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Bay Bridge Toll Evaluation: Final Report

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UC Berkeley
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Executive Summary

On July 1, 2010, the Bay Area Toll Authority (BATA) raised the tolls on the seven state-owned bridges in the San Francisco Bay Area. For six of the bridges, a flat $5 toll was implemented for passenger vehicles with a 50% discount ($2.50 toll) for peak-period 3+ person carpools, which had previously crossed the bridges free of charge. On the San Francisco-Oakland Bay Bridge, a more complex toll structure was put into place. The toll was increased to $6 during weekday peak periods (5-10 a.m. and 3-7 p.m.), and the off-peak weekday toll was left unchanged at $4. The peak period 3+ person carpool toll was set at $2.50, the same as on other bridges.

A year-long independent study was carried out at the University of California, Berkeley, evaluating the effects of the new toll structure on the Bay Bridge. The study examined the following questions:

- What effects did the new tolls have on traffic volumes on the Bay Bridge?
- How did traffic conditions change in response to the peak/off-peak tolls?
- How much of the change in Bay Bridge traffic was due to the toll changes, and how much was due to the recession, increased fuel prices, and other external factors?
- How have carpooling and transit ridership been affected?
- How did the traveling public respond to the changes in bridge tolls?
- How did businesses react to the change in Bay Bridge tolling?

This Executive Summary reports the major findings from the UC Berkeley study.

1.0 Effects on Traffic Volumes

For the first full year of the toll increases, total traffic volumes on the Bay Bridge decreased by 1% compared to the previous year (see Table ES-1). Vehicles in the cash/FasTrak lanes increased by 3% and vehicles in the carpool lanes decreased by 26%. The decrease in carpools affects approximately 13,000 people, assuming an average of three people per vehicle. If they all became solo drivers, there would be 8,700 more vehicles. However, there are only 3,300 more vehicles in the cash/FasTrak lanes. Thus, the majority of carpools did not become drive-alone bridge crossers.

Table ES-1: Average Daily Traffic, Work Days (Bay Bridge)

Lane	Before Toll Increase	After Toll Increase	Vehicle Difference	% difference
Cash/FasTrak Lane	108,112	111,419	3,307	+3%
Carpool Lane	16,898	12,534	(4,364)	-26%
Total	125,010	123,953	(1,057)	-1%

Source: BATA, weekday volumes from 7/1/09 to 6/30/10 compared to volumes from 7/1/10 to 6/30/11

2.0 Changes in Traffic Conditions

Detailed analyses of Bay Bridge traffic data, lane by lane and hour by hour, show that improvements in travel times following the toll increases were relatively large for some times of day and some of the approaches, and less significant for others. Traffic data show that shifts out of the peak into off-peak times of day occurred. Carpool lane usage dropped considerably, but the other lanes continued to function better than before the toll increase, suggesting that the carpoolers did not change to driving alone during the peak commute periods. Findings from surveys and focus groups suggest that some carpoolers switched to transit, some traveled off peak, and some are in two-person carpools in the cash/FasTrak lanes.

3.0 Sorting Out Toll Effects From Other Factors

Traffic changes can result not only from tolls but also from changes in employment levels, costs of operating a motor vehicle (fuel, parking) and competition from transit, among other factors. Models were developed to sort out these factors. The models indicate that the imposition of the HOV toll was responsible for over half the reduction in peak period usage in the carpool lanes, but other factors such as gas price hikes, unemployment levels, and the availability of competitive transit services also contributed to the carpool decline.

4.0 Effects on Carpools and Transit

Vehicles using the peak period HOV lanes declined significantly after the toll was imposed. However, the carpoolers did not just switch to driving alone. Evidence from a variety of sources indicates that some of the former HOV lane users are now in two-person carpools (but are not picking up a third rider), some are using transit, and some have decided to travel off-peak. Some also are consolidating trips, and some are shopping and dining out closer to home. Some travelers who did not previously carpool have started to do so as well. For those who carpooled less, it was no longer an option because of personal circumstances. The reasons often included moving to another city, new job or change in work hours, work-related travel and more personal plans, new relationships and children in the household, and personal injury. Others noted that their carpool partner was no longer available as one of them had changed jobs. Some noted that the new carpool toll combined with perceived increase wait times at the casual carpool sites negated their perceived benefits of carpooling.

The impact on transit has been minor. BART ridership is up, WestCAT has instituted new transbay services, and AC transit transbay services are reportedly holding steady. Transit ridership also is affected by transit service and price changes, as well as others factors such as unemployment.

5.0 Travelers' Responses to Toll Changes

Surveys and focus groups were used to investigate bridge travelers' responses to the toll changes. A common initial reaction to the toll increase was resigned acceptance; and over time this settled into a broader acceptance of the increase. However, there was relatively low public awareness of the reasons for the toll increases or how these charges relate to transport costs and financing mechanisms. Concerns about whether the funds were being well spent and costs controlled persisted throughout the year (reflecting the broader public debate about government spending).

Many of those who participated in surveys or focus groups reported that they use transit more, telecommute more, and try to combine trips. Toll increases were a factor but gas prices and concerns about income security in a time when jobs are being lost were even more significant motivations.

Focus groups with carpoolers indicated that the presence of a toll, and not just the dollar amount of it, contributed to the drop in carpoolers. Casual carpoolers were confronted for the first time whether and how to share costs. The social dynamics this set into motion were uncomfortable for many, and some decided not to continue the practice. In addition, however, focus group participants listed a wide variety of reasons for carpooling less, including loss of carpool partners due to cutbacks in the workforce, changes in work hours, a new job location or new residence, and changes in household composition. Some also reported that employer programs providing assistance to carpoolers and others in a number of instances had been cut back or replaced with a simpler pretax treatment of parking and transit expenses.

6.0 Business Responses to Toll Changes

Interviews with business groups, owners and managers found very little change in practices because of the toll increases. This was partly because the increase was not seen as a major change and partly because only a portion of businesses' employees, customers, clients or suppliers travel to them via a toll bridge. Businesses with highly paid labor forces and those dependent on timely deliveries were broadly supportive of congestion pricing because for them, saving time and expanding the size of the commute shed are important business considerations. Small retailers were thought to be more vulnerable to cost increases affecting early morning or early evening travel across the Bay Bridge and were also thought to be less able to control costs by scheduling deliveries or shipments outside the peak. Freight toll increases had not yet come in to effect, so the full force of these changes could not be observed or studied at this time.

1.0 Overview

On July 1, 2010, the Bay Area Toll Authority (BATA) raised the tolls on the seven state-owned bridges in the Bay Area by $1.00. For six of the bridges, a flat $5 toll was implemented for passenger vehicles and a $2.50 toll was instituted on carpools, which had previously crossed the bridges free of charge.

On the San Francisco-Oakland Bay Bridge, a more complex toll structure was put into place. The toll increased to $6 during weekday peak periods (5-10 a.m. and 3-7 p.m.), leaving the off-peak weekday toll unchanged at $4. Weekend tolls were set at a flat $5. A $2.50 toll was instituted on carpools.

While BATA's principal reason for increasing the toll on the six other state-owned bridges was to help pay for earthquake retrofits, the Bay Bridge toll schedule was specifically designed to serve as a mild form of congestion pricing. It was hoped that the 50% surcharge for peak period travel on the Bay Bridge, one of the most congested highway links in the nation, would induce a portion of the bridge users to schedule their travel off-peak, switch to transit, or otherwise cut back on their peak period use of the facility, reducing congestion and related energy use and emissions.

This report presents findings of a year-long independent study, commissioned by BATA and conducted by researchers at the University of California, Berkeley, evaluating the effects of the new toll structure on the Bay Bridge. The study examined the following questions:

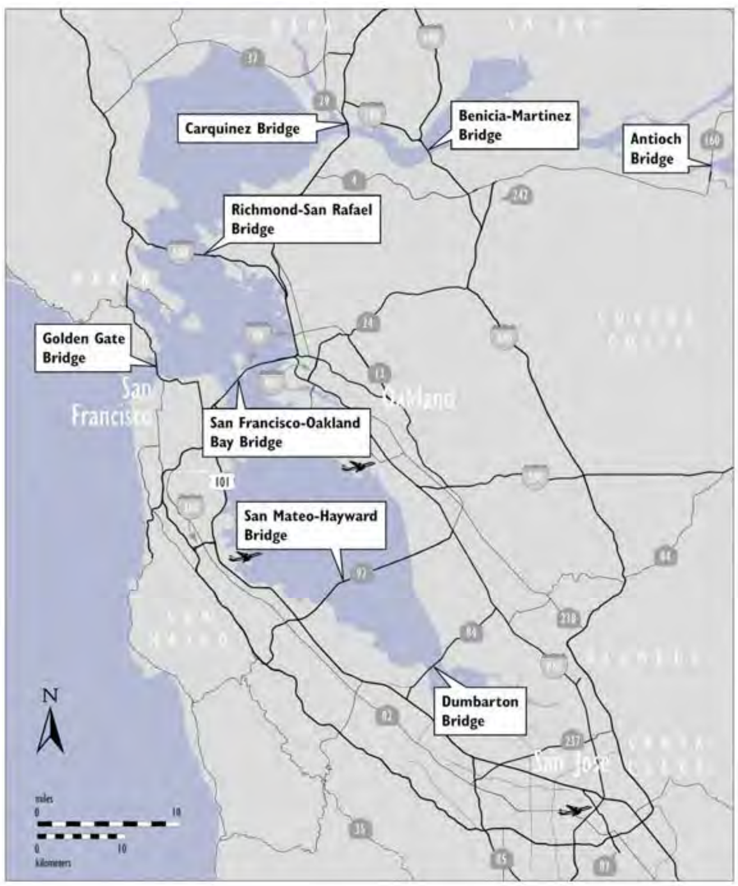
- What effects did the new tolls have on traffic volumes and revenues on the Bay Bridge and the other state-owned bridges?
- How did traffic conditions change in response to the peak/off-peak tolls?
- How much of the change in Bay Bridge traffic was due to the toll changes, and how much was due to the recession, increased fuel prices, and other external factors?
- How have carpooling and transit ridership been affected?
- What are the consequences for energy use and emissions?
- How did the traveling public respond to the changes in bridge tolls?
- How did businesses react to the change in Bay Bridge tolling?

2.0 Background

Eight bridges serve as major travel arteries in the San Francisco Bay Area (Figure 1). The Golden Gate Bridge is owned and operated by the Golden Gate Bridge, Highway and Transportation District. BATA administers the toll revenues from the following seven state-owned bridges:

- Antioch Bridge
- Benicia-Martinez Bridge
- Carquinez Bridge
- Dumbarton Bridge
- Richmond-San Rafael Bridge
- San Francisco-Oakland Bay Bridge
- San Mateo-Hayward Bridge

Figure 1. Toll Bridges in the San Francisco Bay Area



Source: Bay Area Toll Authority

Toll revenues are used for the ongoing operation, maintenance and administration of the bridges. Tolls also help to fund capital improvements and rehabilitation of the bridges and their approaches. In addition, a portion of the toll revenues is used to support transit in the bridge corridors. From time to time, tolls have been increased through legislation to fund various programs and activities (see Tables 1 & 2).

Table 1. Toll History of State-Owned Bay Area Bridges

Year	Toll Level	Amount of Toll Increase (two-axle vehicles)	Total Toll Level	Legislation Authorizing Toll Increase
1989	Varied (Bay Bridge, 75 cents)	Varied (Bay Bridge, 25 cents)	$1.00	Senate Bill 45 (Lockyer) of 1988 and **Regional Measure 1** of 1988 to fund a specific list of transportation projects and programs, such as bridge projects and rail extensions (voter approved)
1998	$1.00	$1.00	$2.00	Senate Bill 60 (Kopp) of 1998 to fund the toll bridge seismic retrofit program
2004	$2.00	$1.00	$3.00	Senate Bill 916 (Perata) of 2003 and **Regional Measure** 2 of 2004 to fund specific transportation projects and programs *(voter approved)*
2007	$3.00	$1.00	$4.00	Assembly Bill 144 (Hancock)/Senate Bill 66 (Torlakson) of 2005 to fund cost increases in the toll bridge seismic retrofit program
2010	$4.00	$1 on all bridges; except for Bay Bridge (Multi axle vehicle toll increase in two phases beginning 7/2011)	$5 all bridges and $2.50 carpool toll; Bay Bridge—weekdays: $6 am and pm peak toll; $4 off-peak toll for non-HOV autos; and $2.50 carpool toll in peak periods	AB 1175 (Torlakson) of 2009 to include retrofit of the Antioch and Dumbarton bridges.

