since the author was a leading proponent of congestion charges? -- chose the first two options. Under the assumptions of Appendix One, Deakin-Harvey estimated that a 15 cents/peak-hour mile charge for all roads would control \$138 million worth of smog per workyear (the same as WSA's 1-cent/mile emission charge), plus \$3.3 billion worth of traffic delay. Our extrapolations of WSA estimates assumed that adding the same charges to surface streets as those that WSA modeled for freeways would produce roughly the same percentage of “good” diversions (to ridesharing, offpeak hours, or trips foregone) systemwide, but not the “bad” net diversion to surface streets. Appendix Thirteen.

Added systems costs would not be prohibitive, maybe five cents per average trip, rather than three. Appendices Ten, Thirteen. Such costs are negligible compared to the dollar or so worth of time per p.m. peak-hour trip which congestion charges could save. See notes to Appendix One, Sections 4 and 5. Under these assumptions, a systemwide 15/30-cents/peak-mile congestion charge would control \$136 million worth of smog (again the same as WSA's 1-cent emission charge), plus \$4 billion worth of traffic delay. The optimal combination from this perspective would be what appears in Appendix Three as WE (i.e., Ward Elliott) CP3+, EM1, a 15/30-cents congestion charge for all roads, combined with a 1-cent per average mile emissions charge proportional to each vehicle's actual emission rates. This would control \$374 million worth of smog per workyear, plus \$4.6 billion worth of traffic delay. The strategy, after deducting systems costs, would save the average household in the Basin \$714 per workyear in health, property, time, and productivity costs. Appendix One, column 14. It would yield \$1,094 per household in net revenue, just enough to cover all of what they paid for gas taxes, vehicle registration fees, and transit fares at 1991 rates (\$1,038 per household), or, alternatively, more than half of what they were paying for property or sales taxes (\$1,700-1,900 per household, calculated from Appendix One).

These estimates could and should be further refined, but both the Elliott estimates and the Deakin-Harvey estimates strongly suggest that massive savings --

several billion dollars in time benefits, along with several hundred millions in smog benefits, plus billions of dollars of extra revenues -- could be realized by an all-roads congestion charge and a 1-cent emissions charge. The same combination with freeways-only congestion charges would yield two or three times lower smog benefits and negligible net time benefits. This was not just true of projections for the year 2010; it was also true of Deakin-Harvey's baseline modeling year, 1991. See D-H's 10¢/peak mile scenario, Appendix One. If the models and assumptions are true, the average household was losing about \$700 in *preventable* smog and congestion costs every work year, in 1991, and has continued to do so for almost a decade of dithering over pricing policy. We shall never get it back. If these estimates are half right, or even a tenth right, the costs of inaction on emission, and, especially, on congestion charges have already far outweighed the costs of action. The Task Force's recommendation to "develop a strategy to implement mid- and long-term, fair and equitable region-wide congestion and emission [fees]" was a prudent, minimal acknowledgement of these costs, and should have been a significant step toward reducing them.

VI. Phasing in with HOT lanes

But no one thought then that Los Angeles could duplicate Singapore's feat, more than 20 years previously, of adopting optimal road pricing overnight, even though it immediately cut traffic in Singapore's central business district by 40 percent and made it one of the most accessible in the world. Singapore was small, disciplined, unified, tolerant of heavy government exactions for owning and using cars, and very far away. The South Coast Basin was and is large, sprawling, decentralized, not so disciplined as Singapore, and intolerant of government exactions, especially those affecting mobility. Road pricing may look good to experts and study committees, but many skeptical people in the general public would have to be persuaded before it can become a reality on the roads here. Settling on a long-range goal was the Task Force's first step. Settling on a way to get there was the second.

The Task Force's Strategy Committee, and, briefly, the Task Force itself, debated between two phase-in strategies. The first alternative was a strategy of low emission charges for everyone, perhaps to be ratcheted up in the future, depending on public acceptance. The second was a strategy of HOT-lane (i.e., high-occupancy/toll) pilot projects, like that on the Riverside Freeway (SR 91). On this then-just-opened project, new fast lanes were paid for by user fees of up to 25 cents a mile during peak hours, but (at the time) were also open free to HOV-3's, vehicles with three or more

occupants. The Task Force settled firmly on the second alternative, HOT lanes, recommending an unspecified number of additional HOT-lane projects by 1999. SCAG endorsed two HOT-lane projects in its Draft 1998 Regional Transportation Plan (SCAG, 1998, p. I-21), one for California SR-14 in Los Angeles County, one for Federal I-15 in Riverside County. Neither of these has materialized, however.

The initial attraction of the universal smog-charge strategy was that most Task Force members, and most respondents to Task Force surveys of the general public, were twice as concerned about smog as they were about congestion. They wanted to make greater smog control the immediate, as well as the ultimate goal of the Task Force. But this approach had three fatal drawbacks. It would not work without a full-blown, Basinwide collection and enforcement infrastructure, which we didn't and don't have. It would have no noticeable effect on smog till it was not only full-scale, but full-price. And, even at full price, it would have had no congestion-control benefits. In practice, it would have been much more like a tax than like an air-cleaner or a road-clearer; the public would have recognized it as such; and the idea would have been dead on arrival.

HOT lanes, by contrast, were already working for congestion purposes (their smog consequences are still not clear) on a small scale at full price. They offered immediate, tangible rewards in faster access, not only to users of the reserved fast lanes, but also to users of the non-reserved lanes, who get the fast-lane users out of their way. They had already become an instant hit with all kinds of users of the SR 91 (Riverside Freeway) project, saving *all* users up to 17-27 minutes of delay (one-way, as of June, 1997), and fast-lane users up to 13 additional minutes of delay on a ten-mile stretch of formerly jammed bottleneck (Sullivan, 1998, p. 3). They since have drawn 60-80% approval from commuters using the link (Sullivan, 1998, p. 7). Subsequently, they also become an instant hit on the I-15 (San Diego Freeway) in San Diego County. Add-a-lane HOT lanes were favored in most of the Task Force's focus groups, and by most respondents to the Task Force's surveys of public attitudes, provided the revenues would be rebated to the public or spent wisely for their advantage.

Experts at the time were cautious about drawing conclusions from I-15 project, which was still on the drawing boards, and even the then up-and-running SR 91 project. They expected that it would take a year or two for its final use patterns to get settled, and that more polls and traffic surveys would be needed before any firm judgements could be made. The I-15, after some initial adjustments, appears to be an unqualified success. The toll lanes of the SR 91 have likewise been an unqualified success. But the free lanes, after dramatic initial success, have been badly gummed up by the growth of traffic, and especially by the opening of the Eastern Toll Road link, which lacked a

connector to the SR 91 toll lanes. These problems could be fixed by yet further widening, pricing the free lanes, or both, but both of these have been stymied by problems of co-ordinating the state freeway link with the two unrelated toll links. After a series of controversial maneuvers, neither the state nor the SR 91 private operator, the California Private Transportation Company, feels free to make the necessary changes under the terms of existing law and CPTC's franchise.¹

It should be noted that both of the extant California HOT lanes are add-a-lane expansions to existing links. The REACH Task Force also considered take-a-lane HOT lanes and thought them worthy of future study. HOT lanes require available unused space on HOV lanes to work, and some SCAG experts believe that HOV lanes in the Basin (mostly HOV-2 lanes) are almost full, running at 60-90% of capacity. If so, little unused space will be available till some HOV-2 lanes overload and are forced to move to HOV-3's.

Nevertheless, both in theory and in practice so far, HOT lanes still look like something which actually does speed up traffic and which the public likes, both on and off the corridor served -- just as congestion-charge advocates predicted two decades ago when HOT lanes and congestion charges were considered politically unthinkable. If the public continues to like HOT lanes, it will probably ask for more, get them, and move toward larger-scale congestion pricing by creating an infrastructure corridor by corridor.

How far should HOT lanes be taken? The maximum answer, consistent with, but not required by the Task Force's examine-and-develop recommendation, would be *all the way to full-scale congestion charges, as fast as the system's infrastructure can be built*. It would shorten the long, punishing wait to save the billions of dollars of annual lost time and health, and it would avoid many of the hybrid start-up problems of projects like the SR 91. A more cautious, and perhaps more appropriate, answer, also consistent with the Task Force's recommendation, might be: *as far and as fast as people want to take them*. This is also a hedge against uncertainties as to how crowded the roads might actually be in 2010 (Meyer, 1994; Gordon and Richardson, 1994). If SCAG's forecasts are correct, and average peak-hour speed basinwide is reduced to 11 miles per hour, it is hard to imagine people wanting to put up with it. How many people in New Jersey would dream of taking Route 1, which is "free," when they can get to Delaware two hours faster by paying a toll and taking the Jersey Turnpike? How many of them would be happier if someone could make the Turnpike's "Lexus Lanes" disappear? How many users of the SR 91, now saving an hour a day of commuting time, would actually want the much-criticized project to go away? How many of them, along with their gridlocked friends and relatives, would not wish for a few more HOT

lanes along their path? Once people get a taste of life in the fast lane, they may well want a lot more of it, and a lot less of life in the slow lane. As one might guess from the section on pricing surface streets, and from Appendix Thirteen, the more lanes that are priced, speeding them up, the more traffic is likely to be diverted to non-priced lanes, slowing them down, and the stronger will be the incentive to price the crowded slow lanes, too, to speed them up. The differences between the most cautious answer and the maximum answer may turn out to be much smaller in the long run than they might seem in the short.

VII. Equity considerations.

What about the inevitable equity objections: does road pricing mean "Lexus Lanes" which will "price the poor off the road?" Certainly, no project perceived as unfair is likely to find a popular base of support. The short answer is "no more than \$20 close-in parking lots price the poor onto \$3 parking lots six blocks away." Few consider such familiar price allocations unfair. Nobody calls them "Lexus Lots."

The longer answer starts from basic principles. There is no one-size-fits-all definition of fairness, but the Task Force invoked five principles of equity:

- (1) *beneficiaries pay costs*: those who benefit from an action should normally pay their proportional share of the costs the action imposes on others;
- (2) *users get to choose*: systems where individual users get a variety of choices are normally preferable to systems which do not offer choices;
- (3) *inter-regional or inter-group equity*: one region or group should not normally be required to pay for another region or group's costs, except to the extent that it caused them;
- (4) *take good care of the poorest*: where a social burden is imposed, it should not normally be imposed more heavily on the poor than the rich; and
- (5) *lighten the biggest, broadest burdens first*: mitigating large damages to the many should normally take precedence over mitigating smaller damages to the few.

Despite loose talk about "Lexus Lanes," HOT lanes present few equity problems that are not presented by other things we take for granted, like differentially priced close-in or far-out parking lots or cellular and ordinary phones. People get to choose, use, and pay for the level of service they want; cheaper alternatives are available; nobody loses anything from the new option; and many come out way ahead. A full-scale system of emissions and congestion charges, if we had one, would be more problematical because it would cut back on some existing options -- albeit far less

drastically than the gridlock it would prevent. But even a full-scale system would be an improvement over the present system by most of the five equity measures. Under the present system, users and taxpayers pay into general funds and trust funds; resource allocation is political, not economic; regressive cross-subsidization of rich groups by poor is the norm; many peak-hour users get only two choices: slow and slower; and billions of dollars of avoidable time losses continue every year while policy-makers worry about getting much less costly details worked out. Emissions and congestion charges would settle the cost of use much more squarely on users; give them more choice; clear away regressive cross-subsidies; and give people back some of the weeks of time and days of life they now lose, preventably, to crowded roads and bad air.

Table 1, adapted from the REACH Task Force final report, may help illustrate some of these points.

Table 1

Salient Base Case Demographic Variables for Understanding Equity Impacts
Income Quintile

	1	2	3	4	5
Median p/c income	\$4,108	\$7,767	\$11,923	\$18,167	\$37,951
Share of income	5.1%	9.7%	19.9%	22.7%	47.5%
Share of Peak VMT	8.8%	15.5%	18.9%	24.8%	32.0%
Share of delay cost	2.2%	6.5%	11.6%	24.0%	57.1%
Share of p.m. transit%	22.2%	20.2%	19.1%	16.7%	21.8%
Pre-1984 veh. VMT%	13.0%	19.0%	21.0%	24.0%	25.0%

Source: TRIPS, 1991 Origin & Destination Survey

Cited in Cameron (1994), p. I-20

Wilbur Smith Associates, "Estimated Annual Transportation Costs and Benefits per Capita," May 22, 1996

The chief lesson of Table 1 is that congestion is not a problem which every class inflicts equally on every other class, far less a problem inflicted on the rich by the poor. It is overwhelmingly a problem inflicted by the nonpoor on each other. The

richest quintile is three or four times more likely than the poorest to be on the road at peak hours. It suffers 26 times as much loss from traffic delay, partly from being much heavier users, partly from having higher time values. Surprisingly, the same could also be true for vehicular smog, at least as measured by miles driven in old cars - only in this case the rich polluters inflict their smog not just on other well-to-do road users, but on everybody in the Basin who breathes. The richest two quintiles each drive almost twice as many miles in pre-1984 vehicles as the poorest quintile. Surprisingly also, transit use is almost equally divided among all five quintiles.

The existing system of road financing is triply regressive. Taxpayers generally, a poorer class, support road users generally, a richer class, with municipal services like fire, police, courts, ambulances, and emergency rooms benefiting road users. Road users generally, a poorer class, support peak-hour road users by paying with their fuel taxes for roads generally sized to accommodate peak-hour users. And five out of the six taxes supporting the existing highway system are themselves regressive (Giuliano, 1994, p. 260).

Table 2, adapted from Giuliano, 1994, helps identify winners and losers from full-scale congestion charges.

Table 2
Estimated Impacts of Congestion Charges in the L.A. Basin

Percentages	Poor	Nonpoor	Total
of adult public	20	80	100
drive cong. rds at peak	5	15	20
equal or better with cc's	4	11	15
worse off with cc's	1	4	5

Source: calculated from Genevieve Giuliano, "Equity and Fairness Considerations of Congestion Pricing," 1994; see Elliott, 1995

Table Two begins to summarize, and proper transportation policy should also reflect, a number of points about driving patterns in the South Coast Basin. These are:

1. *Not everybody drives.* One household in ten in the Los Angeles Basin does

not have a car. Most of this fraction is poor and would benefit, on balance, from anything like congestion charges which gives buses and carpools better access.

