Electronic Road Pricing in Southern California: Policy Obstacles to Congestion Pricing

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ELECTRONIC ROAD PRICING IN SOUTHERN CALIFORNIA: POLICY OBSTACLES TO CONGESTION PRICING

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ABSTRACT

Policy issues obstruct use of advanced traffic management technology in Southern California. Reliable equipment for electronic road pricing (ERP) is available that could establish a regionwide network of high occupancy vehicle (HOV) facilities where single occupant users (SOV) buy access. Private toll roads plan to use automatic vehicle identification (AVI), automatic toll collection (ATC), and changeable message signs to guide traffic into high-occupancy, buy-in lanes. Public agencies oppose expansion of this technology to the regional HOV network. Some hypothesize that the high-occupancy, toll (HOT) lanes would not promote ridesharing and related air quality objectives. This paper tests this hypothesis by applying a multinomial logit model to potential travel in one freeway corridor where private, buy-in lanes are under construction. The hypothesis is not supported; free HOV lanes can be converted to HOT lanes using advanced technology to achieve an increase in average vehicle occupancy (AVO). The effect on congestion is uncertain.

INTRODUCTION

Economists and policy analysts recommend that charging for roads provides the only efficient solution to highway congestion in urban areas. But this view is not widely shared, either by the public who resent being charged for a service that they believe they have already paid for, or by public officials and involved citizens who prefer solutions that mandate ridesharing, expand transit, or build additional highways. We propose a solution to this dilemma by showing how a network of High Occupancy Vehicle (HOV) lanes could be converted to High Occupancy Toll (HOT) lanes in congested urban areas.

Advanced technologies in traffic management are required for the conversion. Automatic vehicle identification (AVI) and electronic road pricing (ERP) allow very high, traffic volumes to use HOT lanes without delay. More importantly, they allow tolls to be varied according to the demand. By varying price with congestion (Congestion Pricing: CP), travelers are encouraged to rideshare or during less congested (lower priced) periods, with the result that more vehicles and travelers can be accommodated. Public agencies are skeptical; some have opposed HOT lanes, because they hypothesize that HOT lanes would discourage ridesharing by reducing the travel time for SOVs who could afford to buy access.

The paper concludes with a test of this hypothesis in Southern California. On the Riverside Freeway (State Route 91), four toll lanes are under construction instead of HOV lanes. The toll lanes, located in the median of an eight-lane freeway, will provide travelers with the choice of conventional freeway lanes or the less congested, toll lanes. The techniques of AVI, ERP, and CP will all be employed to manage traffic and maximize revenue received from users of the toll lanes. To introduce the analytical section, we first describe urban congestion and how ridesharing and CP can reduce congestion. Skepticism about the utility of CP is discussed to emphasize the relevance of the final section where we simulate travel in the study corridor. If advanced technologies are to succeed, their benefits for traffic management must be explained.

URBAN CONGESTION

Highway construction in the 39 largest U.S. urbanized areas has not kept pace with increasing travel. During the 1980s the number of vehicle miles driven increased by 31 percent, while lane miles of expressway and arterial streets increased by only 14 percent (Downs, 1992). Although recent increases in gasoline and sales taxes have raised expenditure on roads to the level of the 1960s, there is still not sufficient revenue for both new construction and maintenance of the existing system.

Southern California is the most severely afflicted area. Hanks and Lomax (1990) constructed an index of congestion by comparing daily vehicle miles traveled per lane mile to optimal capacity. By their index, the Los Angeles Urbanized Area, which includes Orange County, is the most congested metropolitan area in the nation while the adjoining San Bernardino-Riverside and San Diego urbanized areas are almost as congested as Chicago. A superb highway network has been constructed in Southern California, but it is fouled by heavy travel demand. Hanks and Lomax estimated that travel delays cost Los Angeles and Orange county residents and business $6.8 billion in 1988. The loss to individuals is annoying, but the loss to business relying on truck freight is more serious because it impairs productivity growth.

Building a way out of traffic congestion, although popular with highway advocates, is not practical in California. Investment has been neglected for too long, because increasing gasoline taxes is unpopular. Between 1967 and 1982, for example, there was no increase in the fuel tax although annual vehicle miles of travel almost doubled. Recent increases in fuel and sales taxes have financed reconstruction and widening of older facilities, but have been inadequate to cope with demand. Only management solutions can solve the dilemma.

