Implementing Congestion Pricing on Metropolitan Highway Networks with Self-Financing Public-Private Partnerships

This paper presents a new public-private partnership model for road pricing applications either at the facility level or on a region-wide highway network. The model addresses issues of monopoly power and efficiency of delivery of transportation services. The paper also addresses issues relating to financial self-sufficiency of integrated multimodal pricing strategies and assesses the financial self-sufficiency of an ambitious region-wide pricing concept that integrates multimodal mobility choices.

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INTRODUCTION

Roadway congestion pricing includes a group of market-based strategies that involve collecting a variable toll for highway use, with the primary intent of managing travel demand so as to reduce or eliminate congestion on a roadway facility, corridor, or network. In the United States, pricing has been implemented in two types of situations. First, priced lanes have been created on existing toll-free facilities by converting High-Occupancy Vehicle (HOV) lanes to High-Occupancy/ Toll (HOT) lanes, or by adding new lanes. Second, variable charges have been introduced on existing toll facilities that previously charged flat tolls. In 2004, eight pricing projects were in operation in the United States, four in each category (U.S. Department of Transportation 2004), and a ninth project was implemented in May 2005 in Minneapolis, MN, on I-394.

Proposals have been made to extend these pricing concepts to region-wide systems of priced freeways or priced freeway lanes that would maintain free-flowing traffic conditions throughout the network, thus providing a running way that allows introduction of high quality express bus or Bus Rapid Transit (BRT) services. A proposal by the Reason Foundation (Poole and Orski 2003) would create a network of priced lanes on existing toll-free roads, using existing HOV lanes and adding new lanes on segments where no HOV lanes exist. Free service would be provided only to authorized buses and/or vanpools. BRT would operate on the priced HOV lanes. Another region-wide road pricing concept, called "Fast and Intertwined Regular" highways or FAIR highways, would convert *all* lanes on existing freeways to variably priced lanes, exempt HOVs from payment of tolls, provide discounted tolls for low-income motorists, and use surplus toll revenue to fund new express bus services and implement traffic flow improvements on parallel arterial facilities (DeCorla-Souza 2005).

Pricing provides two key benefits for transit services. First, by managing traffic demand on a single lane or multiple lanes to ensure free flow of traffic, pricing provides a busway-like facility for operation of express bus or BRT services. Second, pricing generates a new revenue stream from tolls which may be used to support transit service operations, purchase buses, or construct bus stations and park-and-ride facilities.

Express bus or BRT services increase the technical and political feasibility of pricing in two key ways. First, the effectiveness of pricing strategies increases when travelers have available to them a viable alternative mode that they can choose if they wish to avoid paying the toll. With new express bus or BRT services on priced highways, vehicular travel demand can be reduced without resorting to high toll rates to ensure that traffic volumes do not exceed critical levels at which the free flow of traffic breaks down. Commuters benefit from lower toll rates for those motorists who continue to drive, and better transit service for those who choose it. Second, by keeping toll rates affordable and, by providing a viable alternative for those who may not be able to afford the toll, express bus service ensures that equity is preserved for those commuters who are less able to afford tolls. Addressing equity concerns is key for public and political acceptance of road pricing strategies.

The objective of this paper is to present a new public-private partnership (PPP) approach for road pricing applications that could maximize efficient delivery of highway, transit, and ridesharing services in metropolitan areas, while addressing issues relating to monopoly power. Because financial feasibility is key to successfully moving forward with a PPP, the paper assesses, at a sketch level, the financial self-sufficiency of an ambitious region-wide approach to enhance multimodal metropolitan mobility using roadway pricing in the short-term and long-term.

In the next section, the paper briefly discusses the benefits of PPPs and monopoly power and financial feasibility issues with regard to operating projects as well as proposed networks of priced facilities in metropolitan areas. The following section discusses an approach to address monopoly power issues relating to private provision of roads and illustrates it using a prototypical case. This is followed by a discussion of ways in which the approach may also be applied to deliver complementary transit and ridesharing services. The paper then presents a pricing concept that could address financial feasibility issues relating to networks of priced facilities, while at the same time addressing financing needs for multimodal transportation services. This is supported by a sketch-level analysis of revenues and costs to assess the financial self-sufficiency of the concept in a typical large metropolitan area, both in the short-term and the long-term.

PUBLIC-PRIVATE PARTNERSHIPS - BENEFITS AND ISSUES

In an era of scarce public resources, tolls bring new revenue. The promise of a steady stream of new revenue from tolls makes it possible to increase private sector involvement in the financing, implementation and operation of pricing projects for the mutual benefit of both the public and the private sectors.

Procuring transportation facilities and services through public-private partnerships (PPPs) has many advantages over the traditional publicly financed approach. Projects are generally designed and constructed more quickly and capital demands on the public treasury are reduced. Advances in innovation as well as efficiency may be encouraged. Federal, State, and local governments have shown increasing interest in private sector involvement in the provision of transportation infrastructure and services. However, issues relating to monopoly power and financial feasibility will need to be addressed.

Monopoly Power Issues. Pursuit of PPP arrangements for roadway congestion pricing projects raises issues relating to private monopoly power. Efficient, free-flowing freeway traffic operation is absolutely essential to maintain the high quality of express bus or BRT operations on freeways. This may occasionally require relatively high tolls to keep traffic free flowing during rush hours when travel demand is very high. This may be perceived by the public as “price gouging,” and poses a problem, particularly if the extra revenue goes to the private sector partner. The public may perceive that the private sector partner is attempting to maximize its profits through excessive peak charges. There may be special concerns if a “non-compete” clause in the PPP agreement prevents the public agency from doing anything to relieve congestion on parallel free facilities. This occurred in Orange County, CA, where a “non-compete” clause in the PPP agreement for the priced express lanes in the median of SR 91 prevented the public agency from making improvements on the adjacent free lanes (Sullivan 2000). Simply eliminating or limiting non-compete provisions is not a solution because the private sector would be unwilling to invest in highway projects without adequate protection against future competition.