Table 2. Legislation Related to Toll Bridge Seismic Retrofit Program (1995 to present)

Legislation	Major Provisions
Senate Bill 146 (Maddy), 1995; authorized Proposition 192 of 1996	Provided $2 billion in general obligation bond funds for the state's seismic retrofit program of bridges, highways, and overpasses, including $650 million for state-owned toll bridges.
Senate Bill 60 (Kopp), 1997	Funded approximately $2 billion in cost increases for the toll bridge seismic retrofit program. The state and region evenly funded these added costs. Added $1 seismic retrofit toll surcharge on Bay Area bridges for eight years beginning in 1998 and permitted MTC to extend the toll an additional two years to expend $230 million in toll revenues for "amenities" — a signature tower design, an east span pathway or the Transbay Terminal.
Senate Bill 226 (Kopp), 1997	Created the Bay Area Toll Authority (BATA), whose board is the MTC commission. BATA was given oversight and administration authority over the $1 base toll and the Regional Measure 1 program.
AB 2038 (Migden), 1998	Authorized a proposed pathway for the Bay Bridge's west span as an eligible toll bridge "amenity."
AB 1171 (Dutra), 2001	Funded approximately $2.4 billion in cost increases for the toll bridge seismic retrofit program. Cost increases were shared roughly between the state and region. Extended $1 Bay Area seismic retrofit toll surcharge an additional thirty years.
AB 144 (Hancock) and SB 66 (Torlakson), 2005	Funded $3.6 billion in cost increases for the toll bridge seismic retrofit program. Cost increases were divided as follows: 82.5% from the Bay Area and 17.5% from the state. Increased Bay Area tolls by another $1 to take effect no earlier than January 2007. Transferred full oversight and administrative authority over all revenue received from Bay Area state-owned toll bridges to BATA/MTC. Created the Toll Bridge Program Oversight Committee consisting of MTC/BATA, Caltrans and CTC directors to oversee project management and contracting. The committee must receive BATA approval of contract specifications and bid documents. (SB 66 of 2005 was enacted to clarify various sections of AB 144.)
AB 1175 (Torlakson), 2009	Includes Antioch and Dumbarton bridge retrofit projects as eligible expenses for toll revenues. Allows for toll to vary by bridge and for carpools to receive a discounted toll.

Voters have approved toll increases through two regional measures. Regional Measure 1, approved by Bay Area voters in 1988, raised tolls on the state-owned bridges to standard $1 on all of the stated owned bridges, with the Bay Bridge increasing from 75 cents to $1. It committed the proceeds to specific bridge improvements including a new span for the Benicia-Martinez Bridge, a replacement for the west span of the Carquinez Bridge, and widening of the San Mateo-Hayward Bridge. Regional Measure 2 was approved by Bay Area voters in 2004 and increased tolls on the region's state-owned bridges by an additional $1 to fund new mass transit services and highway improvements intended to relieve congestion along the bridge corridors.

Tolls also have been raised to cover increased costs of operating the bridges and to pay for important projects. Seismic safety projects have been funded by toll surcharges since 1998, when a $1 surcharge was added to help finance seismic safety projects on five of the bridges. The seismic surcharge increased by $1 per vehicle in January 2007, and then by another $1 in July 2010 across all the bridges. However, the July 2010 increase also included congestion pricing for the Bay Bridge and carpool tolling.

3.0 Toll Increases – Effects on Traffic Volumes & Revenues

Table 3 presents data on the total number of toll-paid vehicles and the amount of base toll revenue generated on all of the toll bridges for fiscal years 1994 through 2011. The table shows that toll-paid vehicle volumes peaked in 2003-04, then declined by almost 4% the next year and continued to decline a small amount each year through 2009-10. The declines in bridge traffic reflect a combination of higher tolls, more competitive transit services, and the economic recession, which began in late 2007 and continues to this day. Bridge toll revenues peaked in 2007-08 but then declined the next two years, increasing again in 2010-11 following the July 1, 2011 toll increase.

Table 3. Eighteen Years of Toll Revenue on the Bay Area's Seven State-Owned Bridges

Fiscal Year	Total # of Toll-Paid Vehicles	% Change from Previous Year	Total Toll Revenue
1993-94	111,798,248	1.8%	$125,941,263
1994-95	112,427,726	0.6%	$126,616,941
1995-96	114,598,485	1.9%	$129,199,734
1996-97	115,630,507	0.9%	$131,578,511
1997-98	116,192,149	0.5%	$189,923,549
1998-99	117,386,277	1.0%	$254,627,520
1999-00	120,691,673	2.8%	$261,563,145
2000-01	122,933,994	1.9%	$265,933,515
2001-02	123,826,454	0.7%	$268,230,487
2002-03	124,048,393	0.2%	$272,974,790
2003-04	124,742,532	0.6%	$270,487,917
2004-05*	120,135,213	-3.7%	$369,301,477
2005-06	118,297,920	-1.5%	$374,987,285
2006-07*	116,658,521	-1.4%	$422,354,852
2007-08	114,570,347	-1.8%	$491,685,881
2008-09	113,072,157	-1.3%	$486,964,555
2009-10	112,113,971	-0.8%	$466,085,581
2010-11*	120,011,760	7.0%	$614,944,377

* toll increase in July 2004, January 2007 and July 2010

As shown in Table 4, traffic levels vary by bridge, reflecting differences in markets and travel alternatives. Traffic also fluctuates and not always in the same amounts or direction from bridge to bridge.

Table 4. Traffic Volumes by State-Owned Bridge in the San Francisco Bay Area, 2001 to 2011

Fiscal Year	Antioch	Benicia	Carquinez	Dumbar-ton	Richmond-San Rafael	SF-Oakland	San Mateo - Hayward
2000-01	2,115,873	17,158,684	21,193,743	10,948,299	12,276,754	45,168,355	14,072,286
2001-02	2,325,423	17,732,756	21,677,767	10,778,861	12,468,123	45,117,544	13,725,980
2002-03	2,354,103	17,794,558	21,823,764	10,223,777	12,513,519	44,995,916	14,342,756
2003-04	2,477,631	17,987,638	22,053,941	9,976,620	12,398,819	44,646,387	15,201,496
2004-05	2,472,267	17,116,312	21,344,225	9,297,568	11,758,224	43,357,197	14,789,420
2005-06	2,479,233	17,071,427	20,914,337	9,529,100	11,907,709	41,264,835	15,131,279
2006-07	2,517,369	16,974,626	20,722,097	9,516,215	11,912,958	40,134,300	14,880,956
2007-08	2,365,837	17,440,220	19,875,211	9,193,831	11,782,281	39,555,251	14,357,716
2008-09	2,208,357	17,426,414	19,440,890	8,707,943	11,541,829	40,118,033	13,628,691
2009-10	2,136,215	17,714,805	19,057,158	8,746,234	11,752,427	38,649,493	14,057,639
2010-11	2,121,747	18,013,438	19,631,384	9,646,766	12,002,435	43,370,110	15,225,880

Table 5 shows the toll schedule for the Bay Bridge before and after the increased tolls were put into place in July 2010. On other bridges, a flat $1 increase to $5 was adopted and a carpool toll of $2.50 was introduced for the first time. For the Bay Bridge, the weekday peak period toll was raised to $6, the weekday off-peak tolls were left at $4, and weekend tolls went to a flat $5. As on the other state-owned bridges, a $2.50 carpool toll was added.

Table 5. Toll Schedule for the Bay Bridge

	Weekday Peak *(5AM-10AM, 3PM-7PM)*	Weekday Off-peak	Carpools *(5AM-10AM, 3PM-7PM)*	Weekends
Before 7/1/10	$4.00	$4.00	Free	$4.00
After 7/1/10	$6.00	$4.00	$2.50*	$5.00

**Payable by FasTrak only; must use designated lanes to obtain $2.50 discount toll*

The new toll schedule was intended not only to raise the equivalent amount of revenues as a flat $5 toll would have raised, but also to serve as a mild form of congestion pricing. Studies of have shown that levying a higher toll during congested periods can lead some travelers to travel at other, less congested times of the day, switch to other modes of travel, change the route used, consolidate trips, choose a different destination, or choose to telecommute, teleconference, or teleshop instead of travel. Prior to the toll increase, BATA consultants predicted that once the tolls settled into place, the net effect would be a 3-4% reduction in peak period traffic, due to both a reduction in the number of auto trips and the time that those trips are made.

BATA volume data by time of day indicate that some Bay Bridge travelers have indeed shifted their trips out of the peak period, traveling just before the peak period toll goes into effect or after the peak toll is over. Table 6 shows changes in traffic volumes by lane used (FasTrak, cash, HOV) on the Bay Bridge, comparing April/Early May 2010, before the toll increase, with April 2011, after the new tolls were implemented and travelers had sufficient time to adjust to it or make changes in their travel behavior. The table shows that there were significant changes in both the traffic volume and mix of payment types at various times during the peak periods. Users of the FasTrak lanes increased; cash patronage declined; vehicles in the carpool lanes declined substantially.

Table 6. Bay Bridge Volume Comparison
(April/Early May 2010 vs. April 2011)

	April/Early May 2010				Volume Change (vehicles)				Percent Change			
	Total	FT	HOV	Cash	Total	FT	HOV	Cash	Total	FT	HOV	Cash
4-5 am	2,019	1,162	30	826	***413***	***314***	-21	***120***	***20.4%***	***27.0%***	*	***14.5%***
5-6 am	6,040	3,086	1,108	1,846	***-713***	-121	***-252***	***-340***	***-11.8%***	-3.9%	***-22.7%***	***-18.4%***
6-7 am	8,936	4,291	2,538	2,107	-133	414	***-445***	-102	-1.5%	9.6%	***-17.5%***	-4.8%
7-8 am	8,598	3,363	3,804	1,431	369	***710***	***-446***	105	4.3%	***21.1%***	***-11.7%***	7.3%
8-9 am	8,433	3,688	3,280	1,465	194	***565***	***-462***	91	2.3%	***15.3%***	***-14.1%***	6.2%
9-10 am	7,899	4,235	1,761	1,903	-289	228	***-442***	-75	-3.7%	5.4%	***-25.1%***	-3.9%
10-11 am	7,281	4,332	70	2,880	191	***546***	-3	***-353***	2.6%	***12.6%***	*****	***-12.2%***
2-3 pm	5,977	3,388	54	2,536	***696***	***601***	-4	100	***11.6%***	***17.7%***	*	***3.9%***
3-4 pm	6,693	3,519	785	2,389	-169	125	***-311***	17	-2.5%	3.5%	***-39.6%***	0.7%
4-5 pm	7,622	4,352	883	2,388	-116	186	***-237***	-65	-1.5%	4.3%	***-26.9%***	-2.7%
5-6 pm	7,937	4,779	962	2,196	238	***406***	***-252***	84	3.0%	***8.5%***	***-26.2%***	3.8%
6-7 pm	6,611	3,869	881	1,861	7	***198***	***-339***	***148***	0.1%	***5.1%***	***-38.5%***	8.0%
7-8 pm	4,832	2,861	63	1,908	***669***	***610***	-8	67	***13.8%***	***21.3%***	*	***3.5%***
5-10 am	39,906	18,664	12,491	8,750	-572	***1795***	***-2406***	-320	-1.4%	***9.6%***	***-16.4%***	-3.7%
3-7 pm	28,683	16,519	3,511	8,834	-41	***914***	***-1140***	185	-0.1%	***5.5%***	***-32.5%***	2.1%

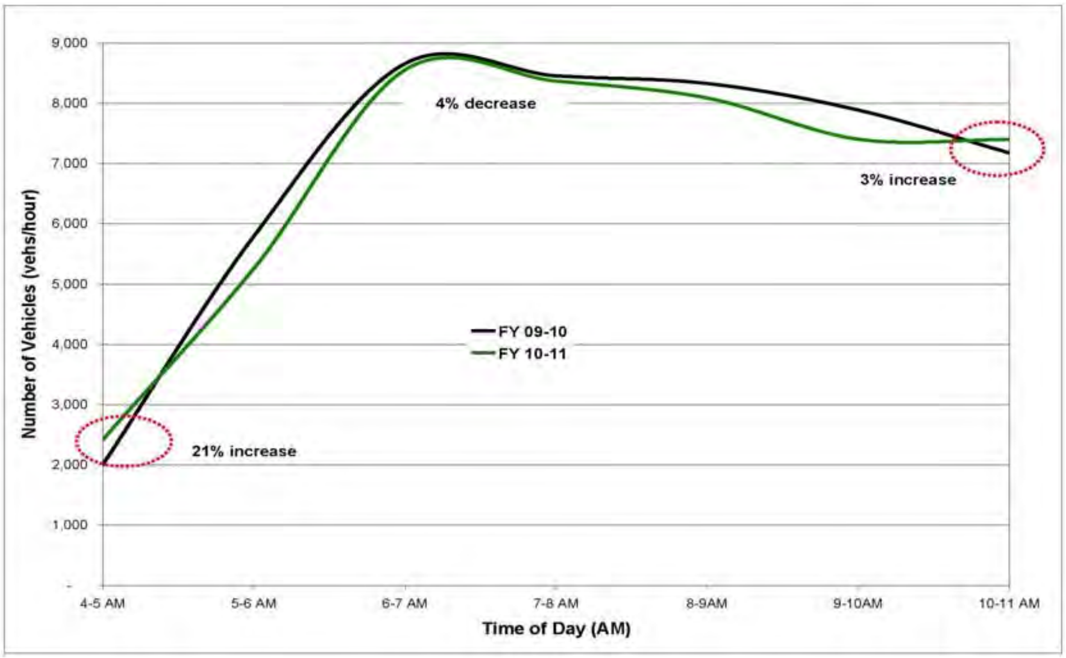
* HOV Volumes measured outside of HOV hours (5a.m.-10a.m., 3 p.m.-7 p.m.) are buses using the bus-only lanes on the far northern side of the toll plaza.