RIDESHARING

Ridesharing has been the most effective management solution. Although ridesharing embraces public transit as well as van and carpooling, we focus on the latter because it leads to the test of our hypothesis about average vehicle occupancy (AVO) in one highway corridor using advanced traffic management techniques. Ridesharing in this limited connotation includes construction of HOV facilities and encouragement of ridesharing through sponsorship of trip matching as well as policies that require firms and public agencies to achieve higher levels of AVO.

Expanding HOV facilities provides an incentive for ridesharing as it allows long-distance, freeway commuters to save time through congested "bottle necks." Once they recovered from the disastrous experience on the Santa Monica Freeway, the California Department of Transportation (Caltrans) has aggressively expanded HOV facilities. With more than 200 lane miles of HOV available and another 400 committed, Southern California has the largest HOV system in the United States. Recent expansion in Los Angeles and Orange counties is impressive. In 1993, 12.7 percent of the freeway miles had HOV lanes, and proposed projects will increase availability to 28.7 percent.

Regional agencies have adopted policies that encourage ridesharing. The Southern California Association of Governments (SCAG), the metropolitan planning agency, requires all new highway projects be designed to achieve an AVO of 1.5 by 1999 as a condition for their inclusion in the regional Transportation Improvement Program. As the current AVO is below 1.2, inclusion of HOV lanes is the only practical design alternative. And the South Coast Air Quality Management District (SCAQMD) has adopted Regulation XV requiring employers with more than 100 employees to develop ridesharing plans and to take responsibility for changing the commuting behavior of their employees (Giuliano, Hwang, and Wachs, 1993).

Despite these policies, the potential benefits from ridesharing have not been realized; ridesharing is increasing slightly - from 13 to 14 percent of commute trips in 1992 - but 77 percent of commute trips are still made in Single Occupant Vehicles (SOV). The mean travel-time savings of 14 minutes, for users of HOV lanes, has not been sufficient to persuade a higher proportion of drivers to forego the convenience, flexibility, and comfort of driving alone. Of the respondents to a 1992 survey of all commuters who have access to commuter lanes, only 28 percent use them occasionally (Collier and Christiansen 1993). Ridesharing has increased, but not nearly to the extent anticipated.

During the peak-of-the-peak travel period, HOV lanes are fully utilized. But during the shoulders of the peak, when other lanes are congested, many HOV facilities are underutilized. This encourages illegal use by SOV, criticism of HOV facilities, and the lowering of eligibility from vehicles with three occupants to those with two (HOV3 to HOV2). As 43 percent of HOV2 users are family members commuting to work, school, or daycare facilities, effectiveness in trip reduction is exaggerated. Regional aspirations to substantially increase ridesharing will require bolder incentives combining money and time savings.

HOT LANES: A STRATEGY FOR RIDESHARING

High Occupancy Toll (HOT) lanes allow SOV as well as HOV to use the same lane (Fielding and Klein, 1993). A HOT lane uses HOV facilities more efficiently by giving free access to vehicles with three or more occupants (HOV3) while permitting other vehicles to pay a toll for access. Tolls should vary with congestion to encourage a shift in departure times, increased vehicle occupancy, and to generate more revenue. Introduction of CP would also demonstrate how advanced technology could manage traffic congestion.

Paying for access, with free access for HOV3, could be a win-win solution as it would make most people better off:

- HOV3 and buses would encounter less congestion and attract more riders.
- HOV2 users could share the cost between riders.
- SOV users who value time savings more than the toll would be better off.
- Regular lanes would operate more effectively, at least for a short time, because more space would be freed up.
- Air pollution would be reduced because there would be an incentive for ridesharing.
- Users would be paying for the additional capacity.
- If successful, HOT lanes could be expanded onto conventional lanes.
- And travelers would have a choice: when they need to save time, travelers could use the toll lanes; when arrival time is not critical, they could save money by using the conventional lanes.