Financial Feasibility Issues. The ability to finance integrated transit/pricing proposals entirely from toll revenue will be an important consideration in moving forward with private sector involvement. However, recently completed feasibility studies suggest that financial self-sufficiency may be difficult to achieve. A feasibility study for a network of HOT lanes in the Twin Cities of Minnesota suggests that tolls could pay only 15% to 55% of the cost of building the lanes (Cambridge Systematics, Inc. and URS Corporation 2005). The consultant-recommended system would have a cost recovery ratio of 33%. Parsons, Brinckerhoff, Quade and Douglas (2005) studied the feasibility of a HOT lane system in Atlanta. They found that as long as a policy is in place to restrict free service to transit vehicles and carpools with four or more persons, the tolls can cover 100% of the costs for technology investments associated with HOT lanes as well as operations and maintenance costs. However, the tolls would not cover the costs for building infrastructure such as new highway lanes. A nationwide study of the feasibility of networks of HOT lanes in eight metropolitan areas by Poole and Orski (2003) suggests that the eight region-wide BRT/HOT systems studied by them will not be financially self-sufficient, and transit system costs, other than "fixed guideway" costs (i.e., highway lane construction costs), would need to be supported entirely by fares and tax dollars. Revenues generated would be inadequate to cover all of the capital costs for highway construction. Nor would they cover continuing maintenance, traffic management and toll operation costs. The main reason is that, in addition to the high cost for adding lanes on segments where HOV lanes do not currently exist, providing special premium-service lanes requires additional shoulders and barriers between HOT and free lanes, and direct access ramps to ensure safe conditions for entry to and exit from the lanes.

ADDRESSING MONOPOLY POWER ISSUES

To address monopoly power issues, a new PPP model is proposed called "Concurrent Regular and Shadow Tolling (CRAST)." This approach would separate the system operator from the toll revenue beneficiary. "Shadow" tolls would compensate the private partner. Shadow tolls are usage payments made by a third party. Real tolls would still be charged to road users concurrently, but all revenues from real tolls would go to the public partner. Although the private partner would set the toll rate to manage demand and ensure that traffic is free flowing (as on the express lanes on SR 91), all revenues would go to the public sector. The public agency would reimburse the private partner using a flat shadow toll rate for each vehicle served at free flow speeds. Because pro-active management of traffic flow with variable tolls is needed only during peak periods, shadow tolls would apply only for peak period traffic.

Free flow speeds are critical to preserve the high quality of express bus service and offer travelers a viable alternative to driving and paying a toll. It also offers toll-paying motorists a fast and reliable trip in exchange for the tolls they pay. Also, because of the nature of traffic flow on a congested freeway, the most economically efficient operation of a freeway is attained at free flow speeds. Recent data on freeway operation in Southern California (Chen and Varaiya 2002) demonstrate that free-flowing freeway traffic breaks down almost instantaneously and unpredictably with just a small increment of traffic volume when traffic volumes are in the range of 1,800 to 2,000 vehicles per lane per hour. After traffic flow breaks down, the data show that traffic volumes carried on a severely congested freeway are reduced to about 1,300 vehicles per lane per hour at much lower speeds. This suggests that managing traffic on a severely congested freeway with pricing could actually allow the freeway to handle more traffic than it did when traffic was unmanaged, and maintaining free-flowing traffic conditions is optimal from both engineering as well as an economic efficiency perspectives.

Under the CRAST model, potential private partners would compete based on the shadow toll rate per vehicle that they are willing to accept as compensation for their infrastructure investments and highway maintenance, operations and toll collection services. Agreements with the private partner would need to include performance standards (e.g., safety, public information, highway signage, billing, customer service centers, etc.), because the private partner may not gain additional revenue if quality of service to the public is reduced. The CRAST model will reduce revenue risk to the private partner while managing public cost risk, and could lead to more efficient and effective transportation service delivery.

Cost risk. Cost risk includes uncertainty of implementation costs, including costs for the innovative technology and operations approaches that will be needed for traffic management and toll collection. Costs for major transportation projects often appear to spiral out of control after they have been approved. With the CRAST model, the public sector would know in advance its maximum cost liability, calculated as the maximum possible vehicle throughput per hour, times the number of peak hours of pricing operations, times the shadow toll per vehicle negotiated with the private partner. To reduce risk associated with reliance on toll revenue, the public partner could prepare a financial plan that allocates future receipts from its normal transportation funding sources to pay for contractual obligations to the private partner.

Revenue risk. Risk with regard to the stream of future revenue from user-paid tolls will be borne by the public sector. The private partner would be assured of an almost guaranteed stream of revenue based on the negotiated shadow toll rate. This would reduce revenue forecast risk-related costs and therefore lower the interest rates demanded by potential bondholders. Also, by having the flexibility to reduce the user-paid toll rates, the private partner would have the ability to counter-act the potential demand-reducing effects of competition from improvements that may be made to parallel highway facilities or competing transit or HOV services. In congested metropolitan areas, priced lanes could be filled to their critical free-flow capacity threshold levels simply by lowering the user-paid toll rate, thus ensuring that the private partner maximizes its shadow toll revenue. Consequently, total payments to the private partner would not be affected by improvements made to competing modes and routes. There would be no need in the PPP agreement for a non-compete clause such as the one that led to the termination of the PPP for the express lanes on SR 91 in Orange County, CA. If the public partner were to choose to improve alternative routes or modes in the travel corridor, it would absorb all the revenue risks due to its actions, because it is the recipient of user-paid toll revenues. Thus, the entity best able to manage risk from competition is the entity that bears the risk of loss of revenue that could result from that competition.

Service delivery. As experience with rate regulation has demonstrated, to maximize its profit the private partner would strive to keep costs down through innovation and would use efficient procurement and management practices. The private partner would attempt to maximize volume of traffic throughput with an acceptable probability of breakdown in traffic flow, because of the incentive to maximize vehicle throughput while ensuring that all traffic moves at free flow speeds. Because the private partner would only be paid for vehicles that are provided with free-flowing premium service, there would be an incentive to ensure that traffic flow does not break down. There would be no incentive for the private operator to keep toll rates high simply to maximize revenue. Higher charges than those needed to manage traffic result in unnecessary mobility losses, because motorists are dissuaded from traveling or are shifted to alternative routes or times of the day while highway capacity goes underused. If traffic disruptions occur (e.g., due to incidents or road repairs), the private partner would be at risk of losing shadow toll revenue and it would have an incentive to clear them quickly. The private partner would also have an incentive to produce innovative solutions to reduce the risk of incidents and accidents, and to reduce the impact of incidents, accidents and maintenance activities on traffic flow during rush hours.

