

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	Nrev /hslid \$/yr	Gr.bft /hslid \$/yr	Tot. Tons Contr	Contr "cost" \$000/t
Hi-res Emission Ch.															
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 Ch.															
D-H 2c/mi	4	4	4	6.4	136	2176	2312	118	3144		3026	432	330	9350	-235
Congestion Ch.															
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 /day	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															
* = 15c/pk/mi CC; moderate EC, fuel, and parking charges, no enhanced transit															
** = 15c/pk. mi CC; stiff EC, fuel, and parking charges, much-enhanced transit															
**+ = 5/10c/pk mi Congestion Charge (CC), fwy only, 1.6c/avge mi. Emission Charge (EC)															
*** = 10/20c/pk mi CC, fwy only; 1c EC															

Notes on Appendix One to Greenbacks Uber 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. 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 NOx 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 NOx, 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 t/d x 250 days = 66,250 t/yr x \$9,000 = \$596.2M ann. costs.
NOx: 261 t/d x 250 days = 65,250 t/yr x \$10,000 = \$653M ann. costs.
PM10: 409 t/d x 250 days = 102,250 t/yr x \$21,000 = \$2,147M ann. costs.

Smog costs, 1991 (from Cameron, 1994)

HC: 605 t/d x 250 days = 151,250 t/yr x \$9,000 = \$1,362M ann. costs.
NOx: 664 t/d x 250 days = 166,000 t/yr x \$10,000 = \$1,660M ann. costs.
PM10: 397 t/d x 250 days = 99,250 t/yr x \$21,000 = \$2,084M 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.