Note: Values that are statistically significant at the 5% level are bolded and italicized.

Source: Bay Area Toll Authority

Figure 2 graphs the before and after hourly traffic volumes on the Bay Bridge during the morning hours. The figure clearly shows that peak period shifts have occurred in the morning peak, thus lowering peak volumes. In the hour before the start of the higher toll (4-5 a.m.) and after the end of the higher toll (10-11 a.m.), there has been a 21% and 3% increase in traffic, respectively.

Figure 2. Bay Bridge Annual Average Traffic (AM Peak)



4.0 Changes in Traffic Conditions

Travel time and delay are key components to monitor with respect to congestion pricing, particularly on the bridge approaches. These are affected by bridge volumes and the extent to which travelers are using the FasTrak only and Cash lanes. Of note, the increase in FasTrak usage in the regular toll lanes reduces delay because FasTrak can process several times as many cars per hour as can a toll collector. The shift of traffic out of the peak of the peak also reduces delay. As a result, cash lane travel times have decreased and these travelers are experiencing faster trips. Average time savings vary by corridor and time of travel, with average savings ranging from 2 minutes to 6 minutes. However, some corridors and FasTrak users at some times of day have not experienced savings (Tables 7 and 8).

With respect to travel speeds, travel time data collected on the Bay Bridge approaches show that peak period average speeds were very low before the toll increase. Before the toll increases, for example, it took almost 15 minutes for FasTrak users to get from the University Avenue on-ramp along I-80 to the metering lights between 7 a.m. and 8 a.m.; from the I-580 approach it took over 12 minutes from Grand Avenue to metering lights. Since these are each about 4 mile distances, the average speed was about 16 mph from University Avenue along I-80 and about 20 mph from Grand Avenue via I-580. After the toll increase, the speeds for FasTrak vehicles along certain approaches improved, except between 6 a.m. and 8 a.m.

With respect to the number of vehicles using the carpool lanes, there also has been a significant drop during the morning and evening peak periods since the institution of the carpool toll and FasTrak toll tag requirement. Vehicles in the four lanes designated for carpool use are down substantially. Travel in the carpool approaches and lanes was largely free-flowing before the toll increase and there has been little change after it.

Table 7. Bay Bridge FasTrak Travel Time Run Comparison
(Data for April/May 2010 compared to February/March 2011)

Hour	"Before" Mean TT (min)			Travel Time Change (min)			Standard Error (min)		
	I-80	I-580	I-880	I-80	I-580	I-880	I-80	I-580	I-880
5-6 am	5.04	4.19	3.08	***-1.01***	***0.20***	0.06	0.12	0.05	0.04
6-7 am	8.15	6.73	5.70	1.36	***2.83***	-0.27	1.30	0.95	0.55
7-8 am	14.90	12.46	14.12	***4.06***	***6.83***	-1.84	1.63	1.82	1.75
8-9 am	15.78	14.01	15.88	-1.11	0.46	***-5.94***	1.69	2.03	1.93
9-10 am	11.68	9.98	9.09	-2.81	0.17	***-3.53***	2.03	1.81	1.28
3-4 pm	8.20	4.60	3.02	***-2.94***	***-0.30***	-0.02	0.69	0.06	0.03
4-5 p.m.	10.75	5.22	3.15	***-5.08***	***-0.97***	-0.05	0.76	0.15	0.06
5-6 p.m.	13.71	6.79	4.06	***-6.36***	***-2.07***	**-0.67**	0.94	0.29	0.32
6-7 p.m.	8.85	7.05	4.89	***-3.85***	***-2.60***	**-1.77**	0.70	0.31	0.62

Note: Values that are statistically significant at the 5% level are bolded and italicized.

Table 8. Bay Bridge Cash Travel Time Run Comparison
(Data for April/May 2010 compared to February/March 2011)

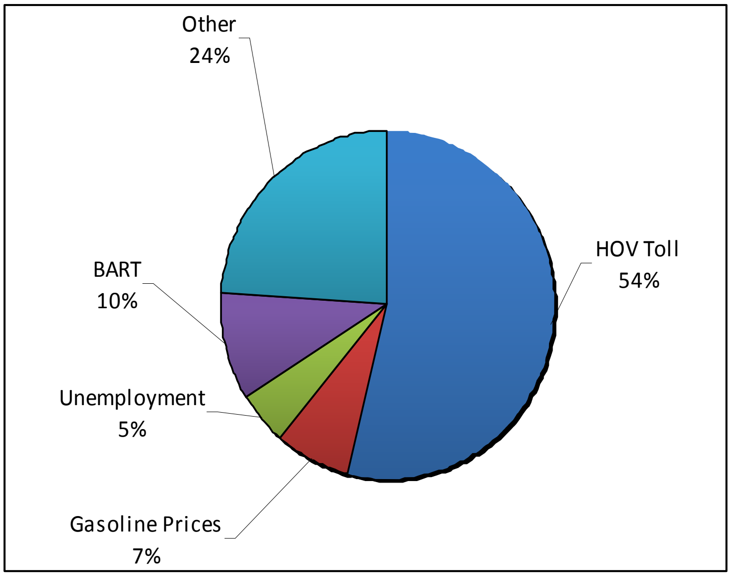
Hour	"Before" Mean TT (min)			Travel Time Change (min)			*Standard Error (min)*		
	I-80	I-580	I-880	I-80	I-580	I-880	*I-80*	*I-580*	*I-880*
5-6 am	4.79	4.86	3.68	-0.33	0.00	-0.14	*0.21*	*0.16*	*0.12*
6-7 am	15.14	17.04	14.43	-4.03	-3.66	***-6.04***	*2.10*	*2.38*	*1.70*
7-8 am	29.89	38.66	32.70	***-9.15***	***-10.74***	***-16.43***	*2.15*	*2.85*	*1.72*
8-9 am	22.28	29.17	23.35	***-4.87***	***-10.34***	***-11.02***	*2.05*	*3.64*	*1.86*
9-10 am	17.50	21.31	17.50	***-6.37***	***-10.87***	***-10.80***	*2.11*	*2.19*	*1.51*
3-4 pm	7.32	5.14	3.78	***-2.06***	***-0.34***	-0.19	*0.53*	*0.17*	*0.16*
4-5 pm	7.85	5.27	3.74	-1.87	-0.25	-0.16	*0.95*	*0.31*	*0.15*
5-6 pm	11.31	6.64	5.83	***-3.96***	***-1.55***	***-1.74***	*1.05*	*0.67*	*0.74*
6-7 pm	10.74	10.52	9.33	***-5.24***	***-4.90***	***-5.79***	*1.81*	*1.73*	*1.39*

5.0 Sorting Out Toll Effects from Other Factors

How much of the change in Bay Bridge traffic was due to the toll changes, and how much was due to the recession, increased fuel prices, and other external factors? To investigate this issue, regression equations were estimated that partial out the influences of the toll charges on traffic volumes controlling for other factors that could explain variation in demand, such as rising gasoline prices and unemployment levels in the region. Separate predictive models were developed for explaining changes in peak-period traffic on HOV lanes (i.e., carpools, motorcycles, and qualified low-emission vehicles) as well as total monthly traffic (i.e., all lanes, peak and off-peak weekdays plus weekends). An effort also was made to apportion changes in traffic to various factors like rising gasoline prices and unemployment, as well as the availability of BART as a substitute mode.

The results suggest that the higher tolls or the new carpool toll had an appreciable effect on bridge traffic volumes. Most motorists and carpoolers appeared willing to absorb the higher toll charges, but the tolls were not inconsequential. The imposition of bridge tolls exerted far stronger influences on Bay Bridge carpool traffic volumes than did other factors, like economic conditions and gasoline prices (Figure 3). The analysis suggests that significant shares of vehicles using the HOV lane during peak periods chose not to travel, switched to off-peak periods, or shifted to transit. Over half of the loss in traffic in the carpool lanes was estimated to be attributable to the introduction of an HOV-lane toll, while less than 25 percent of the lost traffic appears to have switched over to BART or was due to rising unemployment or gasoline prices. For the portion of the pie chart that shows "other" factors, these may include changes in economic conditions, the social relationships of casual carpooling due to the carpool toll and travelers' personal circumstances, such as changes residential and work locations, and household composition. Another reason may be due to the potential reduction in the number of solo travelers traveling in the carpool lanes after the carpool toll and FasTrak requirements went into effect.

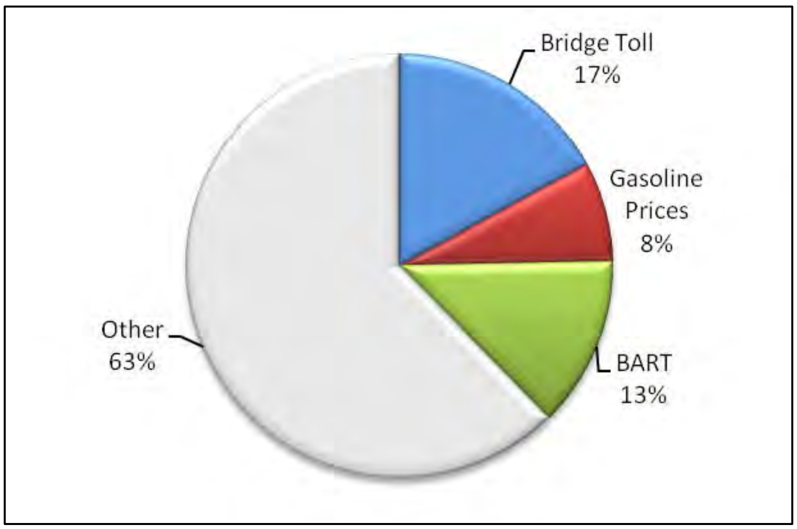
Figure 3. Estimated Effects of Key Factors Influencing Peak-Period HOV Lane Traffic Volumes (January 2009 to May 2011)



Regular (non-HOV-lane) traffic appeared to be less sensitive to the higher peak-period bridge tolls and many other factors in addition to the toll increase, gas prices, and BART as an option were at play in the volume changes (Figure 4). Other factors may include changes in economic conditions and travelers' personal circumstances, such as changes residential and work locations, and household composition.

These findings are generally consistent with those reported for other time-of-day road pricing schemes introduced in the U.S. and abroad, and also are consistent with findings from traveler surveys and focus groups.

Figure 4. Estimated Effects of Changes in Total Volumes (January 2009 to May 2011)



6.0 Effects on Carpools and Transit

A major question for the changes in the Bay Bridge traffic is what happened to the carpools. Two kinds of carpools use the bridge: prearranged carpools and casual carpools. For casual carpools, drivers pick up different passengers at various locations in the East Bay to qualify for using the bridge's carpool bypass lanes to save up to 25 minutes in travel time. (Note that any travel party of three or more people, i.e. three co-workers, parents and their child (ren), friends going to shopping together, etc. are a "carpool"). Surveys of casual carpoolers show the two primary reasons for using this mode are to save time and money on tolls.

