Creating a Financially Feasible, Sustainable, High Performance Metropolitan Transportation System

Patrick DeCorla-Souza[1]
Federal Highway Administration, Washington, DC
Phone: 202-366-4076
Fax: 202-366-3225
E-Mail: patrick.decorla-souza@dot.gov

Abstract

Metropolitan areas are facing increasing congestion but financial resources to provide new or expanded transportation infrastructure will be limited in the future. Moreover, environmental constraints limit expansion of the highway footprint in urban travel corridors. This paper assesses a strategy to alleviate recurring congestion on metropolitan highway systems by adding "dynamic" capacity during peak periods using shoulders as travel lanes, along with variable peak-period user charges levied on all lanes to manage demand and pay for the capacity improvements. It presents an analysis of the traffic, delay, fuel consumption, CO2 emissions, and cost and revenue impacts. The paper then discusses various technical and public acceptance issues with regard to the concept, and how these issues might be addressed.

INTRODUCTION

Major metropolitan areas in the U.S. are facing increasing levels of highway congestion, but it is extremely expensive to widen highways in urban areas, and environmental and social constraints limit the ability to expand the highway footprint. The normal cost of construction to add a lane on an urban freeway is estimated at about $13.4 million per lane mile by the Federal Highway Administration (2007). Weekday peak period use of a lane addition amounts to about 10,000 vehicles per weekday. As shown in Table 1, the cost per lane mile translates to a cost of about $7.00 for a 20-mile trip made on an added urban freeway lane during peak periods. On the other hand, fuel taxes generated from a 20-mile trip amount to a total of only about 40 cents, calculated based on fuel taxes averaging 40 cents per gallon and an average vehicle fuel efficiency rating of 20 mpg. The gap between user-based taxes and cost for a new lane is even higher for high cost urban freeways (see Table 1). Moreover, if new highway capacity is provided for use free of charge, it will continue to encourage low-density land use patterns and increased auto dependence, leading to a return to congestion.

---

[1] ***Disclaimer: The views expressed are those of the author and not necessarily those of the U.S. Department of Transportation or the Federal Highway Administration.***

Table 1. Costs for Highway Construction

Major Urbanized Areas	**Normal Cost**	**High Cost**
Construction cost/ lane mile*	$13.4 M.	$55.9 M.
Daily traffic volume in peak periods (5-6 hours/day)	10,000 vehicles	10,000 vehicles
Const. cost per vehicle per mile	$1,340	$5,590
Const. cost for 20-mile round trip	$26,800	$111,800
Annualized const. cost for 20-mile trip**	$1,742	$7,267
Cost for 20-mile trip per working day	**$7.00**	**$29.00**
Gas tax paid for 20-mile trip (2 cents/mile)	$0.40	$0.40

*Source: FHWA, in 2006 dollars

**Annualization factor 0.065 assuming a 5.25% discount rate and 30-years

This paper assesses a new approach to address metropolitan mobility and access issues. The concept could provide an environmentally sustainable and financially feasible solution to highway congestion. It seeks to reduce the footprint needed for highway expansion in urban areas and reduce its costs while providing a new revenue source to pay for that capacity expansion. At the same time, it ensures that the highway system will maintain a high level of performance throughout the peak periods. The concept builds on emerging strategies implemented in Europe and now being explored by the transportation community in the United States as possible options for providing new highway capacity without the need for new rights-of-way or major reconstruction. However, the safety of these approaches has not yet been fully assessed in the U.S. context. Therefore, the concept proposed in this paper is not ready for immediate application. Rather, the intent is to engender discussion and further exploration through collaboration among the transportation planning, finance, safety, and operations communities to find workable strategies to advance the concept in the United States.

FLEXIBLE AND EFFICIENT EXPRESS (FEE) HIGHWAYS

In congested metropolitan areas, a new “dynamic” travel lane could be created on limited access highways by narrowing existing lanes and using shoulder space. The shoulder travel lane would be open for use in conjunction with active management of all lanes on the highway, using overhead lane controls and dynamic message signs to harmonize speeds and keep traffic flowing freely and safely (see Figure 1). During peak periods, variable user fees would be used in conjunction with ramp metering to keep demand for use within the capacity of the highway. Should an incident occur in any lane, surveillance cameras would automatically communicate with overhead lane controls, which would shut down the appropriate lane(s) in advance of the incident location.

Figure 1. Shoulder Travel Lane with Overhead Lane Controls in the Netherlands

User fee rates would be pre-scheduled according to time of day and location in order to manage demand based on observed traffic patterns. Ramp metering would be used to fine tune access to the highway if demand is too close to capacity. This will ensure that traffic flow does not break down. Fees could be collected electronically at free-flow highway speeds using in-vehicle electronic tags. Vehicles without valid electronic tags would be identified and charged using license plate recognition technology. Buses and pre-registered vanpools would be issued special transponders that would exempt them from the fees. Highway performance could be guaranteed to users. When an incident shuts down a lane or two, leading to congestion delays, all fees could be suspended since users would not get the level of service promised. The potential loss of revenue would provide an additional incentive to the highway operator to clear incidents quickly.