To illustrate the way in which the CRAST model would work, Table 1 presents financial estimates for a prototypical HOT facility similar to the priced express lanes operating in the median of SR 91 in Orange County, CA. To maximize public mobility in both peak and off-peak hours, it is assumed in this example that tolls would only be charged during peak travel periods on weekdays when adjacent lanes are congested. Annualized cost estimates are based on cost data for the 91 express lanes (Orange County Transportation Authority 2004). A discount rate of 7% over a 30-year life was used to annualize capital costs, in order to reflect the expected rate of return for private sector investments.

The analysis demonstrates that, as toll rates increase in the future (because of higher demand when adjacent lanes get more severely congested), the CRAST model will ensure that the significant increase in revenue will stay with the public agency. The private partner will receive a justifiable bonus if it achieves free-flowing traffic conditions more often than the 90 percent success rate assumed in calculating the shadow toll rate. It will receive a relatively

Table 1: Application of the CRAST Model

	Current	Future
Peak period toll revenue estimation		
Number of Lanes	4	4
Tolled traffic volume per lane	1,300	1,300
Free traffic volume per lane (buses and HOVs)	200	200
Number of hours lanes are tolled	6	8
Max. daily tolled traffic volume	31,200	41,600
Max. annual tolled traffic volume (250 days)	7,800,00	10,400,000
Average toll	$4.00	$6.00
Max. annual toll revenue (million $)	**$31.20**	**$62.40**
Net change in revenue to public agency (million $)		**$31.20**
Cost estimation		
Annualized capital cost (million $)	$20.00	$20.00
Max. annual tolled traffic volume	7,800,000	10,400,000
Annual toll-free traffic volume (HOVs and buses)	1,200,000	1,600,000
Max. annual total traffic volume in peak periods	9,000,000	12,000,000
Estimated O & M cost per peak period vehicle	$0.50	$0.50
Annual O & M cost (million $)	$4.50	$6.00
Total annualized cost (million $)	**$24.50**	**$26.00**
Shadow toll estimation		
Max annual traffic volume	9,000,000	12,000,000
Assumed probability that traffic will be at free flow	0.9	0.9
Probable annual “shadow tolled” traffic volume	8,100,000	10,800,000
Estimated bid price for shadow toll	**$3.02**	**$2.41**
Probable shadow toll revenue (million $)	**$24.50**	**$26.00**
Max potential shadow toll revenue (million $)	$27.22	$28.89
Max potential revenue increase (million $)	**$2.72**	**$2.89**

small increase in revenue (and potential bonus) with higher congestion levels in the future, commensurate with the increase in the number of vehicles served. Note that tolling operations will need to be expanded to more hours in the future, because as congestion increases it is likely that the regular lanes of the facility will be congested for a longer period of the day. As the table suggests, shadow toll rates negotiated with the private partner will need to be based on a sliding scale tied to the number of hours of tolling operations needed.

PUBLIC-PRIVATE PARTNERSHIPS FOR COMPLEMENTARY TRANSIT AND HOV SERVICES

A PPP arrangement similar to the CRAST concept described above may be used to compensate private providers for new transit or HOV services to complement highway pricing. For transit, the private partner would be compensated by the public partner with a two-part tariff – a base service fee plus a transit usage payment (TUP) for each transit trip served above a base usage level. This per-trip usage payment would make up for the difference between the fare and the marginal cost per trip for providing service above the base usage level. With usage payments, the private partner stands to increase its revenues (and potentially profits) by encouraging the use of transit. This would increase its incentive to promote transit and maximize resulting public benefits from reduced roadway usage during peak times. Likewise, private partners could provide HOV services (e.g., rideshare matching and park-and-pool facilities) and be compensated on a per-trip basis with an HOV usage payment (HUP) for each HOV commuter above a base level.

HOV and transit usage payments to private partners may not be cost-efficient if they exceed the estimated value of external benefits, e.g., the decrease in external costs resulting from the reduction in solo driver trips. Therefore, it is important for the public agency to have the capability to estimate the value of changes in external costs resulting from an increase in transit or HOV mode share. External benefits may be estimated using the Transportation Research Board's *Guidebook to Estimate and Present Benefits and Disbenefits of Public Transit* (ECONorthwest and Parsons, Brinckerhoff, Quade & Douglas, Inc., 2003). If the bid price from the private partner for usage payments (TUP or HUP) per trip is higher than the marginal external benefit, a PPP contract option for service above the base level may not be economically justified.

Minimum transit performance and safety service standards (e.g., service frequency, passenger load factors and vehicle condition) could be set by the public partner to ensure quality of service. Base service payments to be made to the private transit operator could be determined on the basis of the cost of the minimum required service level set by the public agency (less expected fare revenue), with adjustments allowed for fuel prices. Usage payments for ridership above the specified base level of transit ridership could be based on automatic accounting, facilitated by requiring the use of electronic fare payment (e.g., using a smart card) for anyone wanting to get the subsidized fare.

Carpools and vanpools are often perceived as competitors to transit, because the modes have many common characteristics. A private partner operating transit services would therefore be concerned about the risk of competition from any efforts to increase HOV use. To address this issue, the private partner operating transit services could also be under contract to run the HOV program. Periodic counts of HOV commuters may need to be made to assess the success of the private operator in increasing HOV use. Photographic systems employing near infra-red cameras have achieved some success in counting vehicle occupants, and have been shown to have some potential for further improvement and deployment (University of Minnesota Department of Computer Science 1999). If toll discounts or exemptions were offered to HOVs, keeping track of the number of HOVs would be relatively easy — HOVs could be identified electronically, such as by passing through special lanes upon entry into the priced facilities to receive a toll exemption or discount. The public partner could set HOV toll discount or exemption policies, and the private operator of the priced lanes (who would not necessarily be the same as the transit and HOV service operator) would not be concerned, because compensation will be provided by a shadow toll for *every* vehicle, whether it is a single-occupant vehicle, an HOV, or a transit vehicle. The proposed TUP and HUP models for transit and HOV service delivery could be more economically efficient than conventional service delivery, and could encourage innovation.