2. *Not everybody who drives drives at peak hour.* Although nine out of ten households have a car, only three out of five voters commute to work. The other two are retired, unemployed, homemakers, or students. This 40% would be little affected by congestion charges, which would divert some peak traffic to off-peak hours.

3. *Not everybody who drives at peak hour picks a congested route.* Of the three in five voters who do commute, two say they do not suffer seriously from congestion -- yet. This 40% would be modestly affected by congestion charges, which would divert some traffic from more congested to less congested routes.

4. *Relatively few of the 20% of voters who do drive crowded routes at peak hours are poor.* As we have seen both from Table 1, and from Table 2, peak-hour congestion is overwhelmingly a problem that the non-poor inflict on each other.

5. *Only a small fraction of the few poor who do drive crowded routes would lose from congestion charges.* Harvey calculates, as one would expect, that the poor are more likely to be priced out of their single-occupancy car than the rich (Harvey, 1994, p. 109). But Giuliano finds, perhaps to some people's surprise, that, when the value of their time is considered, average-distance (10-mile each way) drivers, both poor and middle-income, who pay the charge and keep driving, come out slightly ahead of where they would have been without the charge. Anyone who switches to transit or short-distance carpool likewise comes out ahead, even if the carpool has to pay full congestion charges. Poor people whose long-distance (25-mile) carpool commute becomes fully charged come out slightly behind -- which, however, is easily fixable by exempting 3-person carpools from some or all congestion charges.

The only Giuliano category that loses heavily from congestion charges, and whose losses cannot be easily fixed, are long-distance middle-income (and presumably low-income, though these are not calculated separately) commuters who do *not* switch to bus or carpool, but persist in driving a crowded 25-mile peak-hour route, twice a day, every mile of it fully charged. These would come up a stiff \$854 a year poorer with congestion charges than without. However, they are a very small percentage of commuters -- probably less than five percent of a.m.-peak direct-to-work commuters (computed from Peter Gordon 1990

NPTS summary). Less than a quarter of them -- that is, less than one percent of a.m.-peak direct commuters -- could be considered poor. This tiny, overwhelmingly nonpoor five percent imposes much more than its share of delay (and smog) costs on other drivers -- and gets to do it free under the present system. Not everyone would be shocked to see such people strongly incentivized to carpool, bus, move closer to work -- or pay something for their choice to do none of these things. Giuliano's calculations cover about two-thirds of peak-hour drivers: the half that drive ten miles or less, and the 15 percent or so who drive 25 miles or more each way. That leaves out a third of peak-hour drivers who drive between ten and 25 miles. Wherever Giuliano shows short-distance commuters to gain, and long-distance commuters to lose, Table 2 assumes that half of the middle third will be winners, half losers.

These back-of-the-envelope calculations will not be the last word on the subject, but the evidence at hand overwhelmingly suggests that the list of likely losers from congestion charges will be surprising short and nonpoor -- and justly chargeable for their own social costs -- compared to the list of losers from *not* having congestion charges. Are we better off with one or two percent of the public losing \$850 a year for their own wasteful behavior, or with every household in the Basin losing \$900 a year mostly because of other people's wasteful behavior?

6. *Pay for what you get is well accepted for other necessities.* It is true that congestion charges would be regressive, in the sense of charging the poor a higher fraction of their wealth than the rich for the same benefits. But this is no more true of congestion charges than it is of anything where you get what you pay for -- water, gas, electricity, and groceries, for example. Most people, poor people included, would be horrified if we charged the same artificially low prices for these as we do for roads at peak hour, correctly guessing that people would waste them, just as we now waste our time, our roads, and our health.

7. *Congestion charges are much less regressive than the existing system.* The system now in use, as we have seen, is triply regressive. Taxpayers generally, a poorer class, now subsidize road users, a richer class. Road users generally, a poorer class, subsidize peak-hour commuters, a richer class. Five out of the six taxes supporting the existing highway system are themselves regressive (Giuliano, 1994, p. 260). Asking people to pay for what they get would be not only more efficient, but also less regressive than any of these foundations of the existing system.

8. *If necessary, losers can be compensated.* If necessary, where all else fails, the tiny fraction of the poorest or most deserving losers could be compensated with cash or a lifeline access permit. Such compensation, if used at all, should be used sparingly, because its effect would be to expand the compensated class and to undermine somewhat the benefits going to the three-quarters of poor and nonpoor who would come out equal or ahead. But the compensable class, even if it triples, would still be small, and the cash or lifeline subsidy to the few would be far preferable to what we have now -- a universal, open-ended license for everybody to inflict upwards of \$900 worth of delay and pollution on everyone else. This delay, by the way, hurts the poor not only directly by health damage and traffic delay, but also indirectly by stifling productivity in the Basin and driving investment and jobs to other less gridlocked areas.

9. *Even the poor need a fast lane now and then.* Poor people have to meet deadlines, and they don't consider their time worthless. Sometimes, when they are rushing to get to work, catch a bus, pick up a child, or get to the hos/pital, they value their time very highly and would pay a lot to get into a fast lane. Usage of the SR91 toll lanes is only weakly correlated to income. The present system denies poor people the time-saving choice, and the denial can be just as hard on them as it is on the rich. Bottom line: congestion charges are perfectly in keeping with most people's sense of fairness, more so than the system we have now. They do not require a revolution of moral consciousness.

10. *At the rate we are going, we don't have to cross most of the bridges till we get to them.* There are many uncertainties involved in a move toward the fast lane, most of them outweighed by the growing certainty that we are losing our shirts while stuck in the slow lane, and many of them resolvable only by actual experience with congestion charges. It has taken us twenty years longer than Singapore to think seriously about making the move. It will take more years, perhaps many more years, of phase-in to make the actual move. At our deliberate pace there is room for trial and error; not every question has to be fully answered in advance.

11. *Dithering over little equity questions postpones coping with big ones.* What is true on average is not true in every individual case. Some poor people are bound to suffer from changes in incentive structures, even changes that make most poor people better off. It would not be unreasonable to look for ways to ease the impacts of new incentives on such people, nor to start with the least regressive available strategies, such as add-a-lane HOT lanes. What would be

unreasonable, once you realize that the average household, which is neither rich nor poor, suffers thousands of dollars of direct damage a year from smog and congestion, is to delay getting it fixed till you can guarantee that every last dollar of cost to every last person harmed by the change will be fully recompensed. Equity says that if there is a pound of cost from changing to a new system, and a ton of cost from not changing to the new system, it's fair and prudent to consider the pound, but not fair or prudent to ignore the ton.

VII. Impact on truckers

Impact on truckers, though it is barely mentioned in the congestion-charge literature, is probably more important than impact on the poor -- because (1) there probably are more peak-hour truckers than there are low-income drivers; (2) trucks will cause up to 80% of the projected growth in some corridors; (3) the truckers are much more organized than low-income drivers, and their voice is more likely to be heard in the state legislature; and (4) truckers' role in creating and supporting jobs, and supplying goods and services, is far larger and more consequential to the poor (to say nothing of the non-poor) in general than is commuting by a small number of poor individuals. Modern, just-in-time manufacturing already relies heavily on free access by truck. It will probably rely even more so in the future.

Trucks are not likely to be much affected by start-up HOT lanes unless, as seems improbable now, they are permitted to buy onto them. To the extent that start-up, add-a-lane HOT lanes speed up general lanes, they would come out a bit ahead. If and when the charge system approaches full scale, and every available lane is a HOT lane, wholesale exclusion of trucks will no longer make sense. They will need available access to at least some of the lanes at peak hours, and they should pay for it, just like everyone else. How much? I don't have a study of it, but three times as much per mile might be a plausible guess, since trucks are bigger and cause much more congestion, both recurrent and non-recurrent, than cars. They also cost more to own and operate, maybe \$100 an hour with driver, and their drivers are not strangers to deadlines. If they could pay, say, a \$15 congestion charge and thereby save 15 minutes, they would save \$25 worth of operating time and come out \$10 ahead, maybe more when the deadline is really tight. If this were a typical situation (as it probably would be), and the whole of the bargain, truckers should be demanding congestion charges *now* to get themselves into the fast lane.

However, it may not be the whole of the bargain. Any time the talk turns to user fees, it could turn also to other use impacts which truckers would rather not have on the agenda, such as charges for road wear and for nonrecurrent congestion imposed by

accidents. Many think trucks are disproportionately responsible for both of these and are not paying their full share of the costs (Small, et al., 1989). The same could be said of a modern, particulates-dominated estimate of smog costs. Small and Kazimi, for example, reckon smog costs per mile at 3 cents a mile for cars, 53 cents per mile for heavy diesel trucks (1995, p. 25. But see Appendix One for reasons to believe PM10 costs from trucks may be exaggerated). To the extent that these are so, truckers could lose, as well as gain, from a comprehensive application of the pay-for-what-you-use principle. A closer study of the congestion issues, including nonrecurrent, could help sort some of these questions out. Pending such studies, it seems more likely than not that full-scale congestion charges, by themselves, would be a boon to truckers. SCAG is currently contracting for feasibility studies for truck-only toll lanes on several of the truck-impacted highways.

IX. What To Do With the Revenues?

Spending the proceeds is not a big problem with start-up HOT lanes. The revenues from the Route 91 HOT lanes will pay for building them, and, we hope, for a deserved profit to the entrepreneur who builds them. HOT lanes to be built in the future could likewise absorb years of revenue to pay for their construction. But the closer the system gets to full scale the closer we will be to what both WSA and Deakin-Harvey say could be a \$3-billion annual stream of revenue. How might it be spent?

The most detailed recommendation is that of UC Irvine economist Kenneth Small. In 1993 he proposed the following spending package for \$3 billion: 23 percent of it on a \$10-a-month employee commuting allowance; 10-18 percent each on fuel tax reduction (5 cents); sales and property tax reductions (for their transportation subsidies); highway improvements; transit improvements; and transportation services in business centers (Small, 1992, 1993).

One could do worse than recommend the Small package wholesale, though detailed recommendations made years in advance of need also have a downside, that times will change and render them obsolete. A more flexible set of guidelines, generally consistent with the Small recommendations, is that provided by the Task Force. Pricing revenues should be used for:

1. Building and operating the priced facility
2. Improving the transportation system, especially on corridors priced or affected by pricing (congestion fee revenues)
3. Improving air quality (emissions fee revenues)
4. Mitigating equity impacts to individuals and to regional economies

5. Providing return to individuals (e.g., tax rebates, tax cuts, tax credits, cash rebates) and/or to local governments. As we have seen in Section IV above, some systems could more than cover the per-household costs of all current gas taxes, user fees, and fares.

These hardly guarantee that the revenues will never be wasted, and some of them probably will be. But it is hard to imagine any more complete waste than that of people's time and health that takes place under the current system.

X. Public opinion: a major shift favoring pricing

The Task Force commissioned several focus groups and surveys to gauge the public's receptiveness to road pricing alternatives. The response was surprisingly favorable to all three of the Task Force's ultimate recommended policies: emissions charges, congestion charges, and HOT lanes. 58% of a January 1996 Godbe Research Associates sample thought that air pollution fees, by themselves, were a good or excellent idea. 40% thought congestion fees were good or excellent. 70% said that fees would be more acceptable if accompanied by a compensatory tax reduction. A majority of respondents said they would pay \$20 per month to gain 10 miles per hour in peak-hour freeway speeds, and \$30 per month to meet clean air health standards every day. Actual users of the S.R. 91 HOT lanes were paying \$5 a day to save about 20-30 minutes when the REACH Task Force was meeting; this implies that they valued their travel time no less than \$10 to \$15 per hour. Tolls have risen 50% since 1996 and would imply Year 2000 time values of at least \$15 to \$22.50 per hour if the time savings have held constant.

40% of respondents to an August/September 1996 Resources for the Future poll favored emission and congestion fees per se. 50% of respondents with an opinion favored congestion fees with a 50% tax rebate. More than 50% favored emission fees with rebates. Young people, Democrats, independents, Asians, and Hispanics were most favorable to both kinds of fees. About 30% of the interviews were in Spanish.

54% of the RFF respondents favored add-a-lane HOT lanes, 45% favored take-a-lane HOT lanes. 62% of the Godbe January sample favored HOT lanes, with no specification as to whether they were add-a-lane or take-a-lane. Ventura County respondents were hostile to HOT lanes; every other region supported them with comfortable majorities. Early surveys of prospective and actual users of the S.R. 91 HOT lanes showed them to be favored both by reserved-lane users and general-lane users. 1997 surveys of SR 91 commuters showed overwhelming, 60-80% approval of the toll lanes, with toll-lane users' percentages 5-10% higher than free-lane users

(Sullivan, 1998, Executive Summary, p. 7).

Before the REACH studies political sophisticates thought it was so self-evident that people would bitterly oppose being charged for what they now get free that it was hardly worth asking them what they thought about new road pricing schemes. The expectation was that 95% would say "over my dead body." Such hostility to new charges still appears (though not at the 95% level) in recent polls elsewhere: Minneapolis and the Bay Area are examples. And 1996 Task Force focus groups in the Basin still seethed with suspicion and resentment of *other* government exactions. They were sure that the money would be wasted. But most of the focus groups, despite their general hostility to government, nonetheless favored HOT lanes. Ironically, the exception was a panel of liberal West Side non-commuters otherwise enamored of a pervasive government presence, and far removed from the facility. In general, those most hostile to toll lanes have been those with the least experience with them.

What could explain the surprising softening in Southern California, supposedly the most autocentric part of the country, toward three different kinds of car-charging incentives? Worsening congestion? The persistence of our getting-better-but-still-worst in the country air pollution? Putting the questions more shrewdly -- *How would you like to be able to buy on to a fast lane?* instead of *How would you like to be forced to pay for something you now get free?* Several months of growing awareness of the S.R. 91 HOT lanes? Exhaustion of other once-favored decongestants, such as megarail and megaroads? Creeping awareness of what economists and some transportation experts have been saying since 1960? No one knows which, if any, of these explanations figured in the change, but a major change there has been. We may not have seen the end of it.