Vehicles using the carpool lanes decreased by about 26% percent on the Bay Bridge and 30% across all the bridges in total since the new toll schedule's implementation, although counts from previous years also show that carpool volumes have been in decline. This 26% decrease in vehicles using the Bay Bridge carpool lanes affects approximately 13,000 people with three people per vehicle. If they all became solo drivers, there would be 8,700 more cars. However, there are only 3,300 more cars in the cash & FasTrak lanes. Thus, the majority of carpools did not become drive alone bridge crossers.

As discussed in the previous section, predictive modeling attributes about half of the reduction in HOV lane use to the existence of a toll and the rest to other factors. Traveler surveys and focus groups with carpoolers were conducted, and counts of casual carpoolers before and after the toll's introduction conducted by 511 Rideshare were reviewed to explore the reasons for this decline and travel options of former and current carpoolers.

Casual carpoolers tend to take transit home for their return trip or as a back-up, and transit is a logical mode for switching to for some trips or fully. They may be responsible for the modest ridership increases seen for BART (see Figure 5). BART is up by 8% in the morning and 5% in the afternoon. WestCAT, which operates in western Costa County, has instituted new transbay services, resulting in substantial growth for WestCAT service. Even in the face of service cuts and fare increases, AC Transit transbay ridership has remained steady. Transit ridership also is affected by transit service and price changes, as well as others factors such as unemployment.

MTC's 511 Rideshare conducted one-day casual carpool counts before (April/May 2010) and after (May 2011) the toll increase at 13 of the 25 known casual carpool pickup locations in the Bay Area, with 12 sites in the East Bay for the morning commute and one in San Francisco for the evening return (Table 9). The counts show some decline and that these vary across locations. Of note, some locations show slightly higher counts or minimal change.

Figure 5. BART Weekday Hourly Transbay (westbound direction)

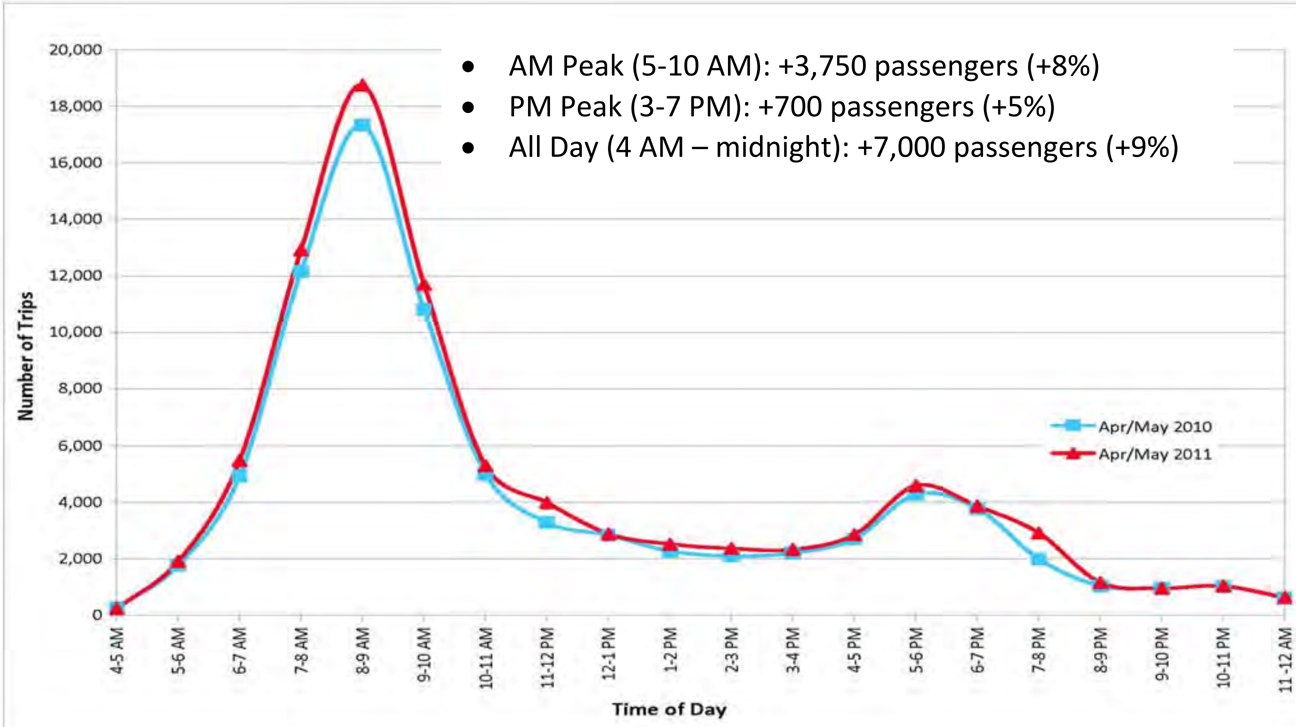


Table 9. Casual Carpool Count Survey, April/May 2010 and May 2011

Morning Commute East Bay to San Francisco (6:00 a.m. to 9:00 a.m.)				
Corridor	**Station**	**Total 2010**	**Total 2011**	**Change**
I 80	Albany/El Cerrito, Pierce Street	85	64	-21
I 80	Vallejo Park and Ride	263	273	10
I 80	N. Berkeley BART	244	210	-34
I 80	El Cerrito Del Norte	224	235	11
I 80	Hercules Park and Ride	141	129	-12
I 80	Fairfield	71	61	-10
Hwy 24	Claremont/Hudson (Oakland)	152	83	-69
Hwy 24	Lafayette BART	82	90	8
Hwy 24	College/Claremont (Oakland)	93	78	-15
I 580	Fruitvale/Montana (Oakland)	142	122	-20
I 580	Lakeshore/Grand (Oakland)	228	197	-31
I 580	Park/Hollywood (Oakland)	84	87	3
I 580	Orinda BART	101	102	1
Total	**Morning commute**	**1910**	**1731**	**-179**

Table 9. Casual Carpool Count Survey, April/May 2010 and May 2011 (cont'd)

Afternoon Commute San Francisco to East Bay (4:00 p.m. to 6:00 p.m.)				
Corridor	**Destination from San Francisco**	**Total 2010**	**Total 2011**	**Change**
I 80	13 Beale St to Hercules	48	50	2
I 80	13 Beale St. to Richmond Parkway	54	47	-7
I 80	13 Beale St to Fairfield/Suisun	53	31	-22
I 80	13 Beale St. to N. Berkeley BART/Del Norte BART	26	23	-3
I 80	13 Beale St. to Vallejo	176	136	-40
Hwy 24	13 Beale St. to Orinda/Lafayette	0	0	0
Hwy 24	13 Beale St. to Walnut Creek/Pleasant	0	4	4
Hwy 24	13 Beale St. to Oakland/Claremont	1	5	4
Total	**Afternoon commute**	**358**	**296**	**-62**

Source: data compiled from 511 Rideshare, 2010 and 2011. 511 Rideshare counts are based on surveying a site one day each year.

BATA also surveyed Bay Bridge FasTrak customers in June 2011. Of 4,042 survey respondents, 2% reported that they carpooled less in the past year, and 9% stated they carpooled more in the past year. They were asked to provide the reasons for their change in travel in open-ended questions. For those that indicated that they carpool more, they cited that the increase in the peak toll to $6 and gas prices have influenced their decision to carpool more. Traffic congestion combined with travel time savings in the carpool lanes also were frequently cited. Others noted that changes in the work and home location have led them to carpool more because new locations now require them to cross the bay or because transit is perceived to be a less convenient travel option. Others indicated that a new co-worker joined the office and became a carpool partner or that a household member's job or family situation changed, thereby allowing them to carpool together. In addition, some viewed the FasTrak lanes specifically as highly congested and saw carpooling as a way to bypass use of these lanes. Interestingly, some indicated that they were concerned about the environment and were carpooling to reduce carbon emissions/environmental impacts.

For travelers who carpool less, many respondents viewed carpooling no longer as an option because of personal circumstances. The reasons often included moving to another city, new job or change in work hours, work-related travel and more personal plans, new relationships and children in the household, and personal injury. Others noted that their carpool partner was no longer available as one of them had changed jobs. Some noted that the new carpool toll combined with perceived increase wait times at the casual carpool sites negated their perceived benefits of carpooling.

Eight focus groups also were held and included casual carpoolers; four of these groups were limited to those who casual carpooled now or had done so in the last year. Participants in the focus groups echoed those in the BATA survey in explaining the reasons for their mode choice. Some reported that they carpooled more, others less; reasons for changing carpool frequency included changes in personal, household, residence, employment, and transport circumstances as well as the toll increase and toll tag requirement. The discussions also revealed that some carpool trips are fairly easy to reschedule or wait until the off-peak. These trips tend to be for social/recreational purposes, such as shopping.

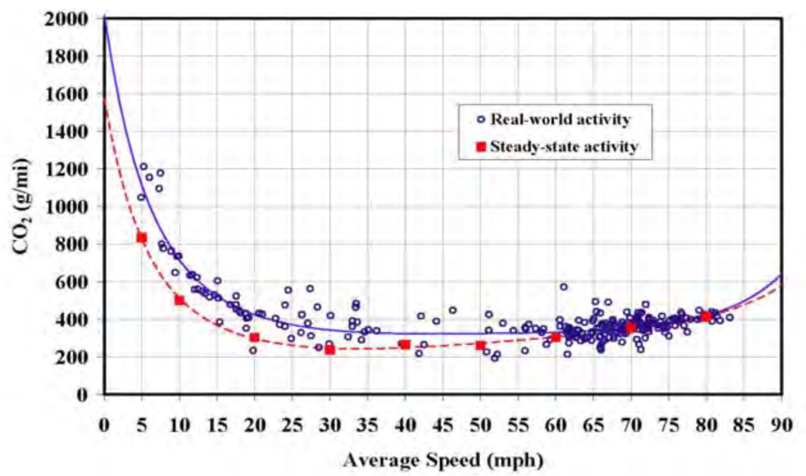
An interesting finding throughout the focus groups was that the payment of the new $2.50 carpool toll has affected social interactions among carpool members. At some locations, participants reported that there is much uncertainty on whether passengers should pay part of the toll and whether drivers should accept such payment when offered. Some participants reported conflicts between drivers and passengers over this issue and noted that it has added tension to an otherwise established set of practices where there was previously little interaction between drivers and passengers.

All traveler surveys and focus groups findings reveal that travel behavior and choices on whether to carpool more or less are complex, and not simply related to the new carpool toll and toll tag requirements. Many are carpooling less because of personal circumstances unrelated to the carpool toll requirements, such as housing and job relocations and household composition. Some travelers are even carpooling more, because of the higher $6 peak toll and recent higher gas prices. They also are carpooling to avoid traffic congestion in the corridor. Some also have switched to taking transit on some days or as their primary mode.

7.0 Energy and Emissions Impacts

Energy use and carbon dioxide (CO2) emissions are major public policy concerns today. Every gallon of fuel burned emits 19.4 lb. of CO2. Vehicles traveling at very low average speeds accelerate and decelerate frequently, which is an energy waster. They also do not travel far, so fuel use and CO2 emissions per mile are high when traffic is slow and congested. As speeds increase, emissions decline up to a point, after which the higher engine load and frequent heavy acceleration episodes associated with high speed driving increase emissions again. Speeds in the 45-55 miles per hour (mph) range result in relatively good speeds with low emissions, which is why speeds were set at 55 mph on freeways in earlier decades when energy conservation was being promoted (Figure 6).