Economic efficiency. Private partners would have an incentive to promote transit use up to the point where the fare (a proxy for the transit rider's benefit) and the usage payment per trip (a proxy for the external benefit) would be just equal to the marginal cost of providing service. Similarly, they would have an incentive to promote HOV use up to the point where the usage payment per HOV commuter trip (a proxy for the external benefit) would just equal the private partners' marginal costs of promoting and providing HOV service. Thus, economic efficiency and net social benefits would be maximized. If usage payment rates were set carefully, private partners would be in a position to seek the most socially cost-efficient mode (i.e., transit or HOV) with which to serve the commuter. Base transit service frequency requirements will ensure that the usage payment per HOV commuter does not provide an incentive to private partners to increase HOV use at the cost of transit ridership to such an extent that it results in a significant reduction in transit service frequency, thus compromising the quality of express bus service. Also, the usage payment rate per HOV person trip would need to be lower than the transit fare that the transit operator would stand to lose if a transit rider shifts to HOV use.

Service effectiveness. The incentive to maximize transit ridership, if successful, could lead to more riders and therefore more frequent service. All transit riders would gain because any increase in service frequency will reduce their waiting time. Private partners would have an incentive to provide new premium services for those willing to pay a higher fare, e.g. door-to-door limousine services (similar to airport shuttles) or vanpool services, provided that these services would still be eligible for usage payments from the public agency. Private partners would also have an incentive to work with transportation management associations to encourage employees to take transit or carpool. They might innovate with fare agreements with employers and building owners, provide new services and conveniences such as station cars and park- and-ride/pool lots, and marketing programs that encourage people to use other ways of traveling rather than driving alone in a car. Availability of parking spaces at park-and-ride facilities is often the limiting factor for carpooling and transit use. Private partners would have an incentive to innovate with new parking arrangements for transit and HOV commuters.

ADDRESSING FINANCIAL FEASIBILITY ISSUES

Could an entire region-wide pricing/express bus system be financially self-sufficient, without an infusion of tax dollars? In an attempt to address the financial deficit issues of the HOT system proposals discussed earlier, two ambitious pricing scenarios involving the "FAIR highways" concept were examined. FAIR highways involve pricing *all* freeway lanes. They may be more financially feasible than concepts that involve pricing only one or two lanes in each direction, because they would bring in more revenue, while avoiding extra infrastructure costs associated with providing premium-service lanes, such as costs for barriers, extra shoulders, and direct access ramps for entry to and exit from the special lanes.

The first FAIR network scenario envisions an application of region-wide pricing on all lanes of the existing freeway system in the short-term (within five years) and therefore involves only minor modifications to the existing freeway system. Large new infrastructure investments are not envisioned under this scenario, and financing is therefore not a major concern. However, a private partner's skills would still be invaluable for deployment of the complex schemes and innovative technologies that would be needed. Also, by shifting the costs for maintaining and operating the existing freeway system to the private sector, limited public resources would be freed up for use on transportation projects off the freeway system.

The second scenario envisions a longer-term (within 25 years) application of pricing, along with significant additions to freeway network capacity to keep up with future growth in travel demand. If the short-term scenario were implemented first, price signals (i.e., higher toll rates on some segments) would provide an indicator of the priority that should be given to segments on which capacity additions are proposed under the long-term scenario. Environmental studies could be initiated or accelerated in these corridors, and private partners could be sought to build, finance and operate the improved facilities for the longer term.

In both scenarios, new *fare-free* express bus services would be introduced to complement congestion-based pricing. Pricing would be implemented on *all lanes* of the limited-access highway system, *but in weekday peak periods only*. This differs from the pricing model represented by SR 91, where tolls are charged only on the express lanes, and apply throughout the day and even on weekends. Under both FAIR highway network scenarios, no tolls would be charged during uncongested off-peak periods, because marginal costs occasioned by motorists when there is no congestion are equal to the average costs borne by them. Therefore tolling is unnecessary. Off-peak tolls may actually reduce social benefits by discouraging use.

Because of the difficulty and costs involved in enforcing vehicle occupancy requirements for HOV preferences, toll exemptions would be provided only to authorized buses and vanpools, but not to other HOVs. To encourage ridesharing, vanpoolers and carpoolers (as well as transit riders) would be provided with free or subsidized parking at expanded park-and-ride facilities. The new fare-free express bus service and enhanced park-and-ride facilities would provide alternative commuting options for those who do not value the new time savings above the going toll rate under the pricing scenarios.

FAIR highways may generate larger social benefits than HOT lanes, because congestion would be relieved on the entire freeway instead of only on the premium service lanes. Because inexpensive and viable alternative modal choices will be provided, there would be little reason for motorists to divert to parallel free arterials and exacerbate congestion on them. But it will be more difficult to get public acceptance for this approach, due to a public perception that "existing roads have already been paid for." However, the public may not be as opposed to new or higher tolls as is commonly believed, as long as commensurate benefits are provided. For example, focus groups conducted as part of the Illinois Tollway Value Pricing Study, which covered the several existing toll facilities in the Chicago area, found that about half of all users of the tollway system would pay at least twice as much for a free-flowing commute (Resource Systems Group 2003).

FAIR HIGHWAY NETWORK TOLL REVENUE

The two FAIR network-pricing scenarios were examined to evaluate their potential for financial self-sufficiency. The Washington, D.C., metropolitan area, which has a population in excess of four million, was used as the prototype for the analysis. The Washington, D.C., metropolitan freeway network consists of approximately 2,040 lane miles (Texas Transportation Institute 2005), or about 300 route miles. As population and travel demand increase in the longer-term future (25 years), freeway traffic is forecasted to increase by about 1.5% per year. To keep up with this growth, the long-term scenario envisions the addition of the equivalent of 600 new freeway lane miles by widening existing facilities.