XI. Lessons Learned from the Task Force.

The REACH Task Force unanimously approved its Final Report on January 22, 1997, calling for outreach and involvement programs to teach market-based transportation concepts to the public. It specifically (some might say astonishingly) called for the "implement[ation] of HOT-lane demonstrations within the region by 1999, if feasible," and of "mid- and long-term, fair and equitable region-wide congestion and emissions-based transportation user fees." Translated from plannerese, it asked for new HOT lanes in the short run, region-wide congestion and emission charges in the longer run. It also called for feasibility studies of five candidate HOT-lane projects. REACH, 1997, pp. 3-4. It continued its analysis of HOT-lane projects through April 1998 and succeeded in getting two add-a-HOT-lane projects (but not regionwide congestion pricing) adopted in the 1998 SCAG Regional Transportation

Plan (SCAG, 1998a, p. I-29). By the Year 2000, none of the proposed HOT-lane projects had come anywhere near adoption, most likely because both of the main forces for creating the Task Force had greatly receded by the late 1990's. These were: extreme shortages of public transportation funds and threatened federal sanctions to force mandatory employee ridesharing. With the EPA in full retreat, Orange County out of bankruptcy, and Los Angeles County back from the brink of bankruptcy, local governments felt free to return to their wasteful, comfortable, old tax-and-spend transportation policies, trust-funded megabus, megaroad, and megarail projects, and they did.

While it lasted, however, the Task Force learned and taught four important lessons, which may one day be taken to heart:²

1. *Resolution matters.* After all the expensive modeling runs, it is clear that *high-resolution, real-time congestion and emissions charges* could spare us much more smog and congestion, at much lower cost, than any of the lower-resolution, supposedly more palatable regulations and pricing strategies (such as employee rideshare mandates or VMT charges) studied. If we had them at full scale, they could save the average household in the Basin hundreds of dollars a year in avoided costs from delay and lost health and productivity.

2. *HOT lanes on crowded corridors are the best start toward testing and achieving a universal, high-resolution system.* If resolution matters, and immediate, full-scale, full-strength implementation is not expected, then it is better to start small-scale, with strong incentives, than large-scale, with weak ones. Strong incentives produce strong impacts, whether in Singapore, on Eastern toll roads, or on California HOT lanes. Pricing always gets you there faster, and the public likes it. Weak incentives are a political dead end. They get no one there faster and would be seen, correctly, as nothing but another tax. If there is any hope of getting to full-scale smog and congestion pricing, it will be from baby steps that produce visible benefits, not baby steps that don't.

3. *The general public in Southern California is surprisingly willing to try road pricing.*

4. *Problems of regressiveness and revenue use are negligible for start-up programs, and non-prohibitive for full-scale systems.* Nothing is either good or bad but alternatives make it so. The existing system is so colossally wasteful that almost any higher-resolution alternative would be an improvement. Counting the value of their time, most low-income drivers (and most other drivers) would be

better off with congestion charges than they are now, regardless of whether they pay the charge or switch to bus or carpool. The system as a whole would be much less regressive than what we have now. It is unjust and unwise to dither over a pound of equity while perpetuating the tons of hours of life and health that the average household in the Basin loses every year to smog and congestion. They will never get it back.

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Notes

¹ The SR 91 link was one of a number of bottlenecks in Southern California roads for which no public improvement funds were available in the 1980's. Rather than tolerate further clogging, the state turned to private toll-road investors like the California Private Transportation Corporation, which built and runs the SR 91 project, to do the improvements and charge for access. CPTC has not publicized its reasons for picking the SR 91 link, but it would be surprising if they didn't pick the most profitable-looking project they could find, that is, whatever available bottleneck seemed most likely to become the worst one with the most expected congestion to relieve.

What their projections were, and whether they were correct, we do not know. CPTC guards its business secrets closely. But we do know that traffic in the corridor has continued to increase; that the SR 91 link is still a bottleneck which, after a sharp initial drop in delay and accidents, has continued to clog up more and more at rush hour (Sullivan, 1998). Since the opening of the Eastern Toll Road (another Orange County private toll facility which dumps traffic onto the tolled 91 segment but unfortunately has no direct connection to its toll lanes themselves), high-speed merging from adjacent links has slowed traffic and sharply increased accidents in the non-reserved lanes. Yet further widening of the segment, and/or pricing of the free lanes, could speed the traffic, cut the accidents, and make political and economic sense from the public's viewpoint. Unlike the cash-strapped 1980's and early 1990's, California had ample public funding to do the widening by the end of the 1990's. But this time Caltrans's new director, Jose Medina, threatened with a \$100-million lawsuit, signed a controversial agreement to honor a no-build clause in the original agreement with CPTC, which would otherwise have lost half its toll-lane revenue to users of the proposed new free lanes. To secure the needed investment in private improvements to the link in the 1990's, the state in effect relinquished for 15 years its right to add needed public investments to the same corridor in the 21st century. To maintain free flow in the toll lanes, CPTC raised its toll rates five times between 1995 and 2000; it also dropped the HOV qualifier, and the lane is no longer technically a HOT lane. In practice the change has made little difference, since HOV occupants can still split the cost of the toll, reducing costs per passenger. Whoever runs the facility in the future is expected to keep on raising rates incrementally, as long as demand continues to

increase.

While these events were playing out, in the late 1990's, amid improbable and unproven rumors that it was losing money on the project, CPTC was secretly negotiating to sell its operations to a nonprofit successor called NewTrac for \$274 million. NewTrac, organized by a coalition of Orange and Riverside County businesspeople, was to be funded by tax-exempt bonds offered by the California Infrastructure and Development Bank, a bank created to offer alternative funding for public-benefit projects. CPTC would have made an enormous immediate profit of \$74 to \$90 million from the transfer and been assured of retaining the operating contract, on an exclusive, no-bid basis, for 15 years. But, thanks to its tax-exempt funding, NewTrac was expected to be self-supporting, even after the massive payout to CPTC. This cozy arrangement for CPTC had some economic advantages from the state's perspective, but the huge windfall for CPTC, and the substitution of tax-exempt funding for private, on a facility where the state did not share any of the revenues, prompted many shifts in the political wind and the ultimate scrapping (as of this writing) of the proposal. James van Loben Sels, Caltrans Director under the outgoing Pete Wilson administration, hesitantly recommended approval, but he was overruled by his boss, Wilson Transportation Secretary Dean Dunphy. Dunphy counseled CPTC to take the matter up with the next administration. They did, and the succeeding Gray Davis administration's Caltrans Director, Jose Medina (the same one who honored the no-build agreement), quickly approved the deal -- but he, too, was resoundingly overruled, amid calls for legislative hearings and investigations, when its terms became public knowledge. Despite all the commotion over the project's corporate structure, financing, and tie-ins with other transportation links, the toll lanes themselves have continued to operate flawlessly. See Poole and Orski, 2000 for a comprehensive treatment of HOT-Lane issues.

² Perhaps the first lesson is that there are many things we don't know and need to find out. REACH's modeling left some major gaps, all of them having to do with giving the models higher resolution. We need to know more about pricing surface streets; pricing trucks and buses; reconciling WSA's findings with those of Deakin-Harvey; and how to use full-cost accounting systematically and consistently to make all the costs and benefits of the various strategies commensurable. None of these gaps, however, are large enough to obscure the lessons from what the models did show.

Appendices

- One. Mobile-Source Strategies Compared by Cost, Yield, 2010
- Two. Gross Smog Reduction Benefits, 2010, Selected Strategies
- Three. Gross Smog, Congestion Benefits, 2010, Selected Strategies
- Four. Systems Costs, 2010, Selected Strategies
- Five. Revenues Minus Systems Costs, Selected Strategies
- Six. Net Benefits & Systems Costs per Household, 2010
- Seven. Deakin-Harvey Strategy Impact Comparisons, 1991
- Eight. Deakin-Harvey Strategy Impact Comparisons, 2010
- Nine. WSA Strategy Impact Comparisons
- Ten. Systems Costs of Congestion, VMT Pricing Alternatives
- Eleven. WSA Revenue Estimates
- Twelve. WSA SOV Trip Breakdowns
- Thirteen. Pricing Surface streets
- Fourteen. Costs of Mobile-Source Pollutants

Glossary of Strategies

WSA EM1, 1-cent/mile: Wilbur Smith Associates (WSA) estimates of impacts of emissions-weighted vehicle miles traveled (VMT) charge, all roads, average charge: 1 cent per mile. *EM2*, *EM3*: same as *EM1*, but with 2 and 3-cent/mile charges.

WSA CP1, freeway only: WSA estimates of impacts of 5-10 cents/peak mile congestion charges, freeways only.

WE CP3+, all roads: WSA freeways-only 15-30-cents/peak mile congestion charge impacts extrapolated to all roads.

D-H Mod-Impact Combination: Deakin-Harvey “moderate-impact” combination of 15 cents/peak mile congestion charge, all roads; 1-cent/mi emissions charge; \$1/day parking charge; 50-cent/gallon fuel surcharge.

WSA CP2, EM1: 10-20-cents/peak mile congestion charge, freeways only, 1-cent /average mile emission charge, all roads.

WSA CP2, EM1, ET: Same as above, but with \$12.5 billion worth of extra “enhanced” transit.

WE CP3+, EM1: WSA 15-30-cents/peak mile congestion charge, extrapolated to all roads, 1-cent/average mile emission charge, all roads.

Appendix One: Major Mobile-Source Strategies Compared by Yield, 2010

Strategy	HC reduc %	NOx reduc %	PM10 reduc %	Time saving % all hrs	Gross smog bft \$ mil/yr	Gross time bft \$mil/yr	Total gr. bft. \$mil/yr	Syst Cost \$mil/yr	Reve- nues \$mil/yr	rev not	Revs - -syst. costs	Net Rev /hsld \$/yr	Gr.bft /hsld \$/yr	Total Tons Contr	Control "cost" \$000/t
Hi-res Emission Charge															
D-H 1c/avg mi	19	16	2	3.3	261	1122	1383	118	980		862	123	198	25073	-50
WSA EM1 1c/mi	8	4	3	0.19	138	65	203	118	1688		1570	224	29	10978	-8
WSA EM3 3c/mi	25	11	6	1.25	350	425	775	118	4930		4812	687	111	29875	-22
WSA EM5 5c/mi	37	17	9	2.78	525	945	1470	118	7958		7840	1120	210	44808	-30
Flat-rate VMT Charge															
D-H 2c/mi	4	4	4	6.4	136	2176	2312	118	3144		3026	432	330	9350	-235
Congestion Charge															
D-H 15c/peak mi, all rds.	8	4	3	9.7	138	3298	3436	369	7343		6974	996	491	10978	-279
WSA CP1: 5/10c fwy only	2	1	3	0.65	83	221	304	306	1419		1113	159	43	5045	0
WE CP2+: 10/20, all rds.	3	3	3	10	102	3400	3502	369	5530	1	5161	737	500	7013	-447
WE CP3+: 15/30c, all rds.	4	4	4	12	136	4080	4216	369	6342	1	5973	853	602	9350	-411
D-H 10c/peak mi, all ('91)	6	3	2	6.8	173	3373	3546	369	3187		2818	542	682	16039	-198
Combinations															
D-H Mod.-impact (91)*	16	12	9	15	605	7440	8045	369	6627		6258	1203	1547	53049	-145
D-H Mod.-impact*	17	12	10	19	394	6460	6854	369	12256		11887	1698	979	29318	-221
D-H Hi-impact**	41	35	22	35.7	945	12138	13083	762	20206		19444	2778	1869	72495	-170
WSA CP1, EM1.6***	15	7	6	0	264	0	264	487	3926		3439	491	38	20640	11
WSA CP2, EM1****	9	5	6	-0.71	215	-241	-26	487	3640		3153	450	-4	15360	33
WSA CP2, EM1 ET****	11	6	7	0	255	0	255	880	3640		2760	394	36	18360	34
WE CP3+, EM1*****	11	11	11	13.6	374	4624	4998	371	8030	2	7659	1094	714	25713	-180
WSA 2010 Baseline Tons /da	265	261	409												
Average yield, all strategies	14	9	6	8	300	2913	3213	359	5932		5573	823	493	23732	-136
Rule 2202 goal	2	0	6												
CP = Congestion Pricing; EM = Emissions-Weighted VMT Charges; ET = Enhanced Transit															
D-H = Deakin-Harvey study for California Air Resources Board															
WSA = Wilbur Smith Associates/COMSIS reports to REACH Task Force															
WE = Ward Elliott extrapolation of WSA estimates to include surface streets															
Rule 2202 mandates employer rideshare programs															

Notes on Appendix One to Greenbacks Über Gridlock, REACH TF strategy paper

Percentage figures from all Wilbur Smith Associates (WSA) and Deakin-Harvey (D-H) strategies taken or calculated from their reports.

All WSA and COMSIS estimates are per Jack Henneman memo to Deborah Redman, August 10, 1996, "COMSIS Detailed Transportation Pricing Scenarios – Emission Summary," briefing paper, July 24, 1996, and "REACH Transportation Pricing Project 2010 Pricing Scenario Impacts, August 28, 1996. Deakin-Harvey estimates are from "Transportation Pricing Strategies for California: An Assessment of Congestion, Emissions, Energy, and Equity Impacts," California Air Resources Board, June, 1995, updated to spring, 1996. If the models are right, almost any of the midrange congestion-charge combinations could save many billions of dollars of delay costs a year, for less than \$400 million a year in systems costs, and produce enough revenues in the process to pay for more than all 1991 transportation taxes, fares, and fees, or, alternatively, more than half of the 1991-level property or sales taxes of every household in the Basin. See Sections 9 and 10 below.