We have termed this concept “Flexible and Efficient Express” or FEE highways. It would require little or no new rights-of-way, could be financed by leveraging the user fee revenue stream, and could be implemented in a relatively short period of time due to limited or no expansion of the highway footprint. Revenues from user fees could be used to pay for operations and maintenance, and for capital costs for new emergency pull-off areas, tolling infrastructure, active traffic management systems, and enhanced transit and ridesharing services to provide viable alternatives to driving alone.

In addition to alleviating recurring congestion, FEE highways could increase person throughput as well as vehicle throughput. Vehicle throughput would increase because an extra lane (i.e., the dynamic shoulder travel lane) would be available for use when needed. Also, demand management with pricing and ramp metering would prevent traffic flow breakdowns and thus eliminate the loss of vehicle throughput that currently occurs on unmanaged highways due to breakdown of traffic flow at bottlenecks (DeCorla-Souza 2010). Person throughput would increase due to increased use of transit and ridesharing, encouraged by investments in these alternative travel modes and by the disincentives to drive provided by the new peak period fees.

Limited access highways with standard lanes and shoulders could be re-striped as follows to create FEE highways:

- Left shoulder with reduced width, if feasible;
- 11 ft.-wide lanes, i.e., the lanes could be reduced from standard 12 ft. width;
- A 13-ft.-wide dynamic shoulder lane on the extreme right. (The wider lane is needed to allow for adequate lateral clearance between vehicles in the lane and any structures on the highway’s edge.)

TRAFFIC IMPACTS

Table 2 presents results from a traffic impact analysis of the FEE highway concept for a 10-mile highway segment with 6 existing lanes (i.e., 3 per direction). For comparison, a “No Pricing” alternative with the same physical lane configuration was also analyzed, and the results are presented in Table 3.

Table 2. Traffic Impacts on a 10-mile long 6-Lane Freeway -- Four FEE lanes per direction

	Existing Config.	Priced Lanes
Traffic volume (demand)	6,930	7,069
Number of lanes per direction	3	4
Traffic volume per lane	2,310	1,767
Capacity per lane at LOS E	2,350	2,307
Service flow volume at LOS C as a percent of capacity	0.65	0.65
Service flow volume per lane at LOS C (Q)	1,528	1,500
V/Q ratio	1.51	1.18
BPR alpha coefficient	0.02	0.02
BPR beta coefficient	10	10
Free flow speed (mph)	65.00	60.70
Travel time per mile with free flow speed (min.)	0.92	0.99
Actual travel time per mile at V/Q ratio (min.)	2.08	1.09
Time saved per mi. relative to Existing Config. (minutes)		0.99
Speed (mph)	28.87	55.01

Table 3. Traffic Impacts on a 10-mile long 6-Lane Freeway -- No Pricing

		Alternative Configuration		
	Existing Config.	**GP Lanes (Initial)**	**GP Lanes incl. Induced traffic**	**Total**
Traffic Impacts				
Traffic volume (demand)	6,930	6,930	7,914	7,914
Number of lanes per direction	3	4	4	4
Traffic volume per lane	2,310	1,733	1,978	
Capacity per lane at LOS E	2,350	2,307	2,307	
Service flow volume at LOS C as a percent of capacity	0.65	0.65	0.65	
Service flow volume per lane at LOS C (Q)	1,528	1,500	1,500	
V/Q ratio	1.51	1.16	1.32	
BPR alpha coefficient	0.02	0.02	0.02	
BPR beta coefficient	10	10	10	
Free flow speed (mph)	65.00	60.70	60.70	
Travel time per mile with free flow speed (minutes)	0.92	0.99	0.99	
Actual travel time per mile at V/Q ratio (minutes)	2.08	1.07	1.30	
Time saved per mi. relative to Existing Config. (minutes)		1.01	0.77	
Speed (mph)	28.87	55.96	46.00	
Induced travel estimation:				
Elasticity		-0.28		
Initial VHT at before expansion speeds		240.02		
Initial VHT after facility expansion		123.84		
Initial VHT savings		116.17		
Delay VHT per additional VMT		0.05		
Induced travel		984		

The analysis was performed for a prototypical urban freeway that is severely congested, based on the *Highway Capacity Manual* (Transportation Research Board 2000), i.e., the HCM, and the following inputs and analytical procedures:

- The existing urban freeway is assumed to have 12 ft.-wide lanes and a 10 ft.-wide right shoulder.
- Existing traffic demand is assumed to be at the maximum level that can be accommodated at Level of Service E (LOS E). For long-term analysis, a 5 percent secular growth is assumed, to account for population and economic growth.
- To be conservative in estimating benefits, it is assumed that there will be no change in travel mode. An increase in transit and carpool use could increase person throughput on the FEE highway, and consequently the benefits.
- Induced and diverted traffic resulting from LOS improvement is estimated using a short-term elasticity of demand relative to travel time reduction of -0.28 and procedures used in the SMITE model (DeCorla-Souza and Cohen 1997). For long-term analysis, an elasticity of -0.57 is used, to account for the additional traffic generated when new land development is precipitated due to the improved mobility provided by highway expansion (*3*). Induced traffic is estimated in the column titled “GP Lanes (Initial)” in Table 3. Note that the FEE highway curbs induced travel through the pricing mechanism, which sets fee rates to maintain a target speed (see Table 2).
- It is assumed that a minimum speed of 55 mph is to be maintained on the FEE highway, and traffic volume on the highway is estimated on that basis.
- Free flow speeds for 12-ft. lanes are based on Exhibit 13-6 of the HCM.
- Free flow speeds for 11-ft lanes are based on Exhibit 23-4 of the HCM; these speeds are further reduced due to reduced right shoulder lateral clearance, based on Exhibit 23-5 of the HCM. The resulting free flow speed is estimated at 60.7 mph.
- Actual operating speeds are estimated based on the Bureau of Public Roads (BPR) formula, with alpha and beta parameters from Nakamura and Kockelman (2002).

Highway lane capacity (at LOS E) is estimated as follows:

- For existing 12 ft.-wide general purpose lanes, Exhibit 13-6 in the HCM is used.
- Base lane capacity (at LOS E) for 11-ft. wide general purpose lanes is estimated as follows, based on Exhibit 23-3 of the HCM:
  - Capacity of 11-ft. wide lane = 1,700 + (10 X Free flow speed) = 1,700 + (10 X 60.7) = 2,307 vehicles

OTHER IMPACTS

Tables 4 and 5 present other impacts of the FEE highway and the No Pricing alternatives respectively. Safety impacts have not been estimated. User benefits (other than safety) are estimated based on the following:

Table 4. Other Impacts on a 10-mile long 6-Lane Freeway -- Four FEE lanes per direction

	Existing Configuration	FEE Highway
User Benefits on 10-mile Facility		
Facility length (mi.)	10.00	10.00
Total travel time on facility per mile (min)	14,401	7,711
Total delay reduced per mi. (minutes)		6,980
Average value of time ($/hour)		$14.60
Value of delay savings/mi./peak hour/direction		$1,698.47
Number of directions	2	2
Peak hours per weekday for both directions	4	4
Number of weekdays per year	250	250
Value of delay savings per mile annually		$3,396,934
Value of annual delay savings for full facility		**$33,969,345**
Annual delay savings for 10-mile facility (hours)		2,326,667
Annual delay savings per 10-mile trip on the facility (hours)		41
Fuel cost per gallon		$2.50
Gallons of fuel saved annually		1,605,401
Value of fuel saved		**$4,013,501**
Total delay and fuel cost saved annually		**$37,982,846**
Toll Revenue on 10-mile Facility		
Travel time saved in priced lanes (min/mi)		0.99
Perecent of traffic volume reduction per lane with pricing		-12%
Percentile in WTP distribution:		12%
Average toll rate per mi.		$0.10
Average toll for 10-mile trip		$0.97
Number of exempt vehicles per hour (passenger car equivalents)		200
Factor to account for revenue during shoulder hours		1.25
Annual toll revenue		**$16,593,749**
Greenhouse gas emissions on 10-mile Facility		
Fuel consumption rate (mpg)	16	23
Annual fuel consumption (gallons)	8,652,619	6,269,372
CO2 emissions per gallon	8,918	8,918
CO2 emissions annually (metric tons)	77,161	55,908
Percent change with FEE highway		-28%

Table 5. Other Impacts on a 10-mile long 6-Lane Freeway -- No Pricing

	Existing Configuration	Alternative Configuration
User Benefits on 10-mile Facility		
Facility length (mi.)	10.00	10.00
Total travel time on facility per mile (min)	14,401	10,323
Total delay reduced per mi. (minutes)		5,742
Average value of time ($/hour)		$14.60
Value of delay savings/mi./peak hour/direction		$1,397.18
Number of directions	2	2
Peak hours per weekday for both directions	4	4
Number of weekdays per year	250	250
Value of delay savings per mile annually		$2,794,363
Value of annual delay savings for full facility		**$27,943,633**
Annual delay savings for 10-mile facility (hours)		1,913,947
Annual delay savings per 10-mile trip on the facility (hours)		30
Fuel cost per gallon		$2.50
Gallons of fuel saved annually		1,320,624
Value of fuel saved		**$3,301,559**
Total delay and fuel cost saved annually		**$31,245,192**
Revenue on 10-mile Facility		
Travel time saved in FEE lane (min/mi)		
Perecent of traffic volume reduction with pricing		
Percentile in WTP distribution:		
Average toll rate per mi.		
Average toll for 10-mile trip		
Number of exempt vehicles per hour (passenger car equivalents)		
Factor to account for revenue during shoulder hours		
Annual toll revenue		
Greenhouse gas emissions on 10-mile Facility		
Fuel consumption rate (mpg)	16	
Annual fuel consumption (gallons)	8,652,619	7,797,092
CO2 emissions per gallon	8,918	8,918
CO2 emissions annually (metric tons)	77,161	69,531
Percent change with Alternative Configuration		-10%