Riverside Freeway: State Route 91 (SR 91)

In the median of SR 91, the primary link between Orange and Riverside counties, the California Private Transportation Corporation (CPTC) has been granted the right to plan, construct, and operate four tolled lanes for 35 years. These lanes will operate like an HOV facility, but unlike the usual HOV facility, vehicles with one or two occupants will be permitted to enter by paying tolls. Vehicles with three or more (HOV3) will travel free at first, and at a discount later, should their use jeopardize the economic viability of the project. But how will tolls affect AVO in these lanes?

Congestion on Route 91 is already severe for five hours each day and expanding as travelers shift to the shoulder of the peak to avoid congestion. Caltrans had planned HOV lanes in the median. Two lanes were to have been built initially with provision for expansion to four HOV lanes. They had cleared the project environmentally, but had insufficient money for construction. By using private funds, lanes will be constructed sooner and state funds can be shifted to higher priority construction projects.

By making excess HOV lane capacity available to toll-paying vehicles, CPTC estimates that tolls will be sufficient to cover operating and maintenance cost as well as a 17 percent rate of return on investment. The private firm can earn an additional 6 percent by increasing vehicle occupancy - promoting ridesharing and transit. Excess income will be shared with the state.

Preliminary studies estimate that, during peak hours, travelers would be willing to pay a toll of $2.50 for the time saved by using the HOT lanes. Discounts will be offered when the highway is uncongested.

Tolls will vary in response to demand. Prices will be increased during peak periods to avoid congesting the restricted lanes, with roadway signs designed to flash numbers as high as $9.99. The aim is to maintain speed so that patrons save time compared to users of the unrestricted lanes. Toll will be based on a value of time saved - estimated at $0.22 per minute, for peak-period commuters in single-occupant vehicles. During the shoulder of the peak and the off-peak periods, tolls will be lowered automatically to encourage use.

Fortune Magazine, April 5, 1993, summarizes operations as follows:

> The new road's most appealing feature is its ability to operate without toll plazas, which often cause backups. To enter the fast lane, a car must have an automatic vehicle identification (AVI) tag clipped to its rearview mirror. The tag, which is being developed by MFS (Omaha, Nebraska) and Texas Instruments, could cost drivers around $30. About the size of a credit card but twice as thick, it incorporates a microchip, an antenna, and a lithium battery. As a car approaches the toll road, the card exchanges radio signals with the highway's computers, which charge the toll against the driver's prepaid account, typically $80 a month. If a car has no AVI tag, the system will alert a waiting highway patrolman to nab the interloper or will videotape the car's license place for ticketing by mail.

Effect of congestion pricing on ridesharing

Both Caltrans and the Federal Highway Administration (FHWA) are troubled by possible adverse effects of HOT lanes on ridesharing. The FWHA has announced that proposals allowing SOV to buy into HOV lanes would be excluded from congestion pricing demonstration projects because: "HOV buy-in projects would not promote the congestion relief and related air quality and energy conservation objectives of the ISTEA." (Federal Register. June 16, 1993).

Skepticism has also been expressed by regional transportation and air quality control agencies. The 1990 Amendments to the federal Clean Air Act allocate increased power to regional agencies to ensure that highway projects contribute to the improvement of air quality. The Regional Mobility Plan adopted by SCAG seeks to achieve an AVO of 1.5 passengers by 1999, and SCAQMD and environmental groups monitor all highway proposals to ensure that they are consistent with this objective. Concern over the possible impact on ridesharing of the SR 91 proposal delayed its inclusion in the Plan. It was only included after the private developer agreed to sign a Memorandum of Understanding that requires the developer to achieve an AVO of 1.5 on the facility by 1999 or allow two of the lanes to be converted to regular HOV lanes. Fear about detrimental effects has hindered progress on HOT lanes. Therefore, simulation of future vehicle and person trips on SR 91 can assist policymakers to understand the potential benefits.