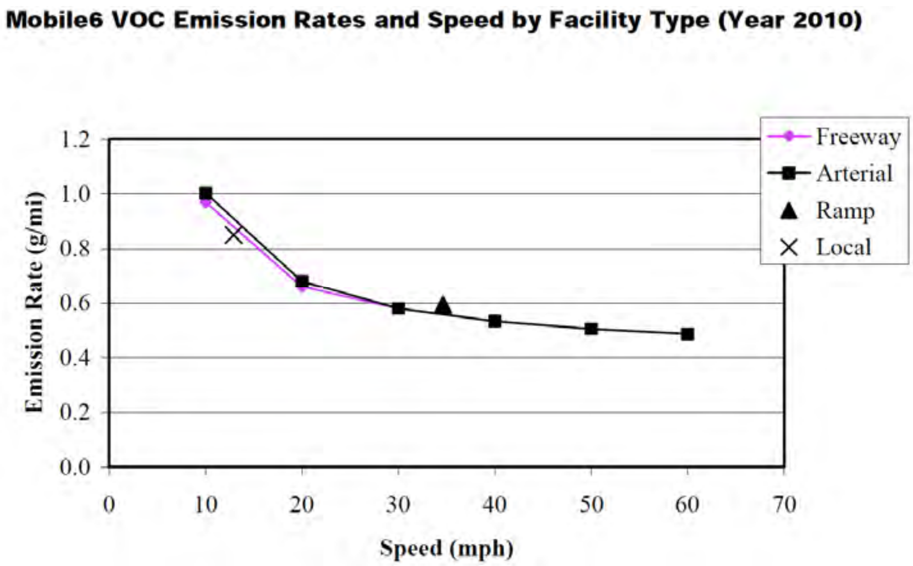
Figure 6. CO2 versus Average Speed

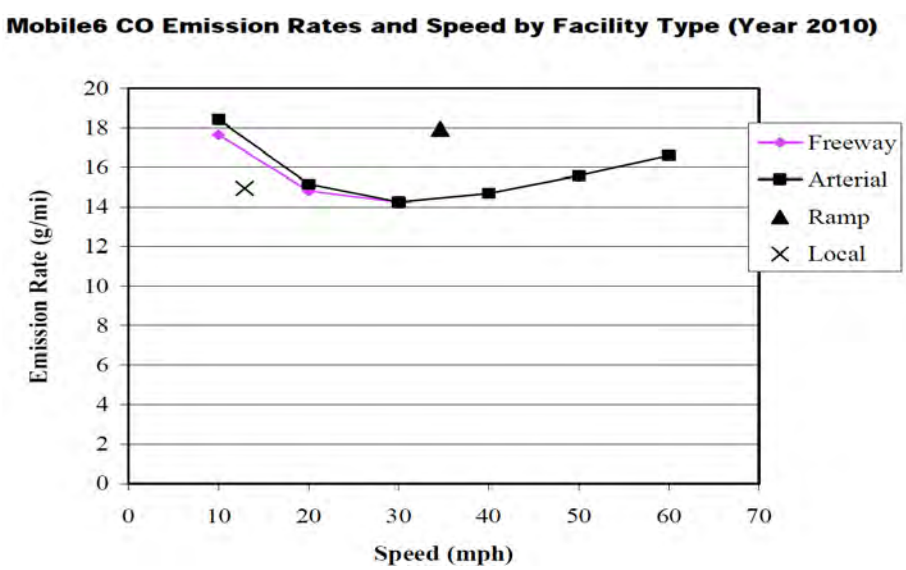


Source: Barth and Boriboonsomsin, 2008

For other key pollutants, emissions also vary with speed, as shown in Figure 7 for hydrocarbons (VOC), carbon dioxide (CO), and oxides of nitrogen (NOx). VOC and CO emissions decline with increasing speeds up to about 60 mph (after which emissions, not shown on the graphs, go up). NOx emissions decline to about 30 mph and then increase sharply.

Figure 7. Emissions Rates as a Function of Speed for VOC, NOx, and CO2





Source: SEMCOG, 2004, based on runs of US EPA's MOBILE6 emissions model

As discussed in Chapter 4.0, travel time data collected on the Bay Bridge approaches show that peak period average speeds were very low before the toll increase. The average speed was about 16 mph from the University Avenue along I-80 and about 20 mph from Grand Ave. via I-580. As shown in Figures 6 and 7, such low speeds are associated with very high emissions of CO2, VOC, CO, and NOx.

After the toll increase, the speeds for FasTrak vehicles along certain approaches improved, except between 6 a.m. and 8 a.m. Speeds in cash lanes increased the most during the worst time period (7-8 a.m.) for travelers coming from all three freeway approaches – again a speed improvement change that produces a significant reduction in emissions. Referring to the emissions-speed curves, it is clear that all pollutants decline substantially with freeway speed increases. Changes in fuel use track closely with CO_2 changes. Speeds in HOV lanes were in the 50-60 mph range before the toll increase and did not change significantly for most times of day after it.

8.0 Travelers' Responses to Toll Changes

Traveler responses to changes in the conditions of travel, such as congestion pricing, are affected by many factors, including the traveler's personal characteristics and those of the household, the other travel options available to the traveler and considered by him or her, and whether alternative destinations are available for the trip. Travel time and reliability as well as out-of-pocket travel costs also are very important determinants of travel choices. For automobiles, travel costs include fuel and some maintenance, as well as tolls and parking charges. It is not always a simple matter to determine an individual traveler's costs, however. When multiple travelers share a ride, the costs may be shared among all occupants, or may be absorbed by the driver. Travel costs also may be subsidized or reimbursed; for example, drivers may have a company car, a employer-provided transit pass, or a commute allowance; trips made for business purposes may be paid for by an employer or deducted as a business expense; parking may be provided free or at a discount by employers, retailers, and local governments.

Uncertainties and time constraints over the full course of the day have been shown to be important elements in travel choices. For example, it might appear that a traveler could take transit to work in the morning. However, if the traveler frequently has to work late, past the hours that transit service is available, transit use in the morning would become far less attractive. Likewise, a traveler might be able to carpool to work and home again, but if the traveler must pick up a child from day care on the way home, carpooling may not be an option.

Travel time and costs, considered from the perspective of the travelers' activity schedule and total daily time budget, explain much, but not all, of mode choice. Psychological and social factors also shape what choices travelers are willing to consider. Individuals who are concerned about safety in parking lots late at night may not be willing to drive to work when they know they have to work late. Individuals who have never used transit may not even consider it when deciding how to get to work, even if its time and costs are better than the alternatives.

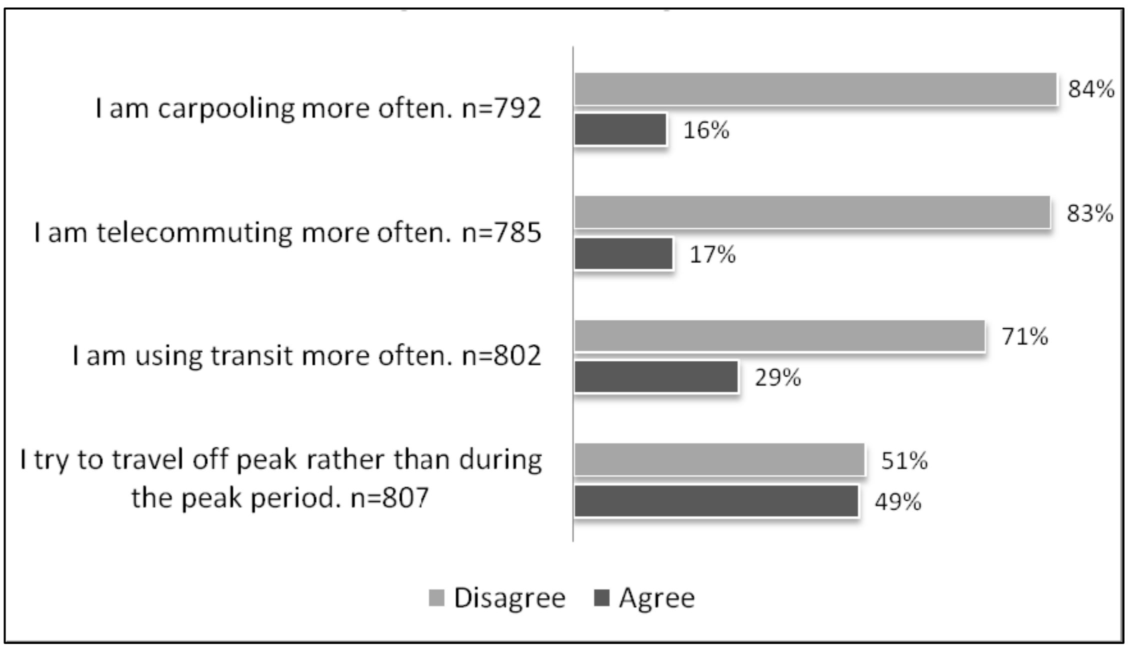
In this light, surveys and focus groups were used to better understand how travelers responded to the new bridge toll structure. BATA conducted surveys before and after the toll increase. UC Berkeley held a total of 16 focus groups with each meeting having between 5 to 12 participants each and lasted for about one hour – allowing for an in-depth discussion about travel considerations. The focus groups and surveys were designed to assess knowledge, attitudes, and responses regarding the new pricing strategy, and to provide greater insights into factors in addition to time and cost considerations that may have affected their travel choices in the Bay Bridge corridor. The results from these different methods were generally consistent with one another.

Few focus group participants knew how the bridge was paid for or what the justification for a higher toll was. Many also thought the "bridge had already been paid for" and did not understand why the tolls were being raised. They had not seen media coverage of the reasons for the increases. Very few participants understood that a higher toll during the peak period was a way to reduce congestion and decrease travel times during peak periods. The toll on carpools was the most puzzling change in policy from the participants' perspective. Instead of being seen as a $3.50 discount from the standard $6 peak period toll, the $2.50 carpool toll was widely viewed as a new toll (penalty) for carpools, with an added burden that FasTrak was now required.

There was a general attitude of "resigned acceptance" to the toll among the Bay Bridge commuters in our focus groups and surveys, including carpoolers. Most respondents saw the new tolls as "not worth fighting about". Indeed, some participants commented that "everything else is going up - why not tolls?" Increased tolls along with higher transit fares for the AC Transit, BART and Muni seemed to many respondents to be "par for the course."

In terms of travel changes, almost half of the respondents in the UC survey said that they are making an effort to travel off-peak more frequently since the increase of the toll (Figure 8). About 29% said they were using transit more often. Seventeen percent are telecommuting more often, and 16% are carpooling more often.

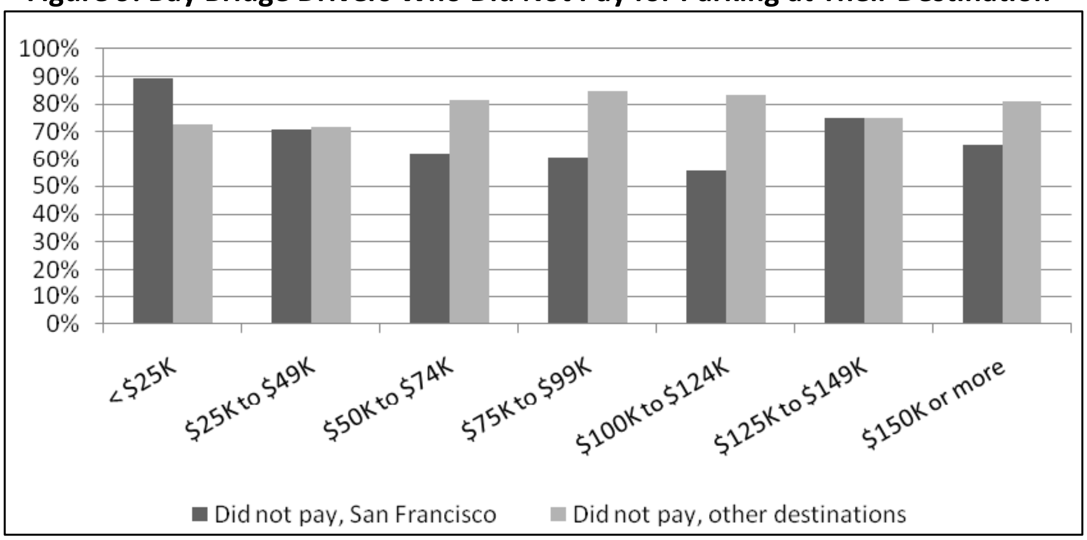
Figure 8. Respondents' Stated Travel Patterns: "Now that there is a higher toll on the bridge…"



Focus group respondents reported changes in many directions and for many reasons; some also made several changes at once. Some solo drivers are trying to telecommute more and to use transit more, though they still drive some of the time. Some carpoolers have moved to transit, some to driving alone, and some to travel off peak. Some have continued to carpool, but with just one other person, so they are not eligible for the HOV lanes at the toll plaza. Some transit riders are driving more because of greater crowding at transit parking facilities. But transportation costs and service levels were not the only reasons for change: loss or change of jobs, moving residences, and changes in household size are some of the reasons given for changing travel patterns. In addition, some focus group members reported that they have been trying to cut back on transportation expenditures because of the uncertain economy and so are reducing outings and combining trips. Others are offering rides to casual carpoolers because they are concerned about people who are short on cash in these hard economic times. Still others are casual carpooling to save money. Those who were driving in the peak period tended to be those who had relatively little flexibility in timing their trip, difficult transit access, and free or low cost parking.