- Value of time saved is based on the nationwide average value of time per vehicle hour from the *Urban Mobility Report* (Texas Transportation Institute 2007).
- Time saved by induced and diverted travelers on free lanes (for the No Pricing alternative) is estimated at half the time saved by prior travelers on the free lanes, consistent with consumer surplus theory.
- Fuel cost is estimated at $2.50 per gallon.
- Fuel consumption savings due to reduced delays is estimated at 0.69 gallons per hour of delay saved based on the relationship between congestion delay and fuel consumption in Exhibit 1 of the 2007 *Urban Mobility Report* (Texas Transportation Institute 2007).
- Congestion levels at LOS E are assumed to prevail only during 4 hours per direction on each weekday, on 250 working weekdays per year. For example, the *inbound* direction of an urban radial freeway may be congested at LOS E for 3 hours in the morning, but for only one hour in the afternoon, for a total of 4 hours each day.

Revenue estimates are based on the following:

- Toll charges are estimated based on travel time saved by those who use the FEE highway, average value of time from the *Urban Mobility Report* (Texas Transportation Institute 2007), the distribution of the value of time (or willingness-to-pay per vehicle hour saved) from FHWA's TRUCE-ST model (HDR Inc. 2009), and the percentage of vehicles "tolled off" the priced highway based on the difference between the total traffic on the highway with No Pricing and the number of vehicles that are accommodated on the FEE highway while meeting the 55 mph speed target.
- For annual revenue estimation, it is assumed that toll-exempt vehicles (i.e., buses and pre-registered vanpools) average 200 passenger car equivalents per hour.
- Congestion levels at LOS E (and the estimated fees) are assumed to apply only during 4 hours per direction on each weekday, on 250 working weekdays per year. However, revenue estimates based on these 4 hours are increased by 25 percent to account for revenues during shoulder hours.

To estimate greenhouse gas emissions, it is assumed that 10 percent of total fuel consumed during peak periods is diesel fuel, and 90 percent is gasoline. The following relationships from FHWA's TRUCE-ST model (HDR Inc. 2009) are used:

- Fuel efficiency (miles per gallon) is estimated based on speed, using the relationship: 8.8 + 0.25* speed.
- CO2 emissions per gallon are estimated based on 8,788 grams per gallon of gasoline and 10,084 grams per gallon of diesel.

The results of the analyses for the two alternatives, for the first year after implementation, are presented in Tables 4 and 5, and summarized in Table 6. The results suggest that the FEE highway alternative will provide much higher user benefits while maximizing greenhouse gas reductions. Long-term analysis results presented in Table 7 suggest that the No Pricing alternative will increase greenhouse gas emissions.

Table 6. Summary of Short-Term Impacts of Alternative Scenarios

For a 6-lane 10-mile Freeway

	Four FEE Lanes	No Pricing
User Benefits		
Annual delay reduced per 10-mile trip (hrs.)	41	30
Annual value of user benefits ($millions)	$37.98	$31.25
Revenues		
Charge for 10-mile trip ($)	$0.97	$0.00
Annual revenues ($millions)	$16.59	$0.00
Sustainability		
Change in peak period CO2 emissions (%)	-28%	-10%

For a 300-mile Freeway Network

	Four FEE Lanes	No Pricing
Number of miles of freeway (avg. 6 lanes)	300	300
Annual value of user benefits ($millions)	$1,139	$937
Annual revenues ($millions)	$498	$0
Annual costs ($millions)	$610	$500
Benefit/cost ratio	1.87	1.87
Annual surplus(+) or deficit (-)	($112.19)	($500.00)

Table 7. Summary of Long-Term Impacts of Alternative Scenarios

For a 6-lane 10-mile Freeway

	Four FEE Lanes	No Pricing
User Benefits		
Annual delay reduced per 10-mile trip (hrs.)	71	29
Annual value of user benefits ($millions)	$65.93	$33.65
Revenues		
Charge for 10-mile trip ($)	$1.97	$0.00
Annual revenues ($millions)	$33.78	$0.00
Sustainability		
Change in peak period CO2 emissions (%)	-39%	7%

For a 300-mile Freeway Network

	Four FEE Lanes	No Pricing
Number of miles of freeway (avg. 6 lanes)	300	300
Annual value of user benefits ($millions)	$1,978	$1,010
Annual revenues ($millions)	$1,013	$0
Annual costs ($millions)	$610	$500
Benefit/cost ratio	3.24	2.02
Annual surplus(+) or deficit (-)	$403.39	($500.00)

REGIONWIDE APPLICATION OF THE FEE HIGHWAY CONCEPT

A typical large metropolitan area such as Seattle, WA or Washington, DC has a freeway network of about 300 miles or 1,800 lane miles. Tables 6 and 7 extrapolate the impacts estimated for a 10-mile highway to a 300-mile highway network. The results in Table 6 represent short-term impacts in the first year after implementation. Table 7 summarizes impacts in the longer term, as traffic grows as a result of population and employment growth as well as new residential and commercial growth “induced” due to improved highway mobility.