PROJECTED TRIP AND VEHICLE DEMAND

A simulation model is used to test the hypothesis that the HOT lanes will lower AVO and congestion on SR91. AVO and average congestion delay are compared for 1996, 2000, 2005, and 2010 under two scenarios: four conventional plus two HOV lanes, and four conventional plus two HOT lanes. (The two HOV or HOT lanes are sometime referred to as the controlled lanes). Three levels of toll are analyzed (Table 1). An equilibration approach is used to account for capacity constraints. Only peak, afternoon travel in the eastbound direction is considered. Under both scenarios, the total demand for vehicle trips is predetermined for each year. Wilbur Smith Associates (1992) projected daily vehicle trips on SR91 for each year. A constant 14.5 percent of these daily vehicle trips are assumed to be during the afternoon peak in the eastbound direction, based on 1990 traffic counts at the county boundary. Person trips are not given; they are determined by the simulation of travel behavior.

Simulation model

The demand side simulation is a logit model adapted from a traffic and revenue study of SR91 (Wilbur Smith Associates, 1992). It was estimated with a stated-preference survey over five alternatives: 1) SOV on the conventional lanes; 2) HOV2 on the conventional lanes; 3) SOV on the controlled lanes; 4) HOV2 on the controlled lanes; and 5) HOV3 on the controlled lanes. Only travel time (in minutes with a coefficient of -0.118) and toll charges (in U.S. dollars with a coefficient of -0.532) are specified as alternative attributes. No personal attributes are specified. Alternative-specific constants for the above alternatives 2 to 5 (-0.594, -1.65, -2.50, and -2.17, respectively) are specified to account for unmeasured differences.

The supply side simulation is simply one where travel time equals a constant, plus a congestion delay term proportional to $(V/C)^k$ with k=4, where V and C are vehicle volume and capacity of a given facility respectively. The values for the constant and proportion assume that average speed decreases from 60 to 40 miles per hour as V/C rises from zero to one. Capacity C varies between the conventional and controlled lanes. The Bureau of Public Roads (1964) and Small, Winston, and Evans (1989) use the same form of this supply model with k=4.

The simulation process begins with starting values of vehicle volumes on each facility. Using these vehicle volumes, the supply model predicts travel times for each facility. Using these travel times and the given level of toll, the demand model predicts the number of person trips for each occupancy type and facility. Person trips are then converted to vehicle trips for each facility, which in turn are compared with the starting values. If the difference is less than a preset tolerance for each facility, convergence is achieved.

The total demand for person trips is adjusted so that the number of vehicle trips at convergence equals the total demand for vehicle trips projected by Wilbur Smith Associates. This adjustment is necessary because the projected demand for travel by WSA is number of vehicle trips. This adjustment is achieved through an iterative process coupled with the equilibration described above. For a given projected

demand for vehicle trips by WSA, the adjustment begins with some small number of person trips. (A good starting point is the projected number of vehicle trips.) At convergence, a new number of vehicle trips is obtained, which is then compared with the projected demand by WSA. If these two numbers differ by less than a preset amount, the adjustment stops. If they differ by more than the preset amount, a larger number of person trips is used and the adjustment continues.
An average occupancy of 3.6 for HOV3 vehicles is assumed. Additionally, it is assumed that 90 percent of HOV3 vehicles purchase transponders to travel free in the controlled lanes; the remaining 10 percent travel in the conventional lanes (WSA, 1992).

Simulation results

Table 1 summarizes the results using three levels of toll. The AVO is higher under the HOT alternatives than under HOV until 2005. In the latter years, higher tolls are required in order to discourage SOVs from crowding out HOV3. In 2005, AVO increases from 1.33 to 1.41 when the toll increases from $1.00 to $3.00. A similar result is observed in 2010. Altering the price is not an option for HOV lanes.

The hypothesis that HOT lanes using electronic road pricing will discourage ridesharing is not supported. In most instances, AVO is increased, and tolls can be raised to achieve this objective. Use of the controlled lanes is attractive to HOV2 because toll cost is shared.

The effect on congestion appears to contradict the common belief that an increase in AVO would reduce congestion. Although AVO is higher under the HOT than under the HOV alternatives in most instances, congestion delay is higher under HOT than under HOV alternatives in most instances.

But AVO and congestion delay can increase together. The common belief is correct along a single route, for a given demand for person trips, because congestion delay is positively related to vehicle volume, which in turn is inversely related to AVO. It is unclear, however, whether the common belief is correct when travel choice is controlled. Table 1 illustrates situations in which the controlled lanes (HOT and HOV) operate as separate, although adjacent, facilities. In some respects, they operate as two parallel routes.