WSA C2+ and C3+ are not WSA calculations, but Elliott extrapolations of earlier WSA figures, to extend their pricing impacts to surface streets, as most congestion-charge advocates recommend. WSA's "freeway-bound" freeway-only pricing scenarios are not an ideal measure of what a comprehensive congestion-charge system could do. They don't charge off-freeway traffic, and, hence, slow down too much moderately fast freeway traffic by moving it to already-jammed, unpriced surface streets. WSA's own model runs show this approach to be self-defeating because it loses too much speed off-freeway to make up for the faster traffic it produces on-freeway. The "price all roads" alternative may not be quite ideal either, because it is not clear that all surface-street traffic should be charged in 2010, only the part that contributes to congestion and is cost-effective to charge. Appendix Thirteen. However, since no one knows where the line between priced and unpriced should ultimately be drawn, a "price all roads" alternative needs to be among those considered, to show a more comprehensive and accurate upper boundary of what congestion charges could do.

Assumptions:

1. If surface streets were priced comparably to freeways, the "freeway diversion to surface" fractions would be blocked and restored proportionally to the other freeway categories. This results in "diversion to better for congestion purposes" of 15.7% and 20% of priced freeway peak-hour trips for the C2+ and C3+ strategies. "Diversion to better" means shifts to transit and carpools, shifts to off-peak, and reduced trips, but not shifts create peak-hour crowding elsewhere in the system. See Appendix Twelve. As we have seen above, these are upper bounds at the rates stated. On the other hand, if necessary, surface-street charges could be made high enough for *average* charges on surface streets to equal

those on freeways, so the scenario is still plausible, if diversion from freeways is as high, and surface-street crowding as great, as WSA's and SCAG's models indicate. Let us suppose that actual tons of emission reductions are about half of these percentages, since trips shifted to off-peak pollute as much as peak-hour trips, and even shifts to transit and carpools do not eliminate all pollution.

2. If surface streets were priced comparably to freeways, they should have comparable percentages of mode shifts to better. That means that, if all peak-hour traffic is priced at C2 and C3 rates, workday vehicle trips on the entire system would be reduced by 15.7% and 20% for congestion purposes, half that for smog tonnage purposes. These percentages, in turn, amount to 6.4% and 8.2% of all workday trips for congestion purposes, 3.2% and 4.1% for smog tonnage purposes.

3. Unlike the modeled impacts of the WSA/COMSIS strategies, these estimates are based on nothing more than VMT reductions, with no allowance for speeding traffic or for strategic timing and placement of reductions. If Deakin-Harvey's all-roads pricing estimates are accurate, this is roughly accurate for PM10 and NOx reductions, but may underestimate HC reductions by as much as half. Absent such adjustments, the mode shifts to better should reduce workday VOC and NOx emissions by 3.2% and 4.1% for the two all-roads scenarios -- much more than for the freeway-bound scenarios.

4. For congestion purposes, these sizable modal and time shifts to better would reduce delay not only on freeways, as in WSA's freeway-bound calculations, but everywhere in the system. How much and where? No one knows exactly. WSA can't model it because their model is not coded for surface streets. But both D-H, which did not exclude surface-street traffic, and the assumptions outlined below, suggest that there would be about a ten-percent time savings from congestion-pricing all roads. Freeway speeds would be somewhat less than with the WSA freeway-bound scenario, because there will be much less diversion to surface streets. Surface-street speeds would be greater than the freeway-bound scenario for the same reason.

Overall system speeds would be greater, thanks to the large modal and time shifts, and WSA-supplied vehicle-hour delay (VHD), estimates give us a way of guessing how much. These estimates are presented with bars, not numbers, in WSA REACH Task Force, Transportation Modeling Results, July 24, 1996, p. 8, but the following numbers can be approximated from the bars:

Workday/Workyear VHD estimates, 1990 and 2010
(in millions)

	1990 Baseline	2010 Baseline
Peak	1.8	4.2
Off-peak	.32	.68
Daily Total	2.12	4.88
Yearly Total	530.0	1,220.00
Yr. Tot Peak	450.0	1,050.00

Between 1990 and 2010 trips increase by a third; delay increases 2.3-fold. About 85% of the delay in both years is during peak hours. What would happen if, instead of increasing by a third, trips increased by a third, minus the estimated mode and time shifts? Peak-hour trips under the all-roads CP2+ and CP3+ scenarios would then have increased only by 12% and 6%, respectively, from the 1990 baseline. That is, 84.3% of 1.33 = 1.12 for CP2+; 80% of 1.33 = 1.06 for CP3+. If there were a linear relationship between trips and delay, the additional delay from increased trips would be reduced by two-thirds and four-fifths, respectively; that is, by the differences between a 33% increase and smaller increases of only 12% and 6%.

Delay reductions of this magnitude would be impressive enough by themselves. But the actual impacts would be even greater because the actual relationship between trips and delay is nonlinear. The first trips diverted get rid of more delay than the last. This means that the true differences in delay from the unbound C2+ and C3+ would be substantially greater than two-thirds and four-fifths. Without an available WSA modeling, let us suppose, conservatively, that the true delay savings are closer to three-quarters and nine-tenths, respectively. The difference between the two baselines is 600 million extra peak-hours of VHD a year (1,050 - 450). 600 million vehicle hours times expected peak-hour AVO of, say, 1.15 = 690 million person hours, times \$6.80/hour time value = \$4.7 billion worth of extra delay, divided by 7 million households = \$670 of extra delay per household. Actual daily AVO is expected to be 1.35, but it drops to 1.15 during peak hours, which account for 85% of the delay. Hence, for purposes of counting delay reduction, a 1.15 AVO is a better common multiplier, even for strategies, such as VMT-fees, which reduce low-delay off-peak traffic, as well as high-delay peak traffic.

Deakin-Harvey's model runs are generally consistent with the hard part of this line of thinking, though they don't say much about the easy part, converting time costs into dollar costs. They predict a 9.7% reduction in travel time from a 15¢/mile peak hour charge; we predict a 10% reduction from a 10/20¢ charge, and a 12% reduction from a 15/30¢ charge.

Cutting the delay 75% or 90%, that is, cutting the total travel time by ten or twelve percent, would save the average household between \$500 and \$600 a year in time costs.

5. It should also lower smog costs by speeding up traffic, especially in the a.m. peak. I don't have enough modeling information and technique to estimate the tonnage myself, but cars do put out half as much VOC per mile at 30 mph as they do at 10 mph. Speeding up surface-street traffic from 12 mph. to 22 mph. would reduce VOC emissions per mile by about 40%. WSA-COMSIS REACH Presentation, July 24, 1996, p. 4. Deakin-Harvey does appear to account for this. Their modeled 15¢/mile congestion charge, which would cut VMT by 3%, would cut NO_x by 4% and VOC by 8%. D-H's modeled figures on air impacts are probably better than my unmodeled ones.

It is also clear from looking at COMSIS emission-plot maps (*Id.*, p. 17) and at WSA congestion-plot maps (WSA Technical Memorandum No. 2Ci, figs. 3 and 4) that the emission hot-spots are the same as the congestion hot-spots, and that most of them are toward the upwind side of the Basin. This means that a given ton of emissions would affect many more people than the same ton emitted farther downwind. Hence, the Elliott calculations used here probably underestimate both tons of emission (especially VOC) and the harm per ton of emissions that would actually occur on the ground -- or should I say in the air?

6. Gross smog benefits are calculated at \$9,000/ton for VOC, \$10,000/ton for NO_x, and \$21,000/ton for PM₁₀, based on average estimated control costs in the 1994 AQMP, and on a conservative adaptation of Jane Hall's PM₁₀ damage-cost estimates. Actual costs in 2010 would probably be higher by a third, because the affected population then is expected to be higher by a third, and the same amount of pollution would do harm to a third more people. Gross time benefits are calculated at \$6.80 per person-hour. These are upper bounds because the induced smog cleanup and mode shift will have some costs. I have not figured out how to count these offsets comprehensively, or whether they are not already netted out in the WSA and D-H models. But any costs not netted out would have to be gigantic to offset the enormous benefits in gross time and smog savings. Consider, for example, the p.m. peak in 2010, Appendix Twelve. Baseline SOV trips are 11.7 million a day. After 15/30¢/peak mile charges, which divert 19% to better, they are only 9.5 million trips a day, each saving about nine minutes, or about a dollar a trip = \$9.7 million worth of time saved a day. Suppose the 19% diverted would have taken 18 minutes longer (50%) in the heavily crowded baseline scenario. The global speedup would cut these trips, too, by about nine minutes, leaving the diverted traffic with a net loss of nine minutes a trip. But these amount to only 2.1 million trips a day, just 22% of the 9.5 million who gain nine minutes a day. If their time value is equal to that of the non-diverted gainers -- which is highly unlikely -- they lose a dollar's worth of time a trip, but it is only 22% of the value of the gained hours. If their time value is lower, the dollar cost of the offset, and, hence, the dollar cost of compensating them for making the diversion, would both be lower, probably a lot lower.

7. Smog costs, 2010:

HC: $265 \text{ t/d} \times 250 \text{ days} = 66,250 \text{ t/yr} \times \$9,000 = \$596.2\text{M ann. costs.}$

NOx: $261 \text{ t/d} \times 250 \text{ days} = 65,250 \text{ t/yr} \times \$10,000 = \$653\text{M ann. costs.}$

PM10: $409 \text{ t/d} \times 250 \text{ days} = 102,250 \text{ t/yr} \times \$21,000 = \$2,147\text{M ann. costs.}$

Smog costs, 1991 (from Cameron, 1994)

HC: $605 \text{ t/d} \times 250 \text{ days} = 151,250 \text{ t/yr} \times \$9,000 = \$1,362\text{M ann. costs.}$

NOx: $664 \text{ t/d} \times 250 \text{ days} = 166,000 \text{ t/yr} \times \$10,000 = \$1,660\text{M ann. costs.}$

PM10: $397 \text{ t/d} \times 250 \text{ days} = 99,250 \text{ t/yr} \times \$21,000 = \$2,084\text{M ann. costs.}$

8. System cost is taken from WSA's estimates for an Open Freeway electronic toll collection (ETC) congestion pricing system and a Computed VMT pricing system with an additional estimated \$27.3 million a year for border stations. WSA Technical Memorandum No. 2Ci: Technology Requirements of Pricing Options, Feb. 20, 1996, with adjustments for adding surface streets. See Appendix Ten. WSA needed 691 zones to price freeways electronically with an "open" system; if every zone is enclosed by two pricing points, this seems to call for about 712 pricing points. No one knows how many pricing points would be needed for surface streets in the Basin. But I once sat down with a partial traffic-zone map of the Basin, counted entrances and exits to each zone, extrapolated to the entire Basin, and got a figure of about 2,000 pricing points. This would imply a total system, including freeways, with four times as many pricing points as WSA's freeway-only scenario. This would raise system costs from \$306 million -- 2.7 cents a trip -- to \$369 million, or 3.3 cents a trip. If I was wildly off in my estimate and twice that number of pricing points are needed, systems costs would go to \$589 million a year, or 5 cents a trip. Three or four cents is a more plausible estimate.

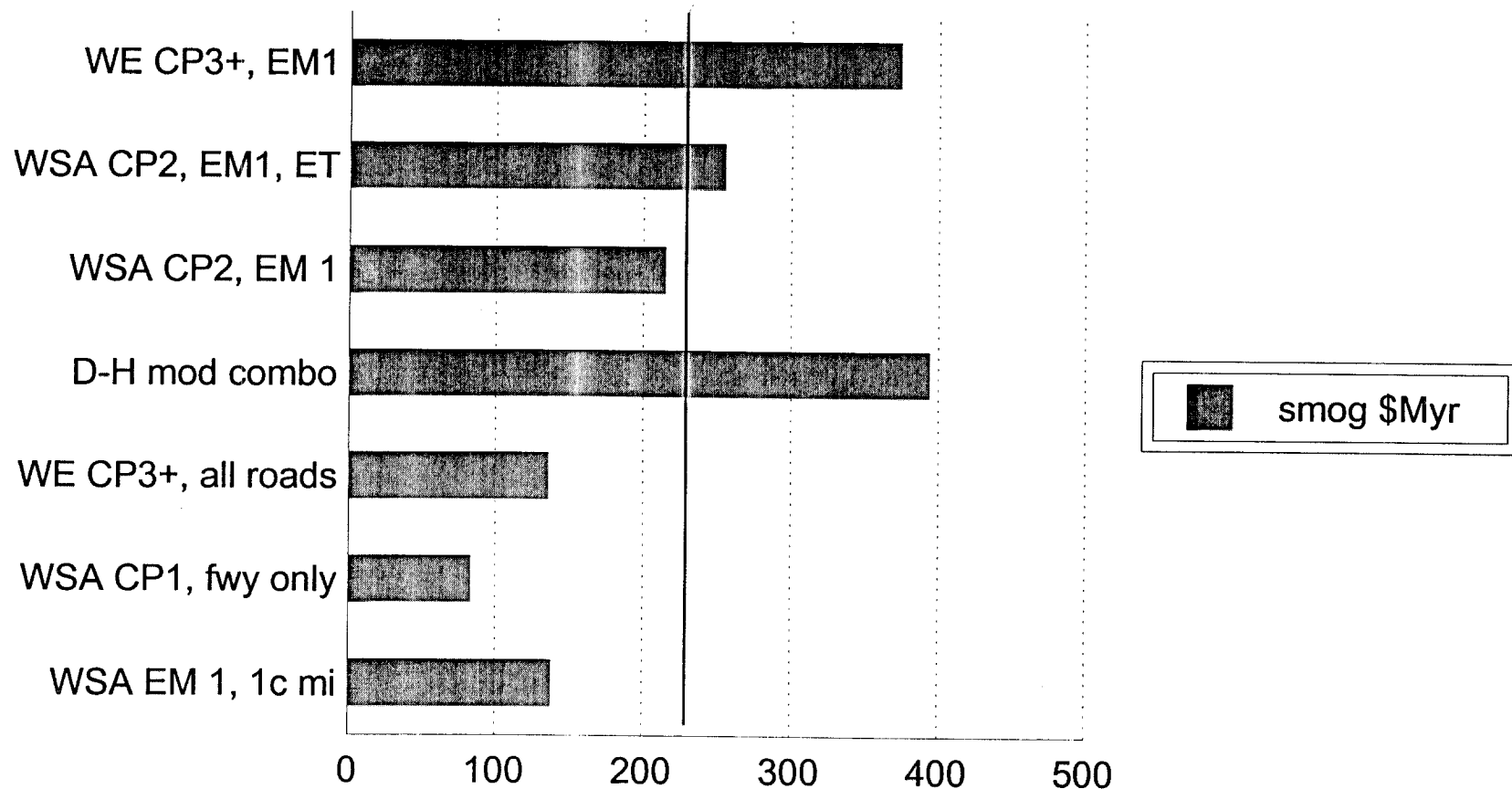
The WSA estimate used for VMT-based charges, including emission charges, is their pay-at-the-pump Computed VMT with a Border Stations estimate added. It could work for VMT charges if the associated technology were developed (it does not exist now), if the default gas tax were doubled, and if people were willing to accept a low-resolution system which could not do congestion charges, cold starts, and other smog benefits, and its systems costs would be lower, about a penny a trip. But put smog benefits aside for a moment. Who would want to forgo a dollar a trip in time benefits to save 3 cents a trip in systems costs? Hybrid systems, such as a combination of electronic toll collection for freeways and pay-at-the-pump for surface streets, would cost more than the most plausible electronic toll collection (ETC) system, four cents a trip, because people would have to pay most of the costs of two separate, and not very complementary systems. Appendix Ten. Unfortunately, WSA's "best" hybrids, C2, EM1, and C2, EM3, ET, have this problem.