Table 6 suggests that, for a 300-mile heavily congested freeway network currently operating at LOS E during peak periods, the FEE highway concept could generate $0.5 billion in the first year after implementation. In the longer term, as shown in Table 7, annual revenues could be as much as $1 billion. All revenue estimates are in real dollars, i.e., they are not adjusted for inflation. Furthermore, the long-term revenue estimates are conservative because value of time parameter was not adjusted to account for increases in real wage rates over time.

Preliminary cost estimates for conversion of standard highways to FEE highways, including tolling and active traffic management, have been prepared for a study in progress by Booz Allen Hamilton for the Federal Highway Administration. Based on the study, annualized capital and operating costs (in real dollars unadjusted for inflation) are estimated at $500 million for the No Pricing alternative and $610 million for the FEE highway alternative. User benefits shown in Tables 6 and 7 for the FEE highway concept exceed these costs. Revenues for the FEE highway concept fall short of costs in the first year, but estimated long-term revenues are more than adequate to pay for the annualized costs, generating significant surpluses. These surpluses could be invested to improve safety and mobility on the FEE highway system including multimodal transportation investments, or they could be returned to motorists in the form of tax rebates against existing fixed vehicle-based taxes such as annual vehicle registration fees.

SAFETY IMPACTS

A summary of research on the safety impacts of narrower lanes is provided by Ng and Small (2009). The authors find that both theoretical and empirical evidence linking narrow lane design to safety are ambiguous. According to the authors, it is an open question whether narrow lanes would in fact reduce safety. They suggest that it would depend on factors that vary from case to case, especially the speeds chosen by drivers. They cite several innovations in Europe that offer hope that roads designed for lower speeds could be accompanied by measures to ensure that lower speeds in fact prevail. For example, they point out that variable speed limits have been used for many years in Germany and the Netherlands, and recently in Copenhagen, primarily to smooth traffic during the onset of congestion — but also with a strong reduction in injury accidents in one German implementation.

A study by the Midwest Research Institute (Bauer et al 2004) suggests that the observed increases in accident frequency when freeways in the U.S. have been re-striped to narrower lanes cannot necessarily be attributed to the use of narrower lanes or the conversion of a shoulder to a travel lane. The study authors suggest that the use of the added narrow lanes as HOV lanes introduce a difference in speed between adjacent lanes, which may be another explanation for the increase in accidents. The FEE highway concept eliminates these speed differentials, since vehicles in all lanes travel at the essentially the same free-flow speed.

Nonetheless, the use of shoulders as travel lanes does present safety challenges, which need to be addressed. The first project in the U.S. to use shoulders as travel lanes "dynamically" during peak periods was implemented on I-35W in Minneapolis in October 2009, and the U.S. will learn from that experiment.

IMPACTS ON ENVIRONMENTAL SUSTAINABILITY

The extra FEE highway lane will increase freeway capacity. Under normal conditions, the faster travel times would lead to induced demand and an increase in vehicle miles traveled (VMT). However, with FEE highways, new user charges curb induced demand by increasing the out-of-pocket cost of driving alone. Moreover, revenue from fees may be used to improve alternative modes and thus can improve the attractiveness of alternative modes, i.e., the demand curves for alternative modes would shift to the right. In conjunction with the increase in demand for alternative modes, demand for driving alone would be reduced, i.e., the demand curve for driving alone would shift to the left.

Fees on the FEE highway could be set high enough to curb all induced traffic and ensure that the traffic volume stays the same as it was before conversion to a FEE highway. Fees will rise in order to keep peak traffic volumes at or below capacity as auto travel demand rises in the future. The higher fees will curb excessive use of the FEE highway, while at the same time generating more surplus revenue to invest transportation capacity improvements, including alternative modes of travel. These investments will help in accommodating growing demand and thus suporting continued growth in economic activity..

TRAFFIC IMPACTS ON ALTERNATIVE FREE ROUTES

The FEE highway's capacity will be higher than the existing highway's capacity, due to the extra FEE lane. If the FEE highway were available for use *free of charge* during peak periods, it could be expected that some drivers who currently drive on parallel facilities to avoid congestion on the highway would shift to the FEE highway, reducing traffic on the parallel facilities. Therefore, the peak period fees charged on the FEE highway will need to be high enough to keep excessive traffic away and maintain free flow of traffic on the expanded capacity. However, fees must also be low enough to ensure that the FEE highway is fully utilized. This will ensure that net diversion to alternative free routes does not occur.