If this effect on congestion is reasonable, then public policies that aim to reduce congestion by raising AVO should be reevaluated. In one of the simulations (not reported in Table 1) entry to the HOV lanes was restricted to HOV3+ vehicles; equivalent to those with free access to the HOT lanes. The AVO increased to 1.52 in 2005 and 1.66 in 2010. Average congestion delay, however, increased to 10.53 and 12.17 respectively. An AVO exceeding 1.5 is achieved, but at high social cost.

The current model has three main limitations. First, as it is restricted to the afternoon peak, it does not allow travelers to move to off-peak periods so as to avoid the higher tolls. Simulation of the entire day would allow this behavior to occur. Although air quality agencies are primarily interested in increasing AVO to reduce vehicle travel, highway agencies are equally concerned with reducing congestion. Our results indicate that congestion delays are greater when road pricing is compared with the HOV scenario. Perhaps negative opinions expressed by the federal highway agency towards HOT lanes have merit. Second, as personal attributes are not included in the current model, it does not allow for behavioral differences among travelers with different attributes. Third, as current tolls are set exogenously, they do not necessarily reflect the marginal social costs of travel. Using a mode and scheduling choice model, Chu (1993) calculates tolls endogenously.

Table 1. Simulation Results: Average Vehicle Occupancy, Average Congestion Delay, and Vehicle and Person Shares by Occupancy and Facility

			Vehicle Shares				Person Shares			
			Occupancy			Uncon-trolled	Occupancy			Uncon-trolled
	Average Vehicle Occupancy	Average Conges-tion Delay	SOV	HOV2	HOV3	Lanes	SOV	HOV2	HOV3	Lanes
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1996										
2HOT:100	1.30	3.68	.757	.209	.034	.829	583	.322	.095	.782
2HOT:200	1.32	4.39	.747	.213	.040	.862	567	.324	.109	.804
2HOT:300	1.33	5.01	.740	.215	.045	.887	556	.323	.121	.819
2HOV:2+	1.21	4.14	.876	.070	.054	.876	.724	.115	.160	.724
2000										
2HOT:100	1.31	4.82	.753	.208	.039	.805	575	.318	.107	.756
2HOT:200	1.33	5.68	.740	.213	.047	.838	.554	.319	.127	.772
2HOT:300	1.36	6.43	.731	.215	.054	.861	.539	.317	.144	.783
2HOV:2+	1.26	5.28	.849	.085	.066	.849	.677	.135	.188	.677
2005										
2HOT:100	1.33	6.98	.746	.207	.047	.764	.562	.311	.128	.708
2HOT:200	1.37	7.81	.727	.212	.061	.790	.531	.310	.159	.713
2HOT:300	1.41	8.60	.711	.214	.075	.811	.505	.305	.191	.714
2HOV:2+	1.34	6.93	.800	.113	.087	.800	.597	.168	.234	.597
2010										
2HOT:100	1.34	9.05	.743	.206	.052	.741	.554	.307	.139	.683
2HOT:200	1.39	9.69	.720	.211	.069	.762	.518	.304	.178	.679
2HOT:300	1.44	10.31	.699	.214	.087	.779	.485	.297	.218	.674
2HOV:2+	1.39	8.45	.769	.131	.101	.769	.552	.187	.261	.552

Notes: Column (1) lists years, scenarios, and levels of toll. There are six lanes: four uncontrolled and two controlled lanes (HOT or HOV) operating eastbound during four peak hours. Under scenario 2HOT, vehicles with three or more travel free, and others pay to travel in the two controlled lanes. Under scenario 2HOV:2+, only vehicles with two or more may travel in the two controlled lanes. Column (2) gives average vehicle occupancy for all lanes. Column (3) gives average congestion delay per person in minutes for all lanes. Columns (4)-(6) sum to 1, and give vehicle shares by occupancy for all lanes. Column (7) gives share of vehicles using the four uncontrolled lanes. Columns (8)-(11) are the same as (4)-(7) except for person shares. The proportion of vehicles paying the toll under the HOT scenarios is 1 - (Column 7 + Column 6).

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