9. Revenue estimates are taken from WSA briefing notes, July 24, 1996, p. 15, and from Deakin-Harvey, Table 7.18. Even if systems costs are deducted, as in the column marked "Revs - systems costs" and "Nrev (i.e., Net Revenue) per household per year," net revenues would be very large in every scenario but the Enhanced Transit (ET) combination (WSA C2, EM3, ET), ranging from \$87 per household to over \$2,000 per household. WSA's model cut SCAG's grossly inflated Rail-x enhanced-transit scenario by three-quarters, but its deflated ET, under the most favorable assumptions, was impossibly expensive. Even after raising \$400 in estimated revenues from the average household, and even assuming the money would all be spent on things worth \$400 to the average household, its massive rail-building costs would still leave the same household \$158 poorer. All other alternatives raise millions or billions of dollars that could (though on one can guarantee that they would) be used to offset other costs, such as gas taxes, bus fares, or property or sales taxes. My own favorite strategy, WE C3+, EM1, could pay for all of the average household's 1991-level state and federal gas taxes, vehicle fees, and transit fares, or for half its property or sales taxes. Even WSA's cramped, freeways-only favorite, WSA C2, EM1, could pay half the gas taxes or a quarter of the sales or property taxes and save \$5.3 billion worth of time without getting to surface streets.

For all but the last column, "control 'cost' per ton," I chose to offset systems costs against revenues. They could just as well be offset against gross benefits, and against net benefits if we could calculate them -- but not against both revenues and benefits at once. That would be double-counting. The last column, "control 'cost' per ton," does subtract systems costs from gross benefits and divides the result by tons per year. It does not change the outcome much. Every ton, even under the absurdly expensive Rail-x scenario, produces savings of tens or hundreds of thousands of dollars.

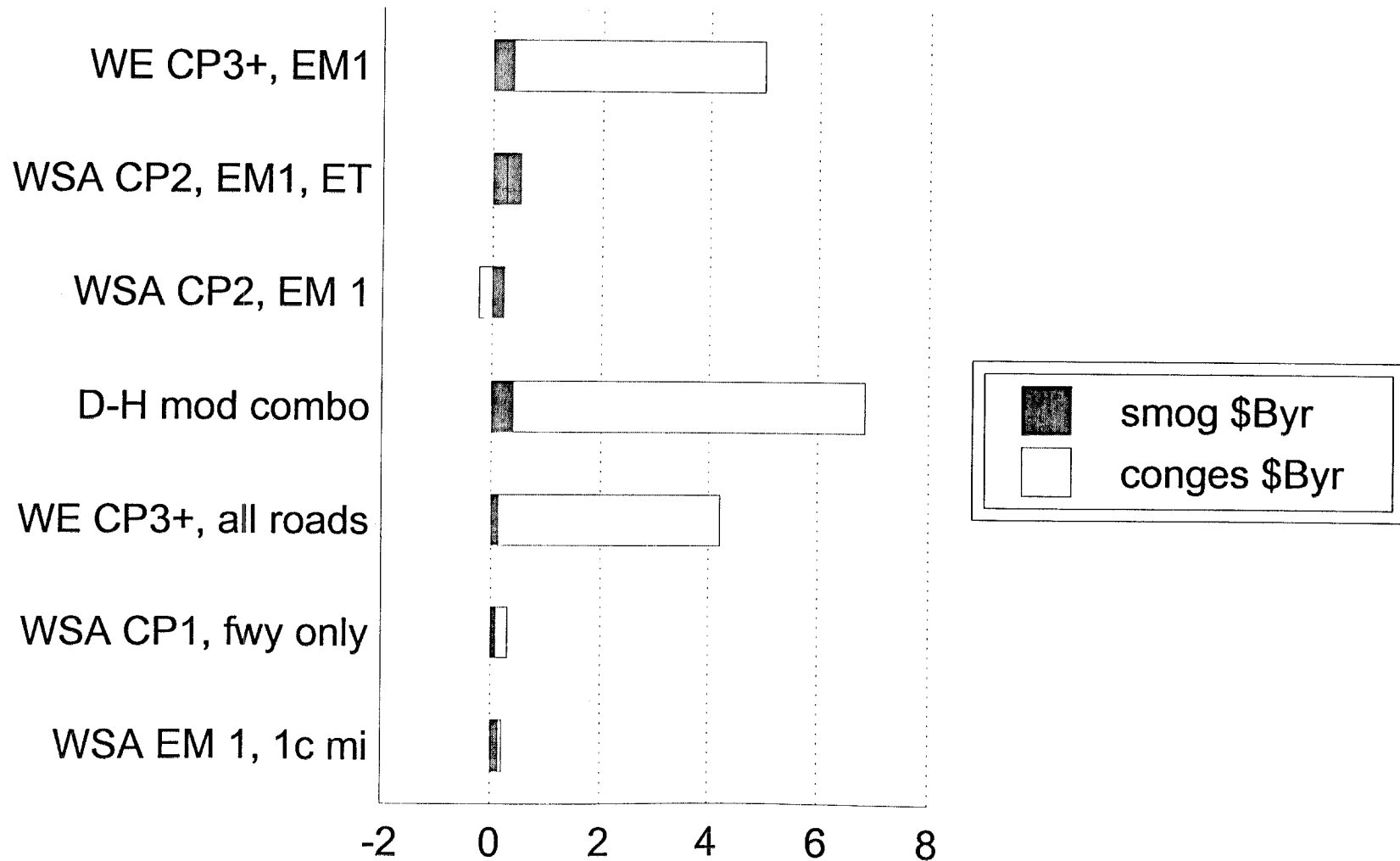
10. Gross benefits are upper-bound because not corrected either for systems costs or for the costs of the additional smog control and mode shifts they produce. But, if the models are right, they constitute a huge pot of potential revenues, ranging from \$114 per household per year, for 1-cent-a-mile emissions charges to over \$2,000 a year for Deakin-Harvey's "High-Impact" combination. Midrange combinations run from \$800 to \$1,100 per household, \$5-7 billion a year in the aggregate. This is not to say that, if an ounce of congestion charges is good, a ton of them would be better. There are upper bounds, both of equity and efficiency, for what the appropriate charges should be for smog and congestion. One-cent-a-mile emission charges amount to about \$17,000 a ton for HC and NOx, maybe less than that if we throw in PM10. If the going upper limit of control cost is \$20,000 a ton for oil companies, it should not be higher than that for ordinary people. The upper bound for congestion charges is whatever it takes to get good traffic flow. 15/30¢ a mile is probably about right wherever congestion, direct or derivative, is a big problem, too much where it is not, and possibly not enough in a few exceptionally congested times and places. If the models are right, almost any of the midrange congestion-charge combinations (except the one with Rail-x) could save upwards of \$5 billion a year in gross delay costs for less than \$400 million in system costs, and without exceeding equitable and prudential limits.

AppendixTwo: Gross Smog Reduction Benefits, 2010, selected strategies



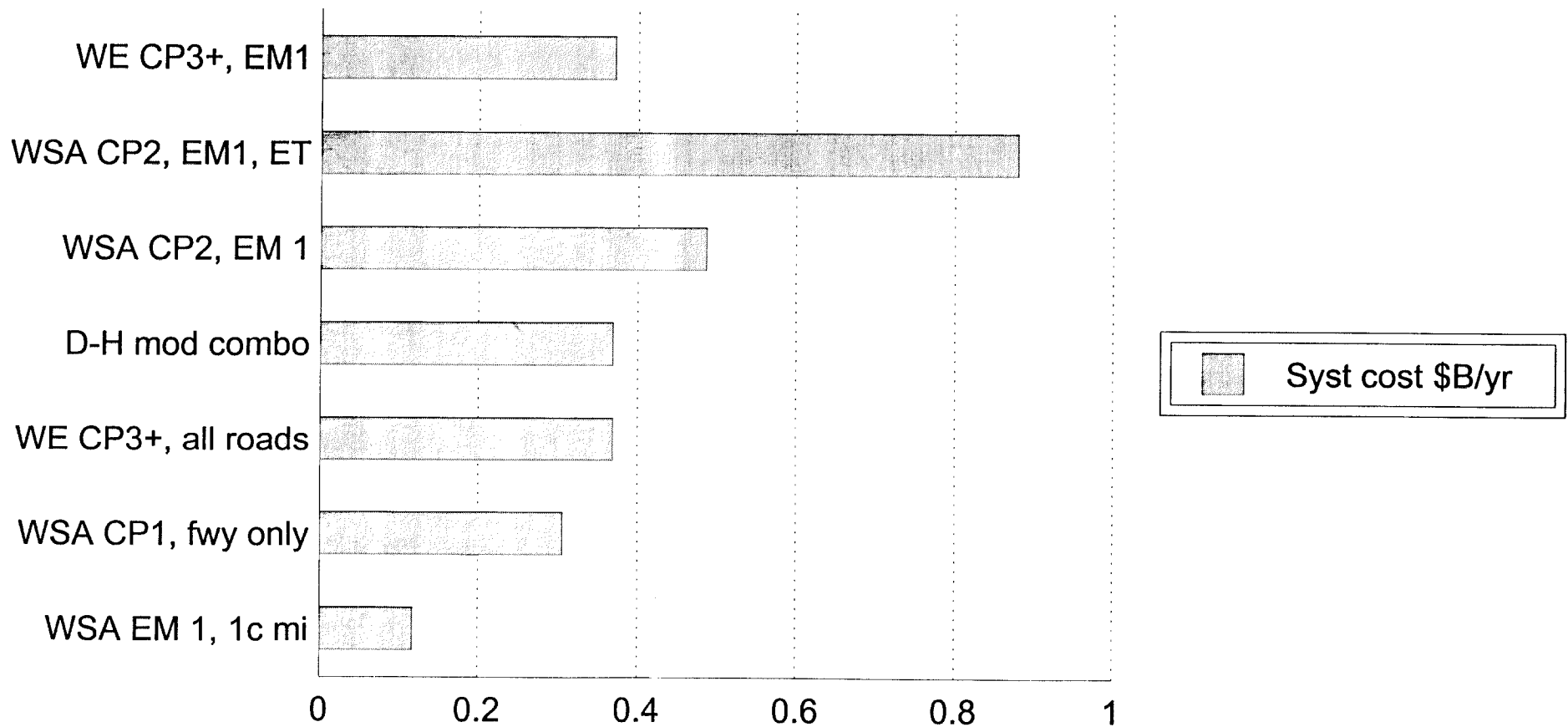
Congestion charges control about as much smog as most-likely 1¢ emissions charges. CC-EC combinations control much more.

Appendix Three: Gross Smog, Congestion Benefits, 2010, selected strategies



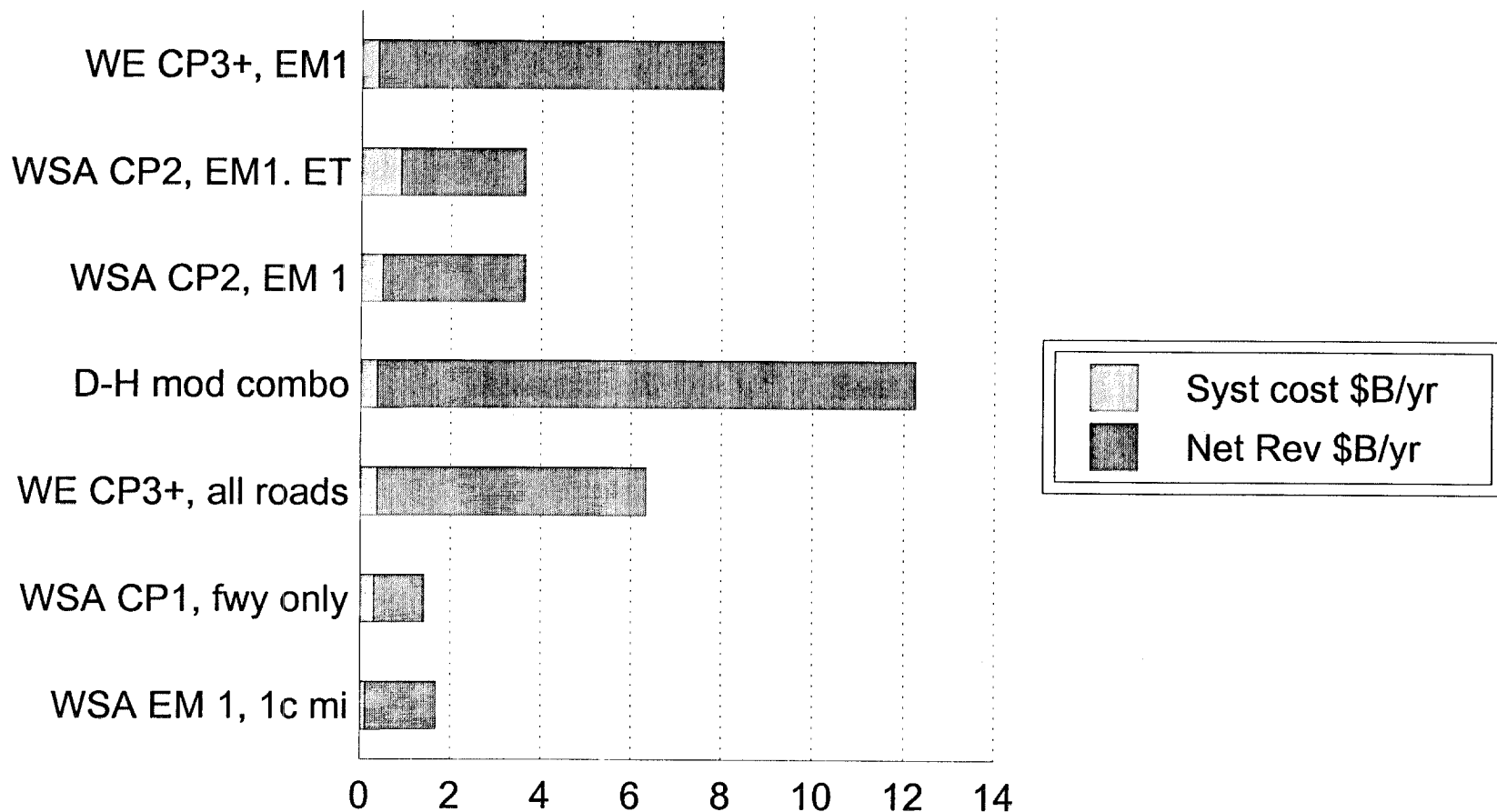
1¢/mi. emission charges control 4x more congestion than smog;
 all-road congestion charges control > 10x more congestion.