Some drivers who do not value their time very highly (and have low willingness-to-pay) are likely to shift to free parallel surface facilities. However, this shift in traffic to free facilities is likely to be counterbalanced by shifts in traffic from free facilities to the FEE highway by those who value their time savings more highly than the fees being charged on the FEE highway.

Thus, what will occur is a redistribution of traffic based on driver values of time, but not necessarily a significant increase in traffic either on the FEE highway or on parallel free facilities. Note that fee rates will be relatively low on the FEE highway, because very few drivers will need to be "priced off" the highway, i.e., only drivers who have very low values of time (and who are therefore at the low end of the willingness-to-pay distribution) will be priced off. This poses an equity issue relative to low-income drivers, which is discussed later in this paper (see Public Acceptance Issues).

OVERALL CONGESTION REDUCTION IMPACTS

In a typical large city, vehicle miles traveled (VMT) on limited access highways tend to exceed VMT on arterials. For example, Seattle's 2007 daily VMT on limited access highways was 30.6 million, vs. only 27.1 million for arterials (Texas Transportation Institute 2009). However, a major portion of the delay faced by travelers tends to be on limited access highways, so FEE highways could alleviate a majority of the recurring congestion delay in metropolitan areas.

The advantage of limiting pricing to major highways is that it can be implemented using existing proven transponder-based technologies which are already widely deployed in the U.S. Another advantage is that it reduces the public's privacy concerns, since information on their exact destinations is not captured. With more ubiquitous pricing (for example, using Global Positioning Systems or GPS) people appear to be concerned that information on their ultimate destinations is being stored electronically on their in-vehicle units and may be available to unauthorized persons.

Recent research under the National Cooperative Highway Research Program (Sorenson et al 2009) explored non-GPS technology that could potentially be used to collect ubiquitous user charges. These technologies may have fewer privacy concerns, since specific location data would not be collected. They could potentially be used to complement the FEE highway concept by deploying time-of-day based pricing on roads off the FEE highway system. There would be no differentiation in toll rates based on location because location-specific data would not be available.

PUBLIC ACCEPTANCE

Concerns About Fairness

Imposing new charges on existing toll-free roads raises fairness concerns. Many members of the public believe that they have already paid for existing roads with their taxes, and new charges would amount to double taxation. However, experience shows that if the public is educated about the high costs for reconstruction and rehabilitation, they may accept congestion pricing as one way to help pay for these costs while receiving improved mobility from congestion relief. For example, the SR 520 floating bridge in the Seattle metropolitan area will become the first existing toll-free facility in the U.S. to charge new tolls that will vary to achieve performance targets. The public in Seattle understands the high costs to replace the SR 520 bridge, and that tax dollars will be insufficient to pay for these costs.

Public opinion surveys suggest that if the public is more accepting of new charges if they are convinced that revenues from new charges will go directly towards providing improved transportation service on the facilities on which the charges are imposed. The public accepts toll roads because they can see that the revenues go to support the specific facility on which they pay tolls. The public prefers tolls to taxes to pay for new highway capacity (Zmud and Arce 2008).

With FEE highways, the public could be convinced that the new charges will go to provide improved peak period service made possible by the extra physical capacity being provided. Such an approach is being successfully implemented in South Africa's Johannesburg/Pretoria metropolitan area, where 115 route miles of existing freeway is being widened and an additional 236 route miles are being upgraded, all of which will be funded through new electronically charged tolls on the existing free system (Poole 2009). This demonstrates that concerns about "double taxation" can be alleviated when the new charges are directly related to the extra benefits being provided.

Concerns About Availability of Travel Choices

The potential for gaining public support for FEE highways will be enhanced when the concept is presented as offering new and better travel choices – including improved alternative transportation modes. However, good transit service is not likely to exist in corridors oriented to suburban employment centers. Future streams of surplus congestion pricing revenues could be leveraged to pay up-front costs for new capital needs for transit rolling stock and park-and-ride facilities. Paratransit could also perhaps play a larger role in providing alternatives. For example, private shuttle services operate successfully without public subsidy for travel to airport destinations not served by transit, because of the high costs to park at airports. Higher costs to drive on suburban highways during peak periods could potentially spur development of such private services oriented to employment centers. Vanpool services are also likely to increase, due to the fee exemption and faster highway speeds. Additionally, employers could be encouraged to provide their employees with opportunities for telework and flexible work schedules to allow commuters to avoid peak period travel altogether.

FEE highways and public transportation can convey mutual benefits, with each supporting and reinforcing the effectiveness of the other. Reduced congestion on FEE highways can help improve the operating speed and reliability of express bus services, leading to increased public transportation ridership and reducing operating costs for public transportation providers. A high-quality public transportation system will enhance FEE highways by providing a viable alternative for serving commuters who decide to shift their mode of travel in light of new charges for highway use in peak periods.

Concerns About Effectiveness

Many members of the public are unconvinced that congestion pricing could actually relieve congestion, because they assume that because they would continue to drive and pay the charges, everyone else would do so too, and traffic levels would be as high as they were before imposition of the new charges.