Another important factor was the role of parking in travel decisions. UC survey results showed that a majority (76%) of respondents did not pay for parking at their destination. 67% reported that they found free parking, and 9% said that an employer, driver, or someone else paid for parking, both in San Francisco and on the Peninsula south of San Francisco. Figure 9 shows the prevalence of free and employer subsidized parking in San Francisco, compared to other destinations on the Peninsula by level of income.

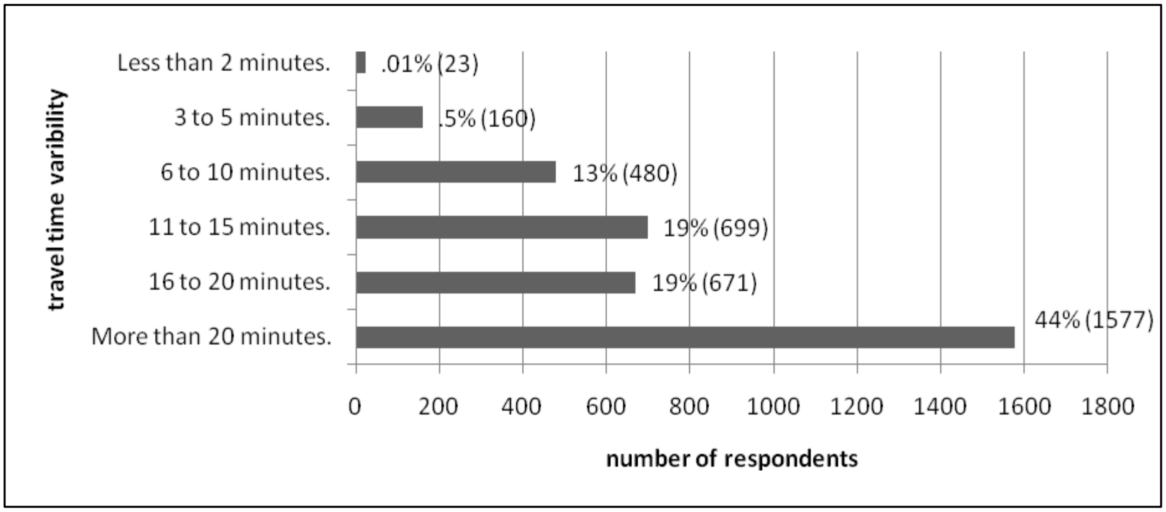
Figure 9. Bay Bridge Drivers Who Did Not Pay for Parking at Their Destination



Focus group participants also emphasized the importance of parking in their decisions to drive across the Bay Bridge. Many reported finding free parking and those that paid for parking acknowledged that it was a major cost that they did not like paying, but still felt that it was the best option when compared to transit for their particular trip. Others said that by paying on a monthly basis, they didn't *feel* like they were paying for parking every day. Moreover, by paying on a monthly basis, several said, there is no incentive for them to reduce their driving trips, since the parking is already paid for (even if the monthly rate is a discount). Some focus group participants even commented that if they are paying for monthly parking, it makes sense to drive to get their "money's worth" from their spot.

Finally, respondents to the BATA "after" survey mentioned above were asked to describe how much their travel time varied on their typical transbay trip. Figure 10 shows that of the 3,610 respondents to this question, a large share experience high variability, with 44% reporting variability longer than 20 minutes, and another 19% reporting travel times that could differ by 16-20 minutes day to day.

Figure 10. Variability in Day-to-Day Travel Time for Transbay Trips



Overall, the general responses and perceptions about congestion pricing were not surprising given that a $2 peak toll increase is just a small portion of the average round trip costs, which can range from $15 to $30. On the other hand, it was surprising that many drivers had access to free parking in San Francisco. Free or highly subsidized parking turned out once again to be a prime determinant of driving versus taking transit.

Importantly, survey and focus group respondents reported high levels of variability in traffic volumes and delay for their transbay trips, not only on the bridge approaches but also at other locations along the way. Thus, the respondents experience varying levels of congestion during their trip whereby minutes "saved" in one part of the trip may be minutes "lost" along other portions, particularly at bottlenecks, such along I-80, I-580 and at the Caldecott Tunnel on Highway 24.

9.0 Business Responses to Toll Changes

Congestion pricing can lead to changes in business practices. Some businesses will take steps to take advantage of improved travel conditions, adjusting hours of operation or expanding activity because of better access to labor, other inputs, and markets. Other businesses will make adjustments that are intended to compensate for higher costs, such as offering commute subsidies to employees or, in the longer run, moving to places that are less congested and therefore do not require congestion pricing. Three types of business practices were considered in this study. First, inquiries were made about changes in travel assistance programs for employees and the extent to which congestion pricing was a factor. Second, changes in business hours of operation and customer incentives such as subsidized parking were explored. Finally, changes in scheduling of freight operations and deliveries were investigated. These changes are ones that might be expected to occur in the short run to medium run in response to congestion pricing, or even in anticipation of it. Review of previous studies on business impacts, interviews with stakeholders, and reports on employer benefits from survey and focus group participants informed the investigation.

Overall, business leaders did not expect a large impact from the Bay Bridge or other toll increases because only a fraction of employees, suppliers, customers or clients would be affected. In addition, the dollar amounts were seen as small, especially as compared to parking charges or even volatile gas prices. Business leaders also recognized that many business travelers and employees could avoid travel in peak periods or use other modes if the toll was a concern. They had no plans to change their practices in response to a $1-$2 / day toll, especially during difficult economic times.

Some businesses that are time-sensitive or employ workers with a high value of time or much-sought-after skills saw the toll increase and congestion pricing in particular as a boon. They believe they will benefit from faster and more reliable transportation and the resulting increase in access to labor pools and markets. Businesses that require deliveries during times of heavy congestion charges, or whose customers are not as time sensitive but may be cost-sensitive, were less sanguine, worrying that they could be adversely impacted.

Freight shippers and delivery services thought that a toll increase of a few dollars would easily be made up by time savings that would allow labor and equipment to be deployed more efficiently. Some speculated that owner-operators would be likely to have less flexibility to adjust to higher tolls, however. In addition, because the study was done before truck toll increases had been implemented, empirical evidence was not available.

10.0 Conclusion

Not all of the time savings on the Bay Bridge is due to the toll increase, since competition from transit, the deterrent of high gas prices, problems with unemployment, and a variety of other factors have affected bridge traffic. Dynamic changes also are occurring in the Bay Area's urban economic structure, its transportation systems, and its consumer activities. These changes show up in mode shares, business formations, location shifts, retail sales figures, and property vacancy rates. Congestion pricing, especially pricing of some facilities and not others, has the potential to affect these dynamics in a variety of ways and over the longer term. Yet the available data are not extensive enough to tease out the net impacts of the Bay Bridge congestion pricing from many other changes in the region.

Nevertheless, the toll increase has contributed to a reduction in travel across the Bay Bridge, and with this reduction comes reductions in travel times, congestion, fuel consumption and emissions for those who continue to use the bridge. Focus groups and surveys conducted with Bridge travelers also support this conclusion.

Acknowledgements

This research is supported by the Bay Area Toll Authority. Additional research assistance also was provided by the University of California Transportation Center.

APPENDIX

Appendix A

Impact of Peak and Off-Peak Tolls on Traffic in the San Francisco-Oakland Bay Bridge Corridor

Impact of Peak and Off-Peak Tolls on Traffic

in the San Francisco-Oakland Bay Bridge Corridor

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November 2011

1. INTRODUCTION

In July 2010, the Bay Area Toll Authority (BATA) increased tolls on the San Francisco-Oakland Bay Bridge from a flat toll collected westbound only, to a weekday peak and off peak toll (see Table 1). Tolls on six other BATA-managed bridges were increased by $1 without any time of day differential. In addition, BATA approved toll increases for multi-axle vehicles that recently took effect in July 2011.

The toll increases were implemented to fund seismic safety projects, but the Bay Bridge toll also serves as a form of congestion pricing: the differential toll can have the additional effects of altering travel behavior and traffic volumes by time of day, mode of travel, vehicle occupancy level, route used, and destination chosen.

TABLE 1 Toll Schedule for the Bay Bridge

	Weekday Peak *(5AM-10AM, 3PM-7PM)*	Weekday Off-peak	Carpools *(5AM-10AM, 3PM-7PM)*	Weekends
Before 7/1/10	$4.00	$4.00	Free	$4.00
After 7/1/10	$6.00	$4.00	$2.50*	$5.00

**Payable by FasTrak only; must use designated lanes to obtain $2.50 discount toll*

Prior to July 2010, peak-period carpools of three or more occupants travelled toll-free through designated carpool lanes on either side of the toll plaza, where they also received priority treatment. However, with the recent toll increase, these carpools must now pay a toll and must use FasTrak, an electronic toll tag, and pass through the designated carpool lanes to get the carpool discount toll of $2.50.

Forecasts prepared by the Bay Area Toll Authority's consultants before the toll increases predicted that between half a percent and three percent of the peak period trips would shift out of the am peak to take advantage of the lower off-peak toll, and that half a percent to two percent would shift out of the pm peak *(1)*. The consultants also estimated a mode shift (to rail, bus, ferry, and carpool) of between 2.0% in the most conservative case and 5% in the most likely scenario Together these changes should have resulted in a reduction in peak period traffic of about 3% to 4%.

The percent changes in traffic must be interpreted in terms of the traffic that would otherwise have occurred on the Bay Bridge. Absent any toll increase, traffic changes could have been observed over the past year as a result of a wide variety of factors, including population changes in the region and in the corridors for which the Bay Bridge is an important link; changes in congestion elsewhere along the corridors leading to the Bay Bridge; changes in fuel prices, parking charges, and household income (since costs are generally considered relative to income); changes in the costs and availability of alternative travel modes, BART, bus, and ferry (where crowding, transit service cutbacks, route reconfigurations, and fare increases also have led some transit users to shift to auto; changes in employment levels and work schedules; changes in household income allocation and participation in discretionary activities (such as shopping, evenings out, and travel), and, changes in household location. Thus, the comparison of data before the toll changes and after the toll changes must be considered in light of the multitude of factors in addition to tolls that could have affected traffic levels.

In addition, the toll itself can be expected to exert pressures that work in opposite directions. Higher tolls may have deterred some travelers from peak period travel and caused them to shift travel to off-peak times of day or weekends, or to other modes, or deterred them from traveling across the Bay Bridge as often as previously or at all. On the other hand, travel time improvements due to less traffic on the bridge also may have led some travelers to decide that driving was now more attractive, resulting in a higher auto mode share and more frequent peak period trips. Whether a toll is a deterrent or a way to make travel easier and more attractive depends on the income available to the individual, the availability of other options for that individual, and the total time and cost of the trip (not just the Bridge portion and including parking costs), since for many trips Bridge tolls may be only a small part of total costs, and Bridge-related travel time only a small part of total travel time.

Data on Bay Bridge toll payments after the toll increase indicate that total bridge crossings have slightly increased, while peak period bridge crossings have decreased substantially. The peak period decrease is mostly driven by a drop in carpool lane volumes. The volume of traffic on the shoulders of the peaks (the hours before and after the peaks) has increased as well, indicating time-of-day shifts are occurring. Sorting out the effects of the toll changes from all the other effects that have occurred is a major challenge.

This paper's purpose is to review and analyze the traffic and travel impacts of the toll changes in greater depth, using data from a variety of sources to document and cross-check findings and to develop explanations for observed changes. The paper examines the following changes on the Bay Bridge:

- changes in volumes and delays at the toll plaza by payment type (Cash, FasTrak, HOV) and time of day
- carpool lane volume changes
- changes in travel times by freeway approach, by time of day and by vehicle type for each approach to the bridge

Several considerations have framed these traffic analyses. First, peak period traffic volumes are known to fluctuate by day and by season, so the underlying variability in traffic levels and seasonal changes have been accounted for to the extent possible. Second, greater monitoring of carpool lanes now that FasTrak and toll payment required may have reduced carpool lane violations and moved violators into the regular lanes or onto other modes; thus consideration of violation rates is an important issue. Third, to avoid attributing traffic changes to the Bridge tolls that might have been caused by secular traffic changes, we have compared changes on the Bridge and its approaches to changes on other bridges and at locations elsewhere in the East Bay. An analysis of other factors affecting travel volumes and travel behavior, such as economic conditions, the level of service on alternative modes, and consumer perspectives about travel choices, are dealt with in companion working papers.) Ideally, all of these effects should be distinguished from the effect of the increased tolls.