Appendix Four: Systems Costs, 2010, selected strategies



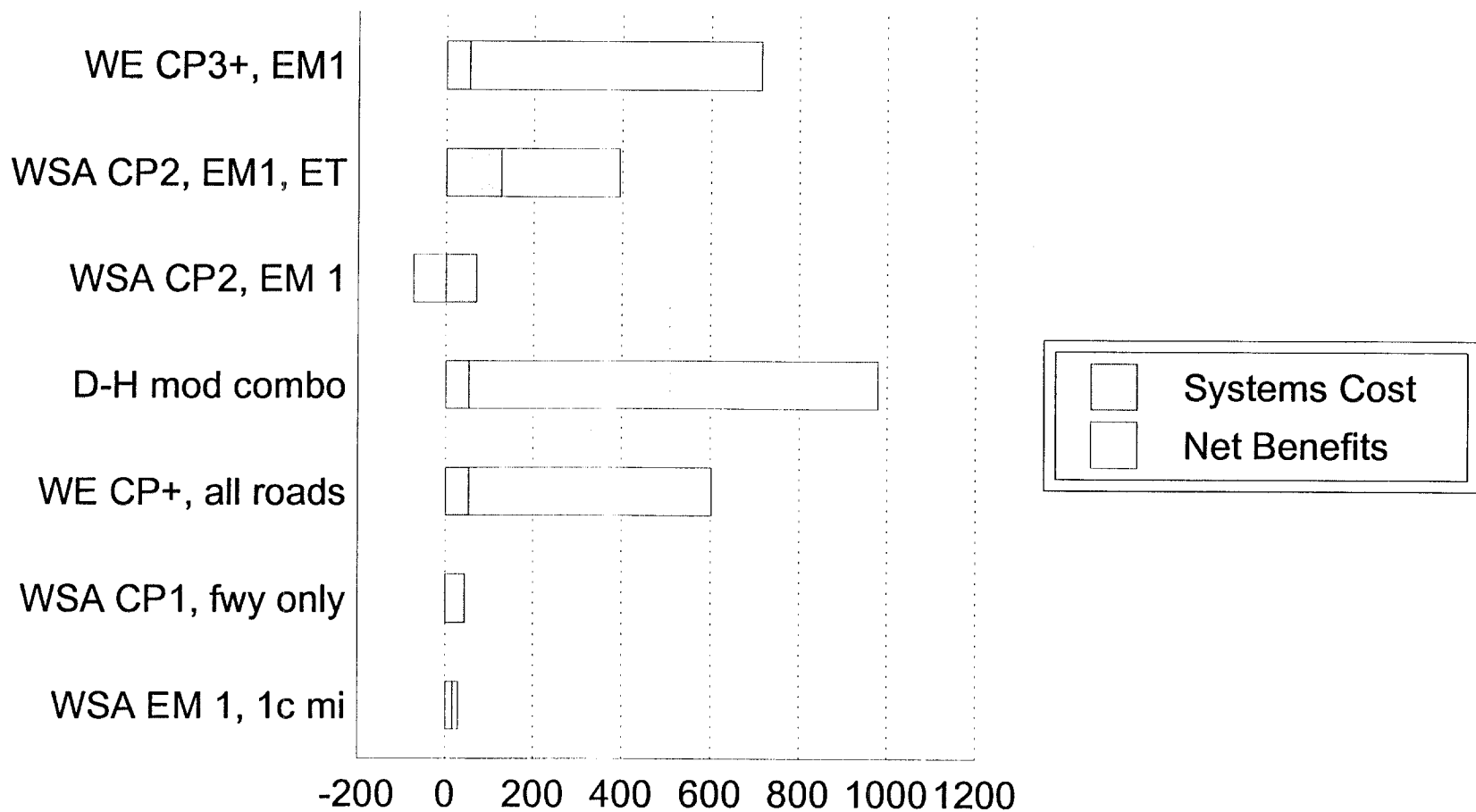
Per household per workday: Pay at pump: 7cents. ETC: 21 cents.
Both, 28 cents. Both, plus enhanced transit, 50 cents

Appendix Five: Revenues Minus Systems Costs, 2010, selected strategies



All all-road strategies generate enough net revenue to cover all current gas taxes, registration fees, and transit fares in Basin.

Appendix Six: Net Benefits and Systems Costs, per household, 2010, selected strategies



in \$ per household per year. Net time savings and health benefits are up to 17x systems costs.

Appendix Seven
Deakin-Harvey Strategy Impact Comparisons
L.A. Basin, 1991

	Strategy	Description	Change from 1991 Mobile Source Baseline							Annual Revenue
			VMT	Trips	Time	Fuel/CO2	ROG	CO	NOx	
1	Regionwide Congestion Pricing (level-of-service D/E) Average of \$0.10 per Mile in Peak	AVI scheme would price regional freeway & arterial system to maintain level-of-service (LOS) D/E	-2.3%	-2.2%	-6.8%	-6.7%	-5.5%	-5.5%	-2.5%	3187
2a	Regionwide Employee Parking Charge of \$1.00 per day	All workers driving alone in region would pay a \$1.00 (1991) per day charge for workplace parking	-1.0%	-1.1%	-1.5%	-1.2%	-1.1%	-1.1%	-1.0%	948
2b	Regionwide Employee Parking Charge of \$3.00 per day	All workers driving alone in region would pay a \$3.00 (1991) per day charge for workplace parking	-2.7%	-3.0%	-4.2%	-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%	-9.1%	-3.8%	-3.7%	-3.5%	2405
3b	Fuel Tax Increase by \$2.00 (1991)		-13.3%	-12.8%	-17.5%	-31.8%	-13.2%	-13.0%	-12.2%	7219
4a	Mileage-and-Emissions-based Registration Fee (Range Appr. 40-400/yr)	Fees would be paid annually at registration based on est. ann. emissions. 4a est based on ave	-2.2%	-1.9%	-2.8%	-4.4%	-7.0%	-6.9%	-6.2%	743
4b	Mileage-and-Emissions-based Registration Fee (Range Appr. 10-1000/yr)	model-year emissions. 4b est. based on actual odometer readings and in-use tailpipe measurements	-1.8%	-1.6%	-2.1%	-7.2%	-19.4%	-19.0%	-17.1%	658
5	VMT Fee of \$0.02/mi	Fees proportional to odometer miles driven, collected at least monthly.	-4.4%	-4.2%	-6.2%	-4.5%	-4.3%	-4.2%	-3.8%	2024
	Example of combined Effects: Moderate Impact	1, 2a, 3a, and 4a, with current level of transit service	-9.1%	-8.6%	-15.1%	-19.4%	-16.0%	-15.9%	-12.4%	6627
	Example of combined Effects: High Impact	1, 2b, 3b, and 4b, with enhanced transit inves. (Rev. not reduced to reflect cost of new transit)	-21.5%	-20.7%	-31.1%	-47.8%	-40.1%	-39.8%	-34.9%	11955

Notes: Revenues in \$millions/yr. Impacts of 4b and 5 may require more frequent payments than annual ones assumed.

Source: CARB, 1995, Table 7.14

**Appendix Eight
Deakin-Harvey Strategy Impact Comparisons
L.A. Basin, 2010**

	Strategy	Description	Change from 2010 Mobile Source Baseline								Annual Revenue
			VMT	Trips	Time	Delay	Fuel/CO2	ROG	CO	NOx	
1	Regionwide Congestion Pricing (level-of-service D/E) Average of \$0.15 per Mile in Peak	AVI scheme would price regional freeway & 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 region would pay a \$1.00 (1991) per day charge for workplace parking	-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 region would pay a \$3.00 (1991) per day charge for workplace parking	-2.5%	-2.8%	-4.2%	-8.5%	-2.7%	-2.6%	-2.7%	-2.6%	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%	-3.6%	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 Registration Fee (Range Appr. 40-400/yr)	Fees would be paid annually at registration based on est. ann. emissions. 4a est based on ave	-2.5%	-2.3%	-3.6%	-6.6%	-3.9%	-5.5%	-5.4%	-4.6%	1106
4b	Mileage-and-Emissions based Registration Fee (Range Appr. 10-1000/yr)	model-year emissions. 4b est. 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/mi	Fees proportional to odometer miles driven, collected at least monthly.	-4.3%	-4.1%	-6.4%	-10.5%	-6.2%	-4.2%	-3.9%		3144
	Example of combined Effects: Moderate Impact	1, 2a, 3a, and 4a, with current level of transit service	-10.3%	-9.7%	18.9%	-43.0%	-21.5%	-17.1%	16.9%	-12.0%	12256
	Example of combined Effects: High Impact	1, 2b, 3b, and 4b, with enhanced transit inves. (Rev. not reduced to reflect cost of new transit)	-22.2%	21.4%	35.7%	-67.4%	-49.5%	41.21%	40.9%	-34.6%	20206

Notes: Revenues in \$millions/yr. VMT = vehicle miles traveled; percentages apply also to PM10 reductions. Trips are weekday vehicle-trips; time is weekday vehicle-hours of travel; delay is weekday vehicle-hours of travel. Fuel is daily gallons of gasoline/diesel; CO2 is daily tons of carbon dioxide; ROG is reactive organic hydrocarbons. CO is carbon monoxide; NOx is oxides of nitrogen.
Source: CARB, 1995, Table 7.18

Appendix Nine

WSA Strategy Impact Comparisons, 2010

Strategy Code & Description	Daily Air Quality Impacts				Mobility Impacts (PM Peak)								
	Daily Emissions				Freeway Congested Segment		Freeway Uncongested Segment		Network Regional Arteries		Modal Split		Trips diverted to non-priced roadways
	Percent Reduction				mph	% chge	mph	% chge	mph	% chge	HOV	Transit	
	TOG%	NOx%	CO%	PM10%									Veh. trip
Baseline	n.a.	n.a.	n.a.	n.a.	34	0	41	0	20	0	20	5	n.a.
2202 Goal	2.2%	0.1%	2.2%	6.1%	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
EM5	36.6%	17.4%	20.5%	8.8%	35	3	42	2	21	5	22	7	n.a.
EM3	25.3%	11.3%	11.4%	5.8%	34	0	41	0	20	0	21	7	n.a.
EM1	8.4%	3.7%	8.3%	2.7%	34	0	41	0	20	0	20	6	n.a.
CP1 EM3	26.6%	12.4%	13.2%	8.2%	43	27	44	7	21	5	24	7	495,800
CP2 EM3	26.0%	12.7%	13.0%	8.8%	45	31	46	12	20	0	25	7	784,400
CP1 EM1	10.0%	4.9%	10.2%	5.2%	42	24	44	7	20	0	23	7	491,976
CP2 EM1	9.3%	5.20%	10.0%	5.8%	44	29	46	12	20	0	24	7	777,875
CP1 EM1.6	15.0%	7.1%	11.1%	6.1%	42	24	44	7	20	0	23	7	492,913
CP2 EM1.2	10.9%	5.9%	10.3%	6.1%	44	29	46	12	20	0	24	7	778,528
CP1EM1/ET	11.2%	6.1%	11.3%	6.6%	43	27	44	7	20	0	23	8	368,757
CP2EM1/ET	10.5%	6.4%	11.2%	7.2%	45	31	46	12	20	0	23	8	583,407
CP1EM3/ET	27.6%	13.5%	14.3%	9.5%	44	29	45	10	21	5	24	8	371,850
CP2EM3/ET	27.0%	13.8%	14.2%	10.1%	46	35	46	12	20	0	24	9	588,300

Notes:

1. Rule 2202 represents a daily-ton reduction of 2% for TOG, 0.1% for NOx, 2.2% for CO, and 6.1% for PM10.
2. EM 1, 3, 5 represent average emission fees of 1, 3, and 5 cents per mile, respectively.
3. CP1: conges. pricing @ 5 cents/mi. uncongested freeways, 10 c./mi. congested freeways. CP2: 10c/20c/mi
4. ET = 'AUG 13' version of SCAG transit network, Smart Shuttles @ 10-min. intervals, effects assumed 1/4 Rail-x.
5. Baseline average PM speed is 34 mph on congested freeways, 41 mph on uncong. fwies, 20 mph all facilities.