However, recent studies (The Louis Berger Group 2009, Noblis, Inc. 2008, Department for Transport 2004) suggest that a relatively small reduction in existing traffic of about 10 percent or less can restore free-flowing traffic conditions on the highway system. This may be observed in metropolitan areas across the U.S. on Columbus Day, when a relatively small percentage of commuters are off work. A similar phenomenon occurs in August in Washington DC, when Congress is not in session. This suggests that no more than 10 percent of vehicles on a congested highway would need to be “tolled off” to significantly reduce highway congestion.

However, since new capacity will be provided on FEE highways, few drivers (if any) would need to be tolled off. The new fees would primarily serve to discourage new trips from being attracted to the highway, i.e., trips by people who previously did not drive on the highway during peak periods, also known as “induced” travel.

Concerns About Equity for Low-Income Divers

Concerns may be expressed that FEE highways may make it too expensive for low-skilled workers to get to their jobs, because entry-level and unskilled jobs are often not well served by public transit. Also, low-income workers tend to have jobs with fixed schedules, and pricing may be particularly unfair to those with less flexible work schedules, since they are unable to shift their time of travel.

A well-designed FEE highway pricing strategy can be less burdensome to low-income citizens with appropriate use of toll revenue. If a portion of the toll revenue is dedicated to transit, low-income transit riders can benefit significantly from toll-financed transit improvements. Policymakers can include protections for low-income individuals, such as “life-line” credits or toll discounts, or reimbursements for tolls paid based on income level. For example, a proposal for congestion pricing in New York City (that was stalled by the state legislature) would have provided reimbursements to low-income individuals qualifying for the federal Earned Income Credit. They would be reimbursed for any fees paid in excess of the fare for a transit trip.

Concerns About Administrative Costs

Concerns are often expressed about the high administrative costs for implementing and operating a congestion pricing scheme, relative to other ways of generating revenue from highway users. Operating costs amount to about 20 percent of revenue for a normal toll facility, based on a study in progress for the U.S. Department of Transportation. By HDR Inc. By comparison, collection of fuel taxes costs only about 1 percent of revenue.

Yet, congestion pricing (i.e., tolls only during peak periods of the day) is justified despite the high costs, because costs for implementation and operation are significantly exceeded by the benefits from reduced congestion and its economic, environmental and social impacts. The purpose of congestion pricing is not to collect revenue, but to achieve other economic, social and environmental goals. If the same amount of revenue as generated from congestion pricing were instead to be raised by fuel taxes, costs would indeed be lower, but the loss of benefits would be far greater.

For decision-making, the costs for implementation and operation of FEE highways must be compared with benefits, not with revenues collected. As Tables 6 and 7 demonstrate, the value of user benefits alone (i.e., time and fuel cost savings) would far exceed costs for implementation and operation of FEE highways. Synergistic combinations of FEE highways and supporting strategies should be subjected to a comparative benefit-cost or cost-effectiveness evaluation and compared with other alternatives. The long-range transportation planning process undertaken by metropolitan planning organizations (MPOs) could be used to educate the public about costs and benefits of alternative approaches. This would begin the discussion about the trade-offs between conventional transportation investment approaches and approaches involving congestion pricing. The MPO in Seattle is showing the way in the U.S. Five synergistic pricing alternatives were recently analyzed and presented for consideration by the public for the Year 2040 regional transportation plan for the Seattle area (Puget Sound Regional Council 2009).

Concerns About Privacy

All of the operating High-Occupancy Toll (HOT) lane projects in the United States and more than 250 other toll facilities across the country use electronic toll collection (ETC). Tolling agencies have devised a method to protect the public's privacy by linking the transponder and the driver's personal information with a generic, internal account number that does not reveal the driver's identity and that is not disclosed to other organizations. In addition, in many cases, a motorist can open an anonymous pre-paid account if he or she so chooses. However, toll facility operators have reported that even when such accounts have been offered to the public, there have been very few who have signed up. Singapore has alleviated privacy concerns by collecting tolls using smart cards with stored value that may be inserted into an in-vehicle unit. These “electronic purses” are replenishable at Automated Teller Machines (ATMs), and may also be used for other purchases unrelated to tolling.

Privacy does not appear to be a major concern with pricing of *only* the limited access highway network using transponder-based toll collection technology. In a focus group study on such a strategy (Patrella, Biernbaum and Lappin 2008), privacy was not an issue that resonated strongly or generated much discussion with most participants, perhaps because vehicle identification technology would be restricted to limited access highways only, and information on trip origins and destinations off the tolled system would not be collected.