2. BACKGROUND ON THE BAY BRIDGE

The San Francisco-Oakland Bay Bridge is located in the heart of the San Francisco Bay Area and connects the East Bay to the City of San Francisco (see Figure 1). The Bay Bridge is one of the region's most travelled links, carrying over 288,000 vehicles and 590,000 people per day *(2).*

The Bay Bridge is a two-level structure that carries 10 lanes of Interstate 80, with westbound (San Francisco-bound) traffic using the upper deck. Traffic crossing the bridge approaches westbound from I-80 to the north and I-880 and I -580 from the south. State Highway 24 connects into I-580 about 3 miles east of the bridge.

At the east end of the bridge, a 20 lane toll plaza collects tolls from westbound drivers (lanes are numbered left-to-right). To aid in the merging of traffic from 20 lanes to 5 lanes, metering lights are located approximately 0.18 mile downstream of the toll plaza (see Figure 2). Metering is activated manually by the California Department of Transportation Traffic Operations Center in Oakland. Carpools with three or more occupants and buses may use the southern left two lanes and the northern right two lanes of the toll plaza to pay a discounted toll and to bypass the meter, thereby also providing major time savings as carpools avoid the large queues on the other lanes. From the I-80 approach, carpools also may use a high-occupancy vehicle lane to further speed their trip.

During the peak periods, 10 out of 16 full fare lanes are cash/FasTrak and the other six are FasTrak only (FasTrak is California's electronic toll collection (ETC) system). The FasTrak only collection lanes have a capacity that is 2 to 3 times greater than that of the cash lanes and one toll lane – Lane #18 – has open road tolling (i.e., no toll booth) which provides a capacity that is even greater than that of the FasTrak only lanes. The remaining 4 lanes serve as HOV bypass lanes during weekday peak periods. During the off-peak carpool lanes # 1 and # 2 convert to cash/FasTrak and #19 and #20 convert to bus only.

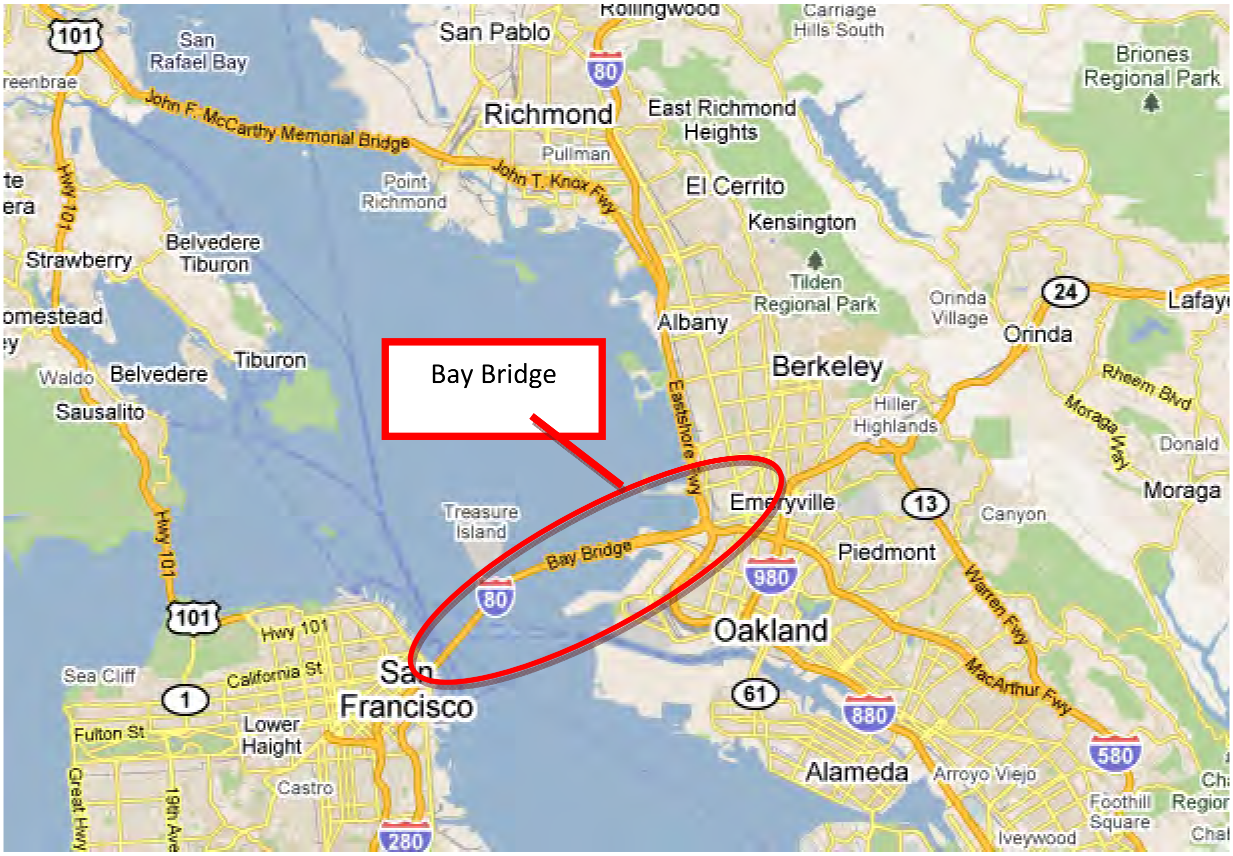

FIGURE 1. Location of the Bay Bridge

Map Source: Google Maps

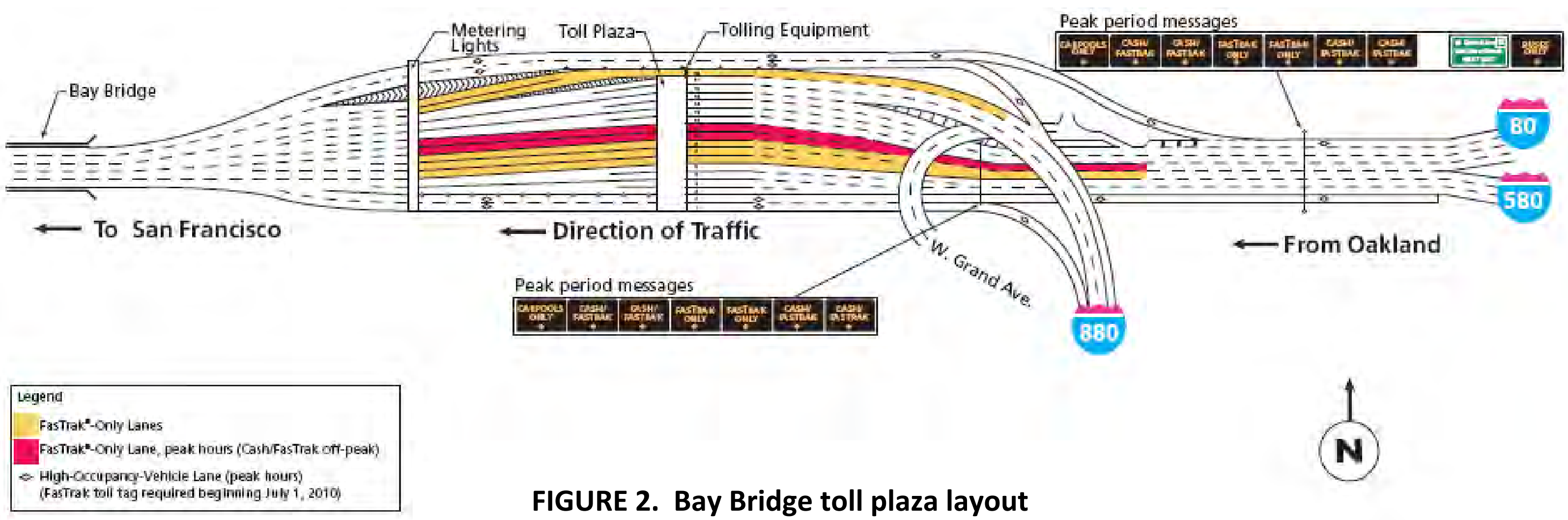

FIGURE 2. Bay Bridge toll plaza layout

Source: Bay Area Toll Authority

3. DATA AND METHODS

Traffic data were collected for the analysis through a multitude of sources. BATA provided the primary traffic volume data from its direct toll collection counts from before and after the toll switch. The data were provided by hour and payment type (cash, FasTrak, HOV after the toll increase). BATA also provided travel time data from floating car runs, and carpool lane violation data. For comparison purposes, UC Berkeley researchers assembled data collected through the California Freeway Performance Measurement System (PEMS). UC also conducted an additional analysis to examine the bridge's metering light operations and their effects on travel times.

3.1 BATA Traffic Volume, Travel Time, and Carpool Lane Violation Data

The BATA data report the actual volumes passing through each of the toll booths. For each vehicle, the record includes a timestamp, payment type (cash, FasTrak, carpool), payment value, and lane used. Because of the sheer number of records for each day, BATA provided only a few (3-5) days of data per analysis period.

3.2 Travel Time Data

Travel time data provided by the Bay Area Toll Authority came from two sources—floating car runs conducted by BATA consultants and toll tag records. Floating cars are vehicles driven by researchers on typical routes to measure travel times of a facility. As with all research methods, sample size and survey design (from route selection, driver, and the particular day especially in corridors with high variability) affect the analysis and results.

Floating car data were collected before the July 1, 2010 toll increase in April and May 2010 and in February and March 2011. The data for the floating car runs were broken down by hour of the peak in which the car started its journey. The April and May data were then averaged together to compute an average travel time for the "before" period, and the February and March data were averaged together to compute an average travel time for the "after" period. BATA consultants used two probe vehicles in the floating car runs to measure travel times for vehicles between prominent starting points on each of the three approaches and the metering lights. The times measured thus included both the time to the toll cordon and the metering-related delays. Multiple runs could be done during each peak period from the selected starting points. The floating car data allowed the UCB researchers to determine how the travel times were changing for each payment type by approach.

The floating car data were initially supplemented with 511 electronic toll collection (ETC) transponder data (FasTrak data). These data are the same data that MTC uses to provide travel times to commuters on the changeable message sign network in the Bay Area. However, because the ETC system does not automatically sort out carpool vehicles that have FasTrak and can use the faster HOV lanes from vehicles that are not carpools and are therefore must use the regular lanes, the data they produce amounts to an "average" travel time for all vehicles rather than the separate estimates for HOV and other vehicles, as needed for our analysis. Another problem with the data is that, while the starting points of the ETC analysis were able to match the starting points of the floating car runs, there is not an ETC data collection point at the metering light overhead structure. The nearest collection point after the toll plaza is at the US 101/I-80 interchange in San Francisco. Given these limitations with the data, the ETC data therefore are not presented here.

3.3 HOV (High Occupancy Vehicle) Lane Violations

BATA provided HOV lane violation data through manual counts conducted by BATA consultants. The number of violators was counted in the two southern toll booths (#1 and #2) in April, May, July and September 2010 (before and after the toll increase). The number of violators was compared to the total number of vehicles in those lanes.

However, the values of carpool lane violators may not reflect the full violation rate as the northern carpool lanes on the right side of the toll plaza were not counted (lanes #19 and #20). Lanes 1 and 2, where the counts were done, are actual toll booths; vehicles must slow to 25 miles per hour, which makes data collection considerably easier. Lanes 19 and 20 do not have toll booths and vehicles travel at free flow in these lanes, 50+ miles per hour. The consultants deemed it too difficult to determine occupancy when cars are traveling at such a speed. This suggests that police enforcement also could be difficult at these locations.

3.4 California Freeway Performance Measurement Systems (PEMS)

Because actual count data could be analyzed only for sample days, and a high variability is known to exist in traffic data, we obtained detector data from the PEMS system for comparison purposes and to formally estimate the variance in day estimates of traffic. PEMS data are generated from inductive loop detectors, which are placed in the pavement on Bay area freeways at about half a mile intervals. These loops measure the number of vehicles crossing and the occupancy (the amount of time that they are occupied by a vehicle). From this occupancy measurement and an estimated average vehicle length, the vehicle speeds can be estimated. The data are sent to the Caltrans District 4 Transportation Management Center (TMC) every thirty seconds for all detector stations in the network and archived for future use. The PeMS system is an online data management system[1] that obtains the raw detector data from the TMC, checks the data for accuracy, aggregates the data into various time scales (5 min, hourly, daily) and computes several performance measures.