In 2003, the average daily congested travel period in major U.S. metropolitan areas amounted to about six and one-half hours, and the share of daily travel subjected to congested roadway conditions amounted to about 40% (Texas Transportation Institute 2005). The Washington, D.C., metropolitan area is even more congested. However, the prototypical freeway network used in the analysis was assumed to have only six hours of congestion, and 33% of daily freeway travel was assumed to occur in congested conditions in the six-hour peak period that would warrant the use of pricing to manage demand. These lower estimates were used to ensure a conservative estimate of tolled traffic and therefore revenue.

Table 2 provides estimates of vehicle miles of travel (VMT) that would be subjected to tolls in the two FAIR highway network scenarios, based on the following:

- Total current daily freeway vehicle miles of travel (VMT) amounts to 37.8 million (Texas Transportation Institute 2005). Over the long-term (i.e., 25 years), without pricing, an increase in freeway VMT of 37.5% is forecasted, i.e., 1.5% per year on average.
- Thirty-three percent of daily freeway travel is currently congested, and 40% would be subjected to congested conditions in the long-term.
- Ten percent of peak period VMT is truck VMT.
- Peak period freeway VMT would be reduced by 10% on congested segments due to the effect of tolls and complementary new transit and HOV services.

While the forecasted reduction in VMT with pricing appears to be low, it should be noted that the *Highway Capacity Manual* (Transportation Research Board 2000) indicates that a freeway remains free flowing and uncongested until about 90% of its maximum possible traffic volume is achieved. Thus, currently congested freeways need a reduction of just 10% of their traffic volumes for free-flowing traffic to be restored. Drivers in the Washington, DC, metropolitan area notice this phenomenon in August every year when peak period traffic is reduced by only small amounts because of some commuters are on vacation. Californians observe it on days when only state government employees are off work because of a state holiday (Wachs 2003). In such situations,

Table 2: Revenue Estimation for Region-wide Pricing

	Short-term (Scenario 1)	**Long-term (Scenario 2)**
Region-wide daily highway VMT ('000)		
Total daily freeway VMT (from FHWA's Highway Statistics)	37,815	51,996
Percent of freeway VMT that is subjected to congestions	33%	40%
Daily freeway VMT subjected to congestion	12,479	20,798
Estimated percent VMT reduction due to pricing	10%	10%
Estimated freeway VMT that will be tolled	11,231	18,718
Percent VMT by trucks in peak periods on freeways	10%	10%
Tolled VMT by trucks in peak periods on freeways	1,123	1,872
Tolled VMT by passenger vehicles in peak periods on freeways	10,108	16,847
Estimate of Toll Revenue ('000)		
Estimate to toll rate per mile for trucks	$0.40	$0.55
Estimate of toll rate per mile for passenger cars	$15	$0.20
Daily toll revenue from trucks	$449	$1,030
Daily toll revenue from passenger cars	$1,516	$3,369
Daily toll revenue total	$1,965	$4,399
Number of days tolling is in effect	250	250
Annual toll revenue	**$491,359**	**$1,099,707**

there is not sufficient time for "equilibrium" with regard to traffic congestion to be restored, i.e., people who previously changed their mode, route, or time of travel choice because of congestion do not immediately get back on the highways during the peak periods to take advantage of the reduced congestion.

With other forms of travel-demand management that might theoretically reduce traffic by 10%, such as prohibiting trucks from using of freeways during peak periods, a large portion of the traffic returns and re-congests the freeway. This is because of the phenomenon of "triple convergence," i.e., demand attracted to the freeway from other routes, other modes and other times of the day due to improved freeway travel times (Downs 1990). Unlike other demand management strategies, pricing keeps induced traffic from materializing by increasing the monetary cost to the motorist at the same time that travel time "cost" is reduced.

Any increase in bus or vanpool VMT will be relatively small. They have been ignored in this illustrative analysis because they will be exempt from tolls. For Scenario 1, average peak charges per mile to ensure free-flowing traffic conditions on currently congested limited-access highway segments are conservatively estimated at about 40 cents for trucks and about 15 cents for passenger cars, based on the following rationale.

- Average peak period tolls on the SR 91 express lanes amount to about 40 cents per mile, based on the current toll schedule (Orange County Transportation Authority 2005). Tolls are charged on only four of 12 lanes (i.e., two of six in each direction). If all 12 lanes of SR 91 were to be tolled in peak periods at levels to assure free flow of traffic (as are the four express lanes), the supply of "express" lanes would increase three-fold. Average peak period tolls per mile for passenger cars would likely be reduced to about one-half of the current toll rate, or about 20 cents per mile. This is based on the assumption that the minimum value of time of newly tolled SR 91 drivers would be at least half of the minimum value of time revealed by willingness-to-pay of those using the four express lanes currently.
- Because SR 91 is a relatively more severely congested facility, the average peak period toll per mile for an "average" congested facility may be somewhat lower. This is estimated at 15 cents per mile, i.e., 25% lower than that estimated for SR 91.
- Since a heavy truck on average consumes two to three times the lane capacity of an automobile in free-flowing traffic, tolls for trucks would need to be about 2 to 3 times the toll for passenger cars, or about 40 cents per mile.

For Scenario 2, it is assumed that growth in real incomes over the next 25-years will increase motorists' willingness to pay tolls. Therefore, an average passenger car toll of 20 cents per mile and an average truck toll of 55 cents per mile (in 2005 dollars) is assumed. Revenue from tolled traffic shown in the lower part of Table 2 is estimated by multiplying traffic that would be subjected to tolls by the respective average toll rates for passenger vehicles and trucks. Assume that an average 10-mile peak period trip on the freeway is subjected to congestion on 6.7 miles (i.e., two-thirds of its freeway trip length). Then, the average peak period toll per trip would be $1 for passenger cars and $2.70 for trucks under Scenario 1, and $1.35 and $3.70 under Scenario 2. Annual revenues were estimated by assuming the pricing schemes would operate on 250 working weekdays each year.

FAIR HIGHWAY NETWORK COSTS

As with revenue estimates in the previous section, all cost estimates are in 2005 dollars. Annualized costs for freeway infrastructure maintenance, including periodic resurfacing, are estimated at about $50,000 per lane mile (2005 dollars) based on data used in the Highway Economic Requirements System (HERS) model (U.S. Department of Transportation 2000), resulting in a total cost of $102 million per year for Scenario 1 and $132 million per year for Scenario 2. For Scenario 2, lane addition costs are estimated at $5.4 billion, based on an average cost of $9 million per lane mile (in 2005 dollars) for urban freeway capacity additions (U.S. Department of Transportation 2000). Annualized at a 7% discount rate over a

30-year period, this amounts to $437.4 million per year.