SUMMARY AND CONCLUSIONS

The sketch-level analysis of the FEE highway concept presented in this paper suggests that it could prove to be a promising solution to metropolitan highway congestion, while at the same time providing a stream of toll revenue that could be leveraged to pay for the concepts' own implementation as well as other complementary multimodal transportation investments and services. However, more detailed assessments of the opportunities and options in specific metropolitan areas will be needed, and safety challenges will need to be addressed. The intent of this paper is to stimulate further exploration and discussion of the concept and to generate other ideas. Further research and study will be needed to develop active traffic management strategies to address operational and safety issues that could result from reduced lane widths and creation of dynamic shoulder lanes.

Acknowledgements: The views expressed are those of the author and not necessarily those of the U.S. Department of Transportation or the Federal Highway Administration..

REFERENCES

Bauer, Karin M., Douglas W. Harwood, Warren E. Hughes, and Karen R. Richard. Safety Effects of Narrow Lanes and Shoulder-Use Lanes to Increase Capacity of Urban Freeways. *Transportation Research Record 1897.* Transportation Research Board, National Research Council, Washington, DC, 2004, pp. 71-80.

Berman, Wayne; Douglas Differt, Kurt Aufschneider, Patrick DeCorla-Souza, Ann Flemer, Lap Hoang, Robert Hull, Eric Schreffler, and Grant Zammit. *Managing Travel Demand – Applying European Perspectives to U.S. Practice.* Report No. FHWA-PL-06-015. Federal Highway Administration. May 2006.

DeCorla-Souza, Patrick and Harry Cohen (1997). Accounting for Induced Travel in Evaluation of Urban Highway Expansion. *Transportation*. Available at: http://www.fhwa.dot.gov/steam/doc.htm

DeCorla-Souza, Patrick (2010). "A Freeway Congestion Pricing Paradox." Presented at the TRB Annual Meeting in January, 2010.

Department for Transport (2004). Feasibility Study of Road Pricing in the U.K. Available at: http://www.dft.gov.uk/pgr/roads/introtoroads/roadcongestion/feasibilitystudy/studyreport/

Federal Highway Administration (2007). *2006 Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance*. *Appendix A: Highway Investment Analysis Methodology.* HERS Highway Improvement Cost Inputs. Available at: http://www.fhwa.dot.gov/policy/2006cpr/appa.htm

HDR, Inc. (2009). *TRUCE-ST User's Guide*. Prepared for the Federal Highway Administration. Available at: http://ops.fhwa.dot.gov/tolling_pricing/value_pricing/tools/index.htm

Nakamura, K. and Kockelman, K. (2002). Congestion Pricing and Roadspace Rationing: An Application to the San Francisco Bay Bridge Corridor. *Transportation Research* 36A (5): 403-417.

Ng, Chen Feng and Kenneth Small. *Tradeoffs among Free-flow Speed, Capacity, Cost, and Environmental Footprint in Highway Design*. Available at: http://www.economics.uci.edu/docs/2008-09/small-04.pdf

Noblis, Inc. (2008). *Roadway Network Productivity Assessment: System-Wide AnalysisUnder Variant Travel Demand*. Available at: http://ops.fhwa.dot.gov/publications/fhwahop09019/fhwahop09019.pdf

Poole, Robert (200). *Surface Transportation Innovations*. Reason Foundation. Issue No. 74, December 2009.

Puget Sound Regional Council (2009). Transportation 2040: Draft Environmental Impact Statement. Available at: http://psrc.org/projects/trans2040/deis/index.htm

Sorensen, Paul; Liisa Ecola, Martin Wachs, Max Donath, Lee Munnich, Betty Serian (2009). *National Cooperative Highway Research Program (NCHRP) Web-Only Document 143: Implementable Strategies for Shifting to Direct Usage-Based Charges for Transportation Funding*. June 2009.

Texas Transportation Institute (2007). *2007 Urban Mobility Report: Appendix A*. Texas A & M University, College Station, Texas.

Texas Transportation Institute (2009). *2009 Urban Mobility Report*. Texas A & M University, College Station, Texas. Available at: http://mobility.tamu.edu/ums/congestion_data/tables/seattle.pdf

The Louis Berger Group, Inc. (2009) *Examining the Speed-Flow-Delay Paradox in the Washington, DC Region: Potential Impacts of Reduced Traffic on Congestion Delay and Potential for Reductions in Discretionary Travel during Peak Periods*. Available at: http://ops.fhwa.dot.gov/publications/fhwahop09017/fhwahop09017.pdf

Transportation Research Board (2000). *Highway Capacity Manual.* National Resreach Council, Washington DC, pp 13-13.

Margaret Petrella, Lee Biernbaum, and Jane Lappin (2008). *Exploring a New Congestion Pricing Concept: Focus Group Findings from Northern Virginia and Philadelphia.* Volpe National Transportation Systems Center. Available at: http://ops.fhwa.dot.gov/tolling_pricing/resources/report/cpcfocusgrp/congestion_focus_grp.pdf

Zmud, Johanna and Carlos Arce. *Compilation of Public Opinion Data on Tolls and Road Pricing*, NCHRP Synthesis 377. Transportation Research Board, 2008. Available at: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_377.pdf.