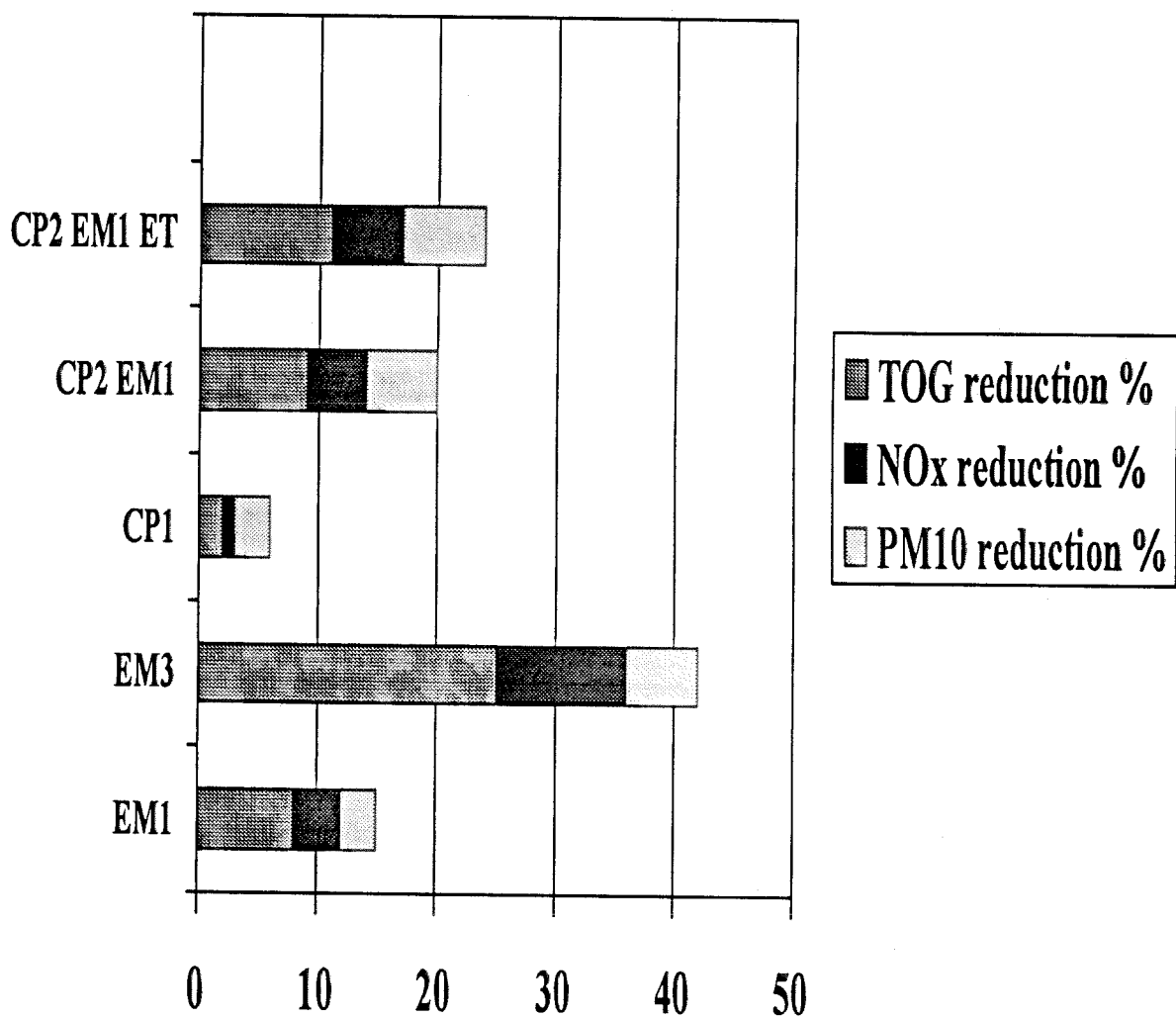
Source: Wilbur Smith Associates, "REACH Transportation Pricing Project," August 28, 1996

Appendix Nine-a
WSA REACH Scenarios Defined

Pricing Scenario	Uncongested Price/Mile	Congested Price/Mile	Emissions Fee/Mile	Enhanced Transit
CP0	0	0	0	NO
CP1	5	10	0	NO
CP2	10	20	0	NO
CP3	15	30	0	NO
CP4	0	10	0	NO
CP5	0	20	0	NO
CP6	0	30	0	NO
EM1	0	0	1	NO
EM3	0	0	3	NO
EM5	0	0	5	NO
C2 EM1	10	20	1	NO
C2 EM3	10	20	3	NO
C2 EM5	10	20	5	NO
CP2 ET	10	20	0	YES
C2 EM1 ET	10	20	1	YES
C2 EM3 ET	10	20	3	YES
C2 EM5 ET	10	20	5	YES

Source: Wilbur Smith Associates REACH TF Scenario List, July 24, 1996

Appendix Nine-b: Estimated Smog Reductions, 2010, selected strategies



Source: WSA/COMSIS estimates, 8/96

Appendix Ten: Systems Costs of Congestion, VMT pricing alternatives compared

	Open Fwy.	Fwy, surface 4x TCP's	Fwy, surface 8x TCP's	Comp VMT w/Border	Hybrid VMT-ETC
CAPITAL COSTS					
Toll Collection Pt	207.3	829.2	1658.4		
Courtesy Station	69.7	69.7	69.7		
Transponders	242.7	242.7	242.7		
Communic. Plant	34.5	40	50		
Central Computer	16	16	16		
Est. cost	570.2	1197.6	2036.8		
Contingency (25%)	142.55	299.4	509.2		
TOTAL CAP. COST	712.75	1497	2546		
OPERATING COSTS					
Ann. Equip. Maint.	12.4	49.6	99.2		
Courtesy Stations	23.4	23.4	23.4		
Admin. Costs	7.2	7.2	7.2		
Enforcement Costs	50	50	50		
Acct. Proc. Costs	60	60	60		
Est. Op. Costs	153.0	190.2	239.8		
Contingency (25%)	38.3	47.6	60.0		
ANN. OP. COSTS	191.3	237.8	299.8		
ANNUAL COSTS					
Amort. Transponder	66.3	66.3	66.3		
Amort. System (9.7%)	48.8	64.8	223.4		
Total amort. cost	115.1	131.1	289.7		
Ann. Op. Cost	191.3	237.8	299.8		
TOTAL ANN. COST	306.4	368.9	589.5	118.0	486.9
Cost per trip (all), cents	2.7	3.3	5.2	1.0	4.3
Cost per chargeable trip	20.7	8.0	12.8	1.0	4.3
Cost per household/\$/yr	44	53	84	17	70

Source: Calculated from WSA Technical Memorandum No. 2Ci, Feb 20, 1996, Tables 1, 6

All figures in \$millions, unless otherwise stated

All trips = 45.1M/workday, 11.275B/work year

Peak trips = 18.5/workday, 4.6B/work year, 41% of all workyear trips

Peak-hour freeway trips = 5.9M/workday, 1.48B/work year, 13% of all workyear trips

"ETC" = Electronic Toll Collection

Toll collection points (TCP): open freeway, 712; 4x for surface streets, 2848; 8x, 5696

"w/Border" adds \$27.3M to WSA's "Computed VMT" cost estimate for Basin border pricing points.

Appendix Eleven

WSA Preliminary Net Revenue Potential Estimates

Scenario	Rate/mile	Average Toll/Trip	Preliminary		
			Annual Revenue Estimates \$ Millions	Annualized Operating Costs \$ Millions	Annual Net Revenue \$ Millions
CP1	5/10	\$1.26	\$1,419	\$306	\$1,113
CP2	10/20	\$2.17	\$2,112	\$306	\$1,806
CP3	15/30	\$2.93	\$2,537	\$306	\$2,231
VMT1	1	\$0.10	\$1,688	91	\$1,587
VMT3	3	\$0.20	\$4,930	91	\$4,839
VMT5	5	\$0.50	\$7,958	91	\$7,867
C2/V1	10/20 +1	\$2.27	\$3,640	397	\$3,243
C2/V3	10/20 +3	\$2.47	\$6,767	397	\$6,370
C2/V5	10/20 +5	\$2.67	\$9,792	397	\$9,395
C2/Rail-x	10/20 + ET	\$2.17	\$1,878	306	\$1,572

Source: Wilbur Smith Associates "Preliminary Net Revenue Potential," 1996

Appendix Twelve: Avge AM SOV trips, SCAG area, 2010, diff. pricing scenarios

	Distance (miles)	Time (min)	Speed (mph)	min/mi	trips (mill)	VMT (mil mi)
Baseline						
Crowded fwy	4	6.5	37	1.62		
Uncrowded fwy	3	3.4	53	1.13		
Total fwy	7	9.9	43	1.41	2.2	46
Surface streets	5	14.1	21	2.82	4.6	40
Total	12	24	30	2	6.8	86

Option AM -10/20 fwy: pricing freeways only, no pricing or equiv. surface streets

Crowded fwy	4	5.2	47	1.28		
Uncrowded fwy	3	3.2	57	1.05		
Total fwy	7	8.4	50	1.2	1.4	34
Surface streets	5	15.6	19	3.12	5.2	42
Total	12	24	30	2	6.6	76

Trip reduction 2.9%

Option AM - 10/20 full: pricing or equiv. all roads, incl. surface streets

Crowded fwy	4					
Uncrowded fwy	3					
Total fwy	7				1.8	
Surface streets	5				3.8	
Total	12				5.6	

Trip reduction 16.8%

Option AM - 15/30 fwy: pricing freeways only, no pricing or equiv. surface streets

Crowded fwy	4	4.6	52	1.15		
Uncrowded fwy	3	3.1	59	1.02		
Total fwy	7	7.7	55	1.1	1.1	
Surface streets	5	18	17	3.6	5.4	
Total	12	25.7	28	2.14	6.5	

Trip reduction 4.4%

Option AM - 15/30 full: pricing or equiv. all roads, incl. surface streets

Crowded fwy	4					
Uncrowded fwy	3					
Total fwy	7				1.7	
Surface streets	5				3.6	
Total	12				5.3	

Trip reduction 22.1%

Appendix Twelve-a

Average PM SOV Commutes, SCAG area, 2010, under different pricing scenarios

	Distance (miles)	Time (min)	Speed (mph)	min/mi	trips (mill)	VMT (mil mi)
Baseline						
Crowded fwy	4	7	34	1.76	2.2	
Uncrowded fwy	3	4	42	1.43	1.5	
Total fwy	7	11	38	1.57	3.7	91
Surface streets	5	25	12	5	8	69
Total	12	36	20	3	11.7	160

Option PM - 10/20 fwy: pricing freeways only, no pricing surface streets

Crowded fwy	4	5.6	43	1.4		
Uncrowded fwy	3	4	45	1.33		
Total fwy	7	9.6	44	1.37	2.5	58
Surface streets	5	26.4	11.4	5.28	8.8	72
Total	12	36	20	3	11.3	143
Trip reduction					3.4%	

Option PM - 10/20 full: pricing or equiv. all roads, incl. surface streets

Crowded fwy	4					
Uncrowded fwy	3					
Total fwy	7				3.2	
Surface streets	5				6.8	
Total	12				10	
Trip reduction					14.5%	

Option PM - 15/30 full: pricing or equiv. all roads, incl. surface streets

Crowded fwy	4					
Uncrowded fwy	3					
Total fwy	7				3	
Surface streets	5				6.5	
Total	12				9.5	
Trip reduction					18.8%	

All peak traffic (AM & PM)

	Distance (miles)	Time (min)	Speed (mph)	min/mi	trips (mill)	VMT (mil mi)
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Baseline

Crowded fwy						
Uncrowded fwy						
Total fwy					5.9	137
Surface streets					12.6	109
Total					18.5	246

Appendix Thirteen

Pricing Surface Streets

Ward Elliott -- August 9, 1996

The REACH Task force after a lot of winnowing, has settled on three economic-incentive (EI) strategies as most promising for reducing smog and congestion in the South Coast Basin: emissions charges, congestion charges, and VMT charges. No decision has been made as to which of these, and in what combination, would make the best comprehensive, long-run strategies for the Basin, but, if a choice were made today based on WSA's and COMSIS's model runs and estimates, it probably would be a hybrid of CP2, 10/20¢ per peak mile charges for freeways only, and EM1 or 2, highly differentiated emissions charges averaging one or two cents a mile for all roads. If either EM1 or 2 is chosen, EM1, whose one cent a mile charge amounts to about \$17,500 per ton of ROG and NO_x, seems a more likely choice than EM2, which would exceed the South Coast AQMD's de facto cost cutoff level of \$25,000 per ton.

Congestion-charge advocates say that if the models are correct, and freeways are congestion-charged, surface streets should be charged also; otherwise a lot of traffic would simply be diverted from fast, priced freeways to slow, unpriced surface streets, with no net gain in average system speed. WSA and SCAG critics argue that pricing surface streets here is politically and administratively unfeasible. No one knows how many pricing points it would require; SCAG has no jurisdiction over surface streets; and there is no constituency pushing it. And trips on surface streets are often short ones, on secondary streets, which would be little affected by pricing.

Advocates believe that only the last of these points has much merit, and that secondary streets, which carry 7% of total VMT, should not normally be charged. Whether primary streets, with a quarter of all VMT, should be charged, is a function of how crowded they are, how long the trips are, and how much good the charges would do. At today's traffic levels, congestion charges might make sense for some arterials and collectors (10% and 8% of all 1990 VMT), but not for most primary streets. At the model-predicted congestion levels, pricing primary streets also might make sense.

As for administrative and political feasibility, congestion charge advocates note that surface streets have been successfully charged for 20 years in Singapore with a simple, low-tech sticker system, with no administrative problems, and that even saturating surface streets with 5,600 electronic pricing points, if necessary, would be far from unfeasible. It would raise the cost per trip from 3¢ to 5¢. The cost per chargeable trip would actually be lowered from the freeway-only level, from 21¢ to 13¢, because more trips would be chargeable (Appendix Ten). If all streets are as crowded as the models say they will be, and if the public accepts charges on freeways

to get them moving, it is hard to imagine the public not also accepting, and even demanding charges on some or all surface streets. It would clear the streets, clear the air, and cost them essentially nothing, since the proceeds could in principle be used to pay a quarter to a half of their property or sales taxes.