Estimates of other annualized costs for the FAIR highway network scenarios for the Washington, D.C., metropolitan area are presented in Tables 3, 4 and 5. They include capital and operating costs for region-wide highway network tolling and traffic management, for express bus service, and for park-and-ride facilities.

Capital and operating costs for region-wide highway network tolling and traffic management shown in Table 3 were estimated based on the following:

- Tolls would be charged only on the formerly congested freeway segments. Tolls would be charged, on average, over 6.7 miles of each freeway trip. This is two-thirds of an average 10-mile freeway commute trip length, based on peak period freeway traffic amounting to 50% of daily traffic, and the 33% of daily traffic estimated to be traveling under congested conditions.
- Average costs for toll collection are estimated at 10 cents per trip, based on an estimate of 5 to 10 cents per trip by ITS Decision, Service and Technologies (2005). Because toll collection costs will

Table 3: Tolling and Traffic Management Costs

	Short-term (Scenario 1)	Long-term (Scenario 2)
Operating Costs		
Estimated daily freeway VMT that will be tolled (‘000)	11,231	18,718
Average length of trip that will be subjected to tolling (mi.)	6.7	6.7
Number of trips tolled daily (‘000)	1,676	2,794
Number of days tolling is in effect	250	250
Number of trips tolled annually (millions)	419	698
Toll collection cost per trip	$0.100	$0.100
Traffic management cost per trip	$0.115	$0.115
Total traffic mgmt. and toll collection cost per trip	$0.215	$0.215
Annual operation costs (million $)	**$90.100**	**$150.166**
Capital Costs		
Number of congested lane miles that will be tolled	1,200	1,800
Number of lane charging points	400	600
Capital cost per lane charging pint	$69,500	$69,500
Capital cost for all lane charging points (million $)	$27.80	$41.70
Video tolling, ETC, communications system capital costs and miscellaneous start-up costs (million $)	$16.80	$16.80
Capital costs for mainline gantries and operations building (million $)	$27.50	$27.50
Total capital costs (million $)	$72.10	$86.00
Annualized capital costs (million $)	**$6.78**	**$8.08**
Annualized capital plus operating cost	**$96.88**	**$158.25**

decrease with large-scale implementation, this is a conservative estimate.

- Annual costs for traffic management and toll collection on the dynamically priced I-15 HOT facility in San Diego were about $0.7 million in fiscal year 2005 (source: I-15 FasTrak budget and expenditure data for FY 2005). The facility carried about 5 million vehicles during that year, about 75% of them non-tolled HOVs and the remaining 25% tolled vehicles. Subtracting costs for tolling the tolled vehicles (at 10 cents per trip), traffic management costs for the year are estimated at $575,000, or 11.5 cents per vehicle served.
- Estimates for toll collection capital costs are based on cost data for open-road tolling provided by Wilbur Smith & Associates (source: personal e-mail communication dated October 28, 2003). It is assumed that toll-charging points will be located at approximately 3-mile intervals along 1,200 lane miles of congested highway segments, resulting in the need for 400 lane-charging points. Capital costs per lane charging point are estimated at $46,000 for electronic toll collection (ETC) costs and $23,500 for video enforcement system (VES) costs, or a total of $69,500 per lane charging point. Video tolling hardware and software, ETC equipment, system software, communications system, other equipment, and miscellaneous installation, project management and training costs are estimated at $16.8 million. Mainline gantry costs are estimated at $25 million, and operations building costs at $2.5 million. Capital costs were annualized assuming a 30-year life and a 7% discount rate.

Capital and operating costs for express bus service shown in Table 4 were estimated based on the following:

- The express bus system would have the capability to carry all travelers who might possibly shift from driving on the freeway, i.e., those travelers accounting for the entire 10% of peak period freeway demand that is reduced. While it is expected that travelers may also shift to carpools or other modes, this will guarantee that the estimated costs are conservative, i.e., that they account for a system that is capable of carrying the maximum possible demand.
- These new transit trip-makers would previously have traveled an average of 6.7 miles each on the congested freeway segments now subjected to tolls.
- Operating cost per new express bus passenger trip are estimated at $2.40, based on the following:
    - Seattle, WA, bus operating costs are estimated at $90 per revenue hour (McDonald 2003). Due to the higher labor costs for split shifts and use of part-time labor for peak period service, costs for a typical express bus network are estimated to be from 1% to 10% higher than for conventional operations (Charles River Associates 2001), or a maximum of about $100 per revenue hour.
    - Average speed of an express bus operating on a free-flowing freeway would be 20 mph, including stops, so that a 50-passenger bus could provide 1,000 passenger seat-miles of service per hour. Assuming average bus occupancy of 50%, 500 passenger miles of service could be provided per bus per revenue hour.
    - Assuming an average trip length of an express bus passenger trip of 12 miles, based on commute trip length data (U.S. Department of Transportation 2005), 42 passengers could be served per bus per hour.
- Annualized capital costs per new express bus passenger trip are estimated at about $1, based on the following:
    - A cost of about $340,000 per bus (American Public Transit Association 2005) annualized assuming a 12-year bus life and 7% discount rate.
    - A cost of about $200,000 per bus for indoor maintenance and storage facilities (American Public Transit Association 2005), annualized assuming a 30-year building life, and 7% discount rate.
    - Each bus provides an average of six hours of revenue service per day.

Table 4: Costs for New Transit Service

	Short-term (Scenario 1)	Long-term (Scenario 2)
Operating Costs		
Daily freeway VMT subjected to congestion (‘000)	12,479	20,798
Estimated percent VMT reduction due to pricing	10%	10%
Daily congested VMT reduced by those shifted from freeway driving (‘000)	1,248	2,080
Prior average vehicle occupancy assumed for these trips	1.00	1.00
Daily congested person miles of travel (PMT) reduced (‘000)	1,248	2,080
Average length of trip that was subjected to congestion (mi.)	6.7	6.7
Number of daily trips shifted from freeway driving (‘000)	186	310
Estimated max. number of new daily transit trips (‘000)	186	310
Estimated max. number of new annual transit trips (millions)	46.56	77.61
Estimated express bus operating cost per passenger	$2.40	$2.40
Estimated annual express bus system operating cost (million $)	**$111.75**	**$186.25**
Capital Costs		
Number of hours of revenue service per bus daily	6	6
Number of passengers served per hour of revenue service	42	42
Number of passengers served per bus annually	63,000	63,000
Total number of buses needed to operate the system	739	1,232
Capital cost per bus (million $)	$0.34	$0.34
Capital cost for all buses needed (million $)	$251.29	$418.82
Annualized capital cost for all buses needed (million $)	**$35.68**	**$59.47**
Capital cost per bus for maintenance and storage facilities (million $)	$0.20	$0.20
Capital cost for storage and maintenance facilities (million $)	$147.82	$246.37
Annualized capital cost for storage and maintenance facilities	**$11.97**	**$19.96**
Estimated express bus system capital cost per passenger	**$1.02**	**$1.02**
Annualized capital plus operating cost	**$159.41**	**$265.68**

Note that the above costs per passenger trip totaling about $3.50 reflect 50% bus occupancy. If the system is less successful in attracting transit riders (e.g., if many travelers found carpooling more convenient), costs per passenger trip would rise, but *overall system costs* are not expected to change significantly because the objective is to maintain high-quality, frequent service.

Capital and operating costs shown in Table 5 for park-and-ride facilities were estimated based on the following:

- Eighty percent of trip-makers that shift from freeway driving (to either transit or HOV passenger modes) would need to park at park-and-ride facilities.
- The cost for construction of a surface parking lot is estimated at about $2,200 per space in 2005 dollars. The annualized maintenance cost for surface parking is estimated $130 per space (U.S. Department of Transportation 1992).
- For a parking garage with three levels or more, construction costs are estimated at $12,300 per space. The annualized maintenance cost is estimated at $250 per space (U.S. Department of Transportation 1992).
- Most of the new park-and-ride spaces will be needed in exurban or suburban locations. At these locations, it is more likely that the public agency will own land within existing rights-of-way near interchanges or along the freeway. It may therefore be possible to build new park-and-ride facilities on surface lots, adjacent to express bus stations. It is assumed that 75% of new spaces at park-and-ride lots will use surface parking on existing highway rights-of-way and the rest will be in multi-story parking garages.
- Capital costs are annualized assuming a 7% discount rate and a 30-year life.

Table 5: Costs for Parking at Park-and-Ride Facilities

	Short-term (Scenario 1)	**Long-term (Scenario 2)**
Operating Costs		
Number of new daily transit or HOV passenger trips (‘000)	186	310
Number of daily round-trips needing parking (‘000)	75	124
Annual O & M cost per space for surface parking	$130.00	$130.00
Annual O & M cost per space for multi-story parking	$250.00	$250.00
Average annual O & M cost per space	$160.00	$160.00
Total annual O & M cost (million $)	**$11.92**	**$19.87**
Capital Costs		
Capital cost per space for surface parking	$2,200.00	$2,200.00
Capital cost per space for multi-story parking	$12,300.00	$12,300.00
Average capital cost per space	$4,725.00	$4,725.00
Total capital cost (million $)	$352.02	$586.70
Annualized capital cost (million $)	**$28.51**	**$47.52**
Annualized capital plus operating cost (million $)	**$40.43**	**$67.39**

SELF-FINANCING POTENTIAL FOR REGION-WIDE PRICING SCENARIOS

Annualized costs and revenues for the two scenarios are summarized in Table 6. A comparison of revenues to costs suggests that, for both scenarios, annual toll revenues will be adequate to pay for annualized costs for highway services as well as transit and park-and-ride services. This suggests that self-financing PPP arrangements may be feasible for both scenarios. The CRAST model may be used to develop agreements with private partners to design, build and operate segments of the system for the long-term scenario. For the short-term scenario, under which capital investments would be small, partners could be sought for contracts to operate larger parts of the regional network, e.g., the Virginia, Maryland and District of Columbia sub-networks. The TUP and HUP models could be used with private partners to operate the transit and park-and-ride facility components under both scenarios.

In the longer-term, as infra-red camera technology for counting vehicle occupants is further developed, it may be possible to base shadow toll rates on the number of persons (instead of vehicles) provided with free flow travel speeds on the system. The private partners operating the highway system would then have a further incentive to strive towards the public goal of maximizing *person* mobility and system *person* throughput, within the constraints of existing limited freeway rights-of-way.

Even after private contractor costs are paid for, the analysis in Table 6 suggests that, for Scenario 1, there will be a large surplus of revenue. Since the Scenario 2 analysis suggests

Table 6: Annualized Costs and Revenues (million $)

	Short-term (Scenario 1)	**Long-term (Scenario 2)**
Capital costs for lane additions	$0.0	$437.4
Freeway maintenance costs	$102.0	$132.0
Capital costs for toll collection/traffic management	$6.8	$8.1
Operations cost for toll collection/traffic management	$90.1	$150.2
Highway cost subtotal	**$198.9**	**$727.7**
Estimated shadow toll per VMT	$0.07	$0.16
Toll Revenues	**$491.4**	**$1,099.7**
Surplus after shadow toll payments	$292.5	$372.1
Express bus service cost	$159.4	$265.7
Cost of parking for transit and HOV users	$40.4	$67.4
Transit/HOV cost subtotal	**$199.8**	**$333.1**
Total multimodal annual costs	$398.7	$1,060.7
Surplus after multimodal payments	**$92.6**	**$39.0**
Potential fuel tax refunds		
Fuel tax per gallon (2005 dollars	$0.40	$0.30
Avg. highway fuel efficiency with free flow (mpg)	30.0	40.0
Fuel tax payments of tolled VMT (million $)	**$37.44**	**$35.10**

that its stream of toll revenue will be adequate to pay for all new multimodal services, surplus revenue under Scenario 1 could provide a source of funding for new investments in highway or transit services off the freeway system to benefit freeway corridor users, such as; (a) traffic management and improvements on parallel arterials which could reduce freeway demand and, therefore, the going toll rates; (b) improvements to arterials used for access to the freeway system; or (c) improvements to ways of accessing express bus stations, such as improved shuttle, carsharing or taxi-sharing services, or improvements to pedestrian and bicycle facilities. (This, again, would help keep rush hour toll rates low by making transit more attractive and therefore, reducing the demand for freeway driving.)