One further note on political feasibility. In one sense the apparent cost would be less than nothing for any given city's inhabitants, who would be substituting a revenue system paid for in part by outsiders passing through for one like property taxes, which are paid for entirely by themselves. Other cities would no doubt have the same realization and adopt the same policies, if they could. On-average, this would probably cancel out the revenue advantages of the first city. What it would not cancel out is the strong incentive, once a revenue-shifting-to-outsiders option is available, for every city to try to use it to its advantage. Will the real problem be coaxing cities into pricing their streets, or keeping the process from getting out of hand?

The key question is not whether people, having embraced congestion pricing for crowded freeways, would reject them for crowded surface streets. This is not an insuperable problem. The real questions are whether they will want congestion pricing for freeways in the first place, and, behind that, whether congestion will be as bad and as soon as the models predict. If the models are right, and congestion becomes insufferable, it is hard to imagine people not wanting something that would clear both the air and the roads, and wanting it wherever they are stalled, not just on freeways.

Appendix Fourteen Costs of Mobile-Source Pollutants

By the latest available midrange estimates, smog costs in the South Coast Basin could be as low as \$6,000-15,000 per average ton of major pollutant (that is, VOC, NO_x, SO_x, and PM₁₀) over the California health standards, and as high as \$50,000 per average ton over old standard -- not counting PM₁₀, which is commonly considered the most costly pollutant!

At the low end would be the South Coast Air Quality Management District's latest estimate, in the 1997 Draft Air Quality Management Plan, that meeting California health standards by 2010 would produce approximately \$4.5 billion in annual health benefits (South Coast AQMD, 1996a, p. 3-13, as revised by AQMB resolution, October, 1996), divided by what looks like about 300,000 t/y of major pollutant reductions required to meet state standards in a midrange year 2006 (South Coast AQMD, 1996a, Table 5-5, p. 5-22; see Hall, 1996. This would amount to about \$15,000 per ton. However, the benefits of meeting federal health standards would supposedly only save \$1.8 to \$1.9 billion, amounting only to about \$6,000 per ton for a slightly smaller tonnage for 2006.

At the high end would be the latest EPA midrange draft estimate for nationwide over-old-standard smog costs, if applied to the South Coast Basin proportionally to its share of the national population and multiplied by, say, three, to allow for the much greater-than-average severity of pollution in the Basin. USEPA, 1996, Tables 1 and 3, pp. xvii and xxi, gives a list of "compliance benefits" (i.e., what controlled emissions would have cost had they not been controlled) for 1990 and a list of the estimated dollar value of each benefit. If one takes the overall midrange estimated benefits of \$20 trillion over 20 years and, very conservatively, divides it equally among the 20 years, it implies 1990 nationwide benefits of a trillion dollars for about a 40% reduction in nationwide VOC, NO_x and SO_x from existing federal pollution controls. If, even more conservatively, one only multiplies each of the estimated 1990 benefits by their estimated values and sums them up, it still amounts to about \$400 Billion in 1990 (EPA figures in this case do not include PM₁₀).

The South Coast Basin population is 5% of national population and would enjoy 5% of the compliance benefits, or \$20 billion, if its pollution benefits were average. But its pollution levels, in fact, are three or four or more times worse than the national average, and its cleanup benefits therefore, let us suppose, at least three times higher, or \$60 billion. If we further suppose, conservatively, that actual pollution reduction in the Basin from federal laws has been closer to 50% than to 40%, it would mean that the

cleaned-up 1990 tonnage would about equal the emitted 1990 tonnage of 3,287 t/d, 1.2 million t/y of VOC, NO_x and SO_x (1997 AQMP, Table 3-1A, p. 3-8) and would have cost about \$50,000 per ton (\$60 billion ÷ 1.2 million t/y), had it not been cleaned up. One should bear in mind that these are taken from midrange estimates; that they don't count PM₁₀, which by most estimates is at least twice as costly per ton as the pollutants measured in the EPA study; and that no allowance is made for additional costs implied by the new, tougher federal EPA standards and their supporting health studies. Allowance for these factors could more than double the high-end cost estimate.

Since neither of these studies was available till after the REACH Task Force's Strategy Committee discussed full-cost estimates of various pollution- and congestion-control strategies, the Committee used a much simpler, more direct approach. Given the huge apparent divergence between current AQMD and EPA estimates, and the difficulties of trying to make them commensurate, the Committee's approach still seems the most practical starting point.

For many years the "going rate" for imputed smog costs of the major pollutants in the South Coast Basin, as measured by the highest per-ton costs in a long series of South Coast Air Quality Management Plans, has been between \$10,000 and \$20,000 per ton. This range seemed in line with then-available scientific evidence (Elliott, 1978, 1985). Jane Hall's landmark 1989 estimate, the foundation of the 1992 and 1994 South Coast Air Quality Management Plans (AQMP's), in effect put the costs of over-standard South Coast smog, in death and disease, at 9.4 to 14 billion dollars a year. (Hall, 1989, pp. 7-35 and 7-36).

The Hall estimates have been interpreted to assign higher costs per ton to PM₁₀ and lower to ozone precursors, VOC and NO_x, than the \$9-20,000 per ton range used by the REACH Strategy Committee, since almost 3/4 of her estimated costs were from particulates (PM₁₀), and only a quarter from ozone. But Hall herself cautioned that her estimates counted only a fraction of ozone health costs, "probably less than half," and they did not count property damage. The South Coast AQMD has continued to use regulatory cost cutoffs between \$10,000 and \$20,000 per ton for all three pollutants in all subsequent plans, including the current draft 1997 AQMP. As we shall see below, by several different reckonings, current estimates since the Hall study would support putting PM₁₀ costs closer to the high \$20,000 end of the spectrum -- and maybe much higher -- and VOC and NO_x costs closer to the low \$10,000 end.

Based on cutoffs in the 1994 AQMP, the REACH Task Force used estimated costs per ton of \$9,000 for VOC, \$10,000 for NO_x, and \$21,000 for PM₁₀; all seem justifiable by present and past regulatory practice and by present and past social-science

evidence. The traditional Hall estimates of \$9.4 and \$14 billion a year, which she believed seriously understated the costs of ozone precursors, implied per-household smog costs of about \$1,800 and \$2,600, respectively. If major pollutants really do cost \$9-21,000 per ton, the total costs of VOC, NO_x, and PM₁₀ in the Basin, under the latest estimated 1993 baseline inventory, would be \$13.4 billion for that year, close to Hall's high estimate of \$14 billion a year. Calculated from South Coast Draft 1997 AQMP, Table 3-3A, p. 3-10. Per-household costs would be about \$2,400 per year.

What share of mobile-source pollution's costs come from ozone and its precursors? Despite the high, well-documented costs of PM₁₀, by several different measures, VOC and NO_x still seem to be responsible for at least four-fifths of mobile-source smog costs, PM₁₀ for the rest, with estimates ranging from 76% to 98% (Table 1-1). Stated differently, if all three major pollutants had about the same costs per ton, and if official inventory estimates were accurate, ozone precursors would be responsible for three-quarters of mobile-source smog damage under the 1991 Harvey/Cameron mobile-source inventory and 98% under the South Coast AQMD's current estimated baseline inventory for 1993 (see South Coast Draft AQMP, 1997. Table 3-3A, p. 3-10, and Table 1-1, below).

How much do the actual costs per ton of different pollutants differ from each other? No one knows, because there is no real market for all the pollutants. Regulators and analysts have been obliged to infer smog costs from various pieces of less-than-conclusive evidence. One way of doing this is to consider the control costs per ton, or per part per million, that regulators have actually been willing to impose. A second is "hedonic," reckoned by how much more people are willing to pay for low-smog property than for high-smog property. A third is to try to measure the costs directly.

If smog costs were imputed from imposed control costs in the South Coast Basin, VOC, NO_x, and SO_x would be in roughly the same range of cost per ton since the South Coast AQMD, following state and national mandates, has long treated them - - and still treats them -- with more or less the same degree of control stringency. CO would be an order of magnitude lower in cost. The most expensive controls in the 1982 South Coast AQMP were \$9,500 per ton of VOC; \$17,500 per ton of NO_x; \$15,700 per ton of SO_x; \$3,850 per ton of particulates; and only \$620 per ton of CO. The most expensive controls listed in the 1994 AQMP summary are \$30,000 per ton of VOC; \$11,300 per ton of NO_x; \$3,500 per ton of SO_x; and \$4,100 or \$12,300 per ton of PM₁₀. 1994 South Coast AQMP, Table 6-5. The 1997 Draft AQMP does not say much about PM₁₀ but does propose controls costing as much as \$12,000 per ton for VOC and \$9,000 per ton for NO_x. Table 6-6, p. 6-22. These priorities are consistent

with economic studies in the 1970's and 1980's, both hedonic and direct, which also implied a cost range of \$8-20,000 per ton of major pollutant in the South Coast Basin. See summary, Elliott, 1985, p. 53. If one were to adjust this old range for inflation and population growth since 1982 (both have increased by about a quarter), it would be about \$10-30,000 per ton today.

Jane Hall (1989, p. 6-34) introduced evidence that PM10 causes more than 2,700 premature deaths a year in the Basin. [1996 estimates by the Natural Resources Defense Fund are more than twice that high, 6,000 deaths a year. Los Angeles *Times*, May 9, 1996, p. A1.] For Hall, the high mortality implied overall costs of \$6-10 billion per year (pp. 7-35, 7-36), and, hence, costs per ton on the order of \$20,000, if one counted every ton in the inventory, but \$80,000 to \$100,000 if one counted only those tons exceeding the safe carrying capacity of the Basin. She also calculated morbidity costs for ozone, of \$2.5 billion for the Basin, but warned that this was only a partial estimate of ozone costs, "probably less than half" (p. E-4), since it did not count long-term ozone health effects, nor damage to crops or property (p. E-13).

Some subsequent analyses conclude that all the Hall estimates are too high (Krupnick and Portney, 1991, p. 525 (South Coast PM10 mortality costs only \$2 billion, ozone short-term morbidity costs only \$.3 billion)). Some give a range of possibilities which seems wide enough to encompass both the highest and the lowest of estimates. Delucchi, et al., 1987 (nationwide health costs between \$4 billion and \$85 billion for all auto exhaust pollutants; see summary of studies, Cannon, 1990). As we have seen, current South Coast AQMD and EPA estimates diverge widely, with the South Coast's estimate seemingly a bit higher than Krupnick and Portney, and the EPA much higher than Delucchi's high-end estimate. The two most detailed and impressive analyses, Small and Kazimi, 1995, and Cameron [and Harvey], 1994, have taken all the Hall cost estimates, high for PM10 and low for ozone precursors, very seriously. Small and Kazimi, for example, give a baseline estimate of \$102,000 per ton over carrying capacity for PM10 costs, but only \$10,670 per ton for NOx and \$2,920 per ton for VOC (1995, p. 22). Cameron and Harvey use figures which seem to imply a cost of about \$87,000 per ton of PM10 over carrying capacity, but only \$3,256 per ton of ozone precursors (calculated from Cameron, 1994, p. I-18, Table I-8).

Both of these estimates are true, in a sense, but not one that, by itself, produces an accurate division of mobile-source pollutant costs between PM10 and ozone precursors. They scrupulously follow Hall's calculations, which were of not the costs of all the pollutants, but only that portion of them which is over the Basin's safe carrying capacity -- that is, 85 percent of VOC, 70 percent of NOx, but only 20 percent of all PM10. If you equate "benefits of reducing the pollution" with "costs imposed by

the pollution," as most tend to do, this does not greatly distort the costs of NO_x and VOC, three-quarters of which are over carrying capacity, but it does distort the cost of PM₁₀, only 20 percent of which is over carrying capacity. Both Cameron/Hall and Small/Kazimi pack all the PM₁₀ cost into the last 20 percent, and then pack it again into the mobile-source sector, which accounts for only 37 percent of the 1991 PM₁₀ inventory. As best we can tell from Jane Hall's evidence, it is probably true that the last 20 percent of PM₁₀ costs us the 2,700 lives a year. But it is not clear in the real world *which* of the 1,075 tons of PM₁₀ are "over-carrying-capacity" and produce \$100,000 worth of health damage per ton, and which are "under capacity" and whose cost per ton is treated for analytical purposes as if it were zero. Nor is it clear that all of the benefits of cleaning up the over-capacity tons should be allocated to mobile sources, since we don't know whether the same benefits might be achieved more cheaply or effectively by stationary-source controls. A less packed, more realistic allocation, for purposes of appropriately dividing mobile-source costs between different pollutants, would be to spread at least the costs of PM₁₀ over all the daily 1,075 tons, not just the 220 tons per day over carrying capacity. For the 1991 inventory, this would imply PM₁₀ costs of \$17,840 per average ton.

Has the evidence of ozone's social costs actually changed for the worse since the mid-1980's? Or has a partial change for the better turned out to have raised the standard for acceptable, "substantiable" evidence? One wonders whether Hall's impressive quantification of ozone morbidity costs, in defiance of Gresham's law, and despite her warnings, might not have driven out the softer, but all-too-plausible evidence that preceded it, that ozone rots rubber, peels paint, and destroys lung function. She didn't assign a dollar cost to these, but it hardly follows that their cost is therefore zero. Whether or not the actual evidence of ozone's high social costs has deteriorated since the 1980's, there has been what looks like a shift in the burden of proof. Smog scholars used to resolve uncertainties in favor of protecting health; now they are just as likely to resolve them in favor of keeping control costs down. This seems much more a shift of attitudes than an actual downward change in the costs of ozone. With billions of dollars of smog costs and control costs at stake, it makes all the sense in the world to push for better numbers. But it makes less sense to restructure control priorities every time there is a shift in the scholarly wind -- unless the shift represents genuinely better evidence. The new scholarship on PM₁₀ does seem strong enough to justify at least a shift from the low end of the traditional \$10-20,000-a-ton range, to the high end, and perhaps well beyond it. The new scholarship on ozone precursors is not strong enough to justify a comparable downward shift.

Two final notes: Small and Kazimi, who give us the latest and most fully documented revisionist estimates of the relative costs of VOC and PM₁₀, are not