Some or all of the surpluses could alternatively be refunded to motorists in the form of rebates on fixed auto-related charges such as vehicle registration fees or drivers license fees. The bottom line of Table 6 suggests that fuel taxes paid by vehicles driving on tolled segments of the system could be refunded to motorists from the surpluses. This could reduce "double taxation" concerns, i.e., the public perception that tolls are a second tax for use of the same facility. This may increase the acceptability of new tolls.

SUMMARY AND CONCLUSIONS

The new public-private partnership approach developed in this paper can facilitate private involvement in the delivery of integrated roadway pricing and transit/HOV systems in metropolitan areas. The approach employs outcome-based contracting systems and incorporates financial incentives to maximize public mobility goals, with clear performance standards to ensure service quality. It addresses issues relating to unfettered private sector monopoly power as well as private sector concerns about revenue risk from possible future public agency actions to enhance competing alternatives to the tolled facility.

To evaluate financial self-sufficiency of a region-wide application of the concept, two region-wide pricing scenarios were assessed at a sketch level of analysis – a short-term scenario involving pricing all existing lanes on the limited access highway system and a long-term scenario involving addition of capacity at the most critical locations on the limited-access highway system. The results of the analysis suggest that both scenarios would generate new toll revenue sufficient to pay for all capital and operating costs, including costs for traffic management and toll operations, new fare-free express bus service, new park-and-ride facilities and freeway maintenance, and costs for new lanes under the long-term scenario. These results are dependent on several simplifying assumptions that were made to estimate costs and revenues. More detailed analysis will be needed to verify them in specific metropolitan areas.

References

American Public Transit Association web page accessed August 29, 2005, at: http://www.apta.com/research/stats/bus/buscost.cfm

Cambridge Systematics, Inc. and URS Corporation. *MnPass System Study*. Report prepared for the Minnesota Department of Transportation. 2005.

Charles River Associates, Inc. *Part Time Operators: The Trends and Impacts.* TCRP Report 58, Transportation Research Board, National Academy Press, Washington D.C. 2001.

Chen, Chao and Varaiya, Pravin. The Freeway-Congestion Paradox. *Access*. Number 20, Spring 2002: pp 40-41.

DeCorla-Souza, Patrick. FAIR Highway Networks: A New Approach to Eliminate Congestion on Metropolitan Freeways. *Public Works Management & Policy.* Volume 9, Number 3, 2005: pp 196-205.

Downs, Anthony. *Stuck in Traffic: Coping with Peak-Hour Traffic Congestion.* Brookings Institution Press. 1992

ECONorthwest and Parsons Brinckerhoff Quade & Douglas, Inc. TCRP Report 78, *Estimating the Benefits and Costs of Public Transit Projects: A Guidebook for Practitioners.* Transportation Research Board, Washington D.C., 2003. Available on the web at: http://gulliver.trb.org/publications/tcrp/tcrp78/index.htm

ITS Decision, Service and Technologies. Web site accessed May 6, 2005: http://www.calccit.org/itsdecision/serv_and_tech/Electronic_toll_collection/electron_toll_collection_report.html

MacDonald, Douglas B. *Measures, Markets and Mileposts.* The Gray Notebook for the Quarter Ending March 31, 2003, page 33. Washington State Department of Transportation. 2003.

Orange County Transportation Authority. *Success in the Fast Lanes: Fiscal Year 2004 Annual Report.* 2004. Available at: http://www.91expresslanes.com/generalinfo/91annualreport.pdf

Orange County Transportation Authority. *91 Expresslanes: Toll Schedules*, 2005. Available on the web at: http://www.91expresslanes.com/tollschedules.asp?p=m3

Parsons, Brinckerhoff, Quade and Douglas, Inc. *High Occupancy Toll Lanes – Potential for Implementation in the Atlanta Region*. Report prepared for the Georgia State Road and Tollway Authority, 2005.

Poole, Robert and C. Kenneth Orski. *HOT Networks: A New Plan for Congestion Relief and Better Transit.* Reason Public Policy Institute. Policy Study No. 305. February 2003. Available at: http://www.rppi.org/ps305.pdf

Resource Systems Group. *Illinois Tollway Value Pricing Focus Group Summary Report.* Prepared for the Illinois State Toll Highway Authority, 2003.

Sullivan, Edward. *Continuation Study to Evaluate the Impacts of the SR 91 Value-Priced Express Lanes.* Cal Poly State University, San Luis Obispo, CA, 2000. Downloadable from website: http://ceenve.calpoly.edu/sullivan/sr91/

Texas Transportation Institute. *2005 Urban Mobility Study*. Texas A & M University, College Station, TX. 2005.

Transportation Research Board. *Highway Capacity Manual.* 2000.

University of Minnesota Department of Computer Science. *Automobile Passenger Counting in the HOV Lane.* Prepared for Minnesota Department of Transportation. 1999.

U.S. Department of Transportation. *Characteristics of Urban Transportation Systems.* Publication Number DOT-T-93-07. Revised Edition. September 1992.

U.S. Department of Transportation. *Highway Economic Requirements System, Volume IV: Technical Report.* December 2000.

U.S. Department of Transportation. *Report on the Value Pricing Pilot Program through March 2004.* Available at:

http://knowledge fhwa.dot.gov/cops/hcx.nsf/All+Documents/AD276ECC2E3A077885257005006B5614/$FILE/March%202004%20Report%20of%20Congress.pdf

U.S. Department of Transportation. *National Household Travel Survey 2001.* Accessed August 2005 at: http://nhts.ornl.gov/2001

Wachs, Martin. Congestion in Cities – Where, When, What Kind, How Much. *Traffic Congestion: Issues and Options*. Presentation at the Conference held in Washington D.C., June 26-27, 2003. UCLA Extension Public Policy Program.

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