PEMS was used to obtain data from two detector stations (I-80 at West Grand Avenue and I-880 west of Maritime Street) for all non-holiday typical weekdays (Tuesdays, Wednesdays and Thursdays) from January 1, 2009 to January 31, 2011, for a total of 319 days. These data were checked for errors due to various causes (communication failure, problems with detector cards, etc). Data from loops with a working rate below 50% were dropped from the analysis. This caused 16 days worth of data (out of the 319) to be eliminated from the data set. An additional 2 days of data were omitted due to an emergency closure of the Bay Bridge in 2009. The I-80/I-580 approach data from PEMS lane-by-lane

[1] www.pems.dat.ca.gov

volumes were used to estimate FasTrak and cash volumes based on the layout of the lanes as they approach the toll plaza with regards to FasTrak-only lanes (see Figure 2). The I-880 volumes from PEMS were apportioned to FasTrak and cash volumes by applying the proportion of FasTrak and cash patrons in the BATA toll volume data.

PEMS also was used to generate lane-by-lane volumes for the I-80/I-580 combined approach and the I-880 approach. The I-80/I-580 approach was counted using the detector station at the I-80 carpool lane bypass split (approximate absolute post mile 7.70), and the I-880 approach was counted using the detector station west of Maritime Street in Oakland. Each lane was assigned to its designated payment type (cash or FasTrak).

HOV volumes could not be produced by PEMS due to a lack of detection infrastructure on the I-80/I-580 combined approach. Thus PEMS data should be used to supplement the analysis on full-fare toll volumes only.

The PEMS lane by lane volumes may contain errors due to the assumptions about lane assignments described earlier. We believe these errors are small because the data was validated against the BATA lane by lane data and discrepancies at the daily volume level were very small, approximately 1%. The data cannot be compared by hour and peak period because the data collection points do not match and time shifts introduced by peak period delays could introduce substantial errors.

3.5 Metering Light Data

Since the travel time measurements were from the Bay Bridge approaches to the metering lights, the metering rates in operation could make a significant difference in the measured travel times because at times queues back up from the meters to well past the toll booths. Data regarding the operation of the metering lights from the Caltrans District 4 TMC was gathered from the TMC's handwritten records of meter operation. UC Berkeley researchers recorded this information in Excel spreadsheets for the analysis. The amount and percent of time during the morning and evening peak periods that the metering lights were active were calculated for all Tuesdays, Wednesdays and Thursdays from September 1 to November 15 in 2009 and 2010 (excluding holidays). This analysis was conducted to assess whether there have been operational changes in response to changes in traffic flows due in part to the implementation of congestion pricing.

3.6 Statistical Testing

Statistical tests are performed as part of this overall traffic evaluation. These tests establish whether two averages of are statistically different. We were particularly interested to see if the average of a particular variable before the toll increase, say bridge volumes from 8 a.m. to 9 a.m., was significantly different from the average of that variable after the toll increase. These statistical tests are important to conduct when using data that have high daily variability, such as the volumes and travel times of the Bay Bridge.

The t-statistic was calculated for each difference taken in the analysis. This t-statistic was then compared to critical values of the t-statistic for a given level of significance, 5% or 1%, to determine whether there was actually a change. If the absolute value of the calculated t-statistic is greater than the critical value of the t-statistic, it can be concluded that there is a statistically significant change.

4. ANALYSIS

4.1 Travel times by freeway approach

Floating Car Data

Using floating car data provided by BATA, the change in travel time for the I-80, I-580 and I-880 approaches to the Bay Bridge was computed by payment type (cash, FasTrak and HOV access lanes) by hour and are presented below. These corridors are depicted in Figure 3.

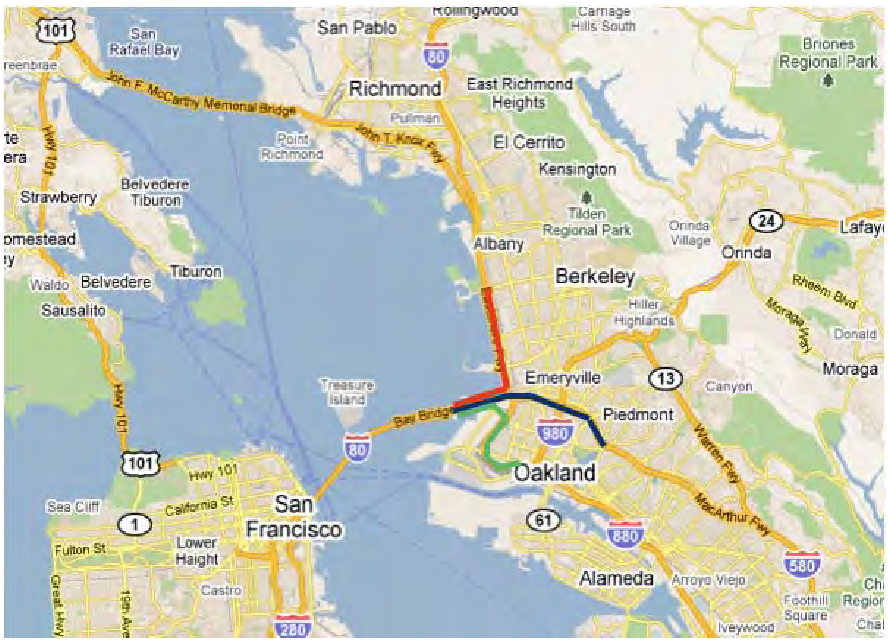

FIGURE 3. Floating car data corridors
Map Source: Google Maps

The I-80 travel times start from University Avenue in Berkeley (depicted in red) (~ 4 mi to the toll plaza), the I-580 travel times start at Grand Avenue on-ramp in Oakland (in black ~ 4 mi to the toll plaza and the I-880 travel times start at the Union Street on-ramp in Oakland (in green) (3 mi.). Travel times are calculated from these starting points to the metering lights.

For cash paying drivers, the travel time changes are presented in Table 2. The "before" period consists of April and May 2010 floating car run data; it was compared to February and March 2011 floating car run data. There may be some seasonal effects in the data, reflecting differences in weather as well as activity patterns in winter versus spring months. Table 3 details the number of cash floating car runs during each time period.

TABLE 2. Bay Bridge Cash Customer Travel Time Comparison

Hour	"Before" Mean TT (min)			Travel Time Change (min)			*Standard Error (min)*		
	I-80	I-580	I-880	I-80	I-580	I-880	*I-80*	*I-580*	*I-880*
5-6 a.m.	4.79	4.86	3.68	-0.33	0.00	-0.14	*0.21*	*0.16*	*0.12*
6-7 a.m.	15.14	17.04	14.43	-4.03	-3.66	***-6.04***	*2.10*	*2.38*	*1.70*
7-8 a.m.	29.89	38.66	32.70	***-9.15***	***-10.74***	***-16.43***	*2.15*	*2.85*	*1.72*
8-9 a.m.	22.28	29.17	23.35	***-4.87***	***-10.34***	***-11.02***	*2.05*	*3.64*	*1.86*
9-10 a.m.	17.50	21.31	17.50	***-6.37***	***-10.87***	***-10.80***	*2.11*	*2.19*	*1.51*
3-4 p.m.	7.32	5.14	3.78	***-2.06***	***-0.34***	-0.19	*0.53*	*0.17*	*0.16*
4-5 p.m.	7.85	5.27	3.74	-1.87	-0.25	-0.16	*0.95*	*0.31*	*0.15*
5-6 p.m.	11.31	6.64	5.83	***-3.96***	***-1.55***	***-1.74***	*1.05*	*0.67*	*0.74*
6-7 p.m.	10.74	10.52	9.33	***-5.24***	***-4.90***	***-5.79***	*1.81*	*1.73*	*1.39*

Notes: Values that are statistically significant at the 5% level are bolded and italicized. Standard error = standard deviation divided by square root of (n-1). Travel times are measured from starting points to the metering lights. Metering rates are set to give a time advantage to FasTrak users so cash lane users would ordinarily experience greater travel times than FasTrak users.

TABLE 3. Bay Bridge Cash Customer Floating Car Runs by Approach and Months

Hour	April/May 2010			*February/March 2011*		
	I-80	I-580	I-880	*I-80*	*I-580*	*I-880*
5-6 a.m.	33	39	40	*16*	*21*	*26*
6-7 a.m.	21	24	29	*16*	*13*	*18*
7-8 a.m.	11	15	16	*8*	*8*	*14*
8-9 a.m.	11	11	16	*8*	*10*	*12*
9-10 a.m.	16	12	14	*11*	*10*	*15*
3-4 p.m.	25	33	42	*15*	*22*	*23*
4-5 p.m.	15	26	35	*11*	*16*	*21*
5-6 p.m.	17	24	31	*9*	*16*	*22*
6-7 p.m.	16	19	22	*13*	*15*	*19*

As seen from Table 3, there appears to be a large and statistically significant travel time savings for cash customers in the latter half of the a.m. peak and the first hour and last half of the p.m. peak. The data also show that the cash customers experience substantially different delays (and time savings) depending on where their trip is starting and whether they are a.m. or p.m. peak travelers. Savings in the am peak vary from statistically insignificant changes to 5-16 min. savings that are statistically significant. Savings also vary considerably by approach.

For customers using FasTrak, travel time changes are presented in Table 4. The data from the "before" period for the I-80 and I-580 approaches consisted of data from the 511/electronic toll tag travel time system for April and May 2010, and the "after" period data consisted of floating car runs from February and March 2011 using the same starting and ending points as the "before" data.

For the I-880 approach, all of the data was produced from floating car runs during the same time periods for before/after as described for the I-80 and I-580 approach. The number of samples/runs for each time period is presented in Table 5.

The sample size for the April/May 2010 data listed above is conservative. Because the data in this period are from ETC measurements, the number of travel time samples in each 5-minute interval is in the thousands. However, BATA aggregated the data into 5 minute segments and did not provide an estimate of the sample variance. For this study, the variance of the sample was assumed to be the variance among the 5-minute segments, thus the use of 12 as the number of samples per hour. It is also important to note that in the February/March 2011 time period there were a small number of runs for the 7 a.m. to 8 a.m. hour on I-80 and I-580. This low sample size may affect the calculation of the change in travel times (presented below in Table 5). The values for the change in travel time, which appear to be statistically significant at the 5% level, are bolded and italicized in Table 5.

TABLE 4. Bay Bridge FasTrak Customer Travel Time Run Comparison

Hour	"Before" Mean TT (min)			Travel Time Change (min)			Standard Error (min)		
	I-80	I-580	I-880	I-80	I-580	I-880	I-80	I-580	I-880
5-6 a.m.	5.04	4.19	3.08	***-1.01***	***0.20***	0.06	0.12	0.05	0.04
6-7 a.m.	8.15	6.73	5.70	1.36	***2.83***	-0.27	1.30	0.95	0.55
7-8 a.m.	14.90	12.46	14.12	***4.06***	***6.83***	-1.84	1.63	1.82	1.75
8-9 a.m.	15.78	14.01	15.88	-1.11	0.46	***-5.94***	1.69	2.03	1.93
9-10 a.m.	11.68	9.98	9.09	-2.81	0.17	***-3.53***	2.03	1.81	1.28
3-4 p.m.	8.20	4.60	3.02	**-2.94**	**-0.30**	-0.02	0.69	0.06	0.03
4-5 p.m.	10.75	5.22	3.15	**-5.08**	**-0.97**	-0.05	0.76	0.15	0.06
5-6 p.m.	13.71	6.79	4.06	**-6.36**	**-2.07**	**-0.67**	0.94	0.29	0.32
6-7 p.m.	8.85	7.05	4.89	**-3.85**	**-2.60**	**-1.77**	0.70	0.31	0.62

Note: Values that are statistically significant at the 5% level are bolded and italicized.

TABLE 5. Number of Bay Bridge FasTrak Customer Floating Car Runs

Hour	April/May 2010			February/March 2011		
	I-80	I-580	I-880	I-80	I-580	I-880
5-6 a.m.	12	12	27	15	20	41
6-7 a.m.	12	12	18	15	16	32
7-8 a.m.	12	12	14	9	5	21
8-9 a.m.	12	12	12	10	10	17
9-10a.m.	12	12	17	7	11	16
3-4 p.m.	12	12	42	15	22	23
4-5 p.m.	12	12	37	11	15	21
5-6 p.m.	12	12	31	9	15	21
6-7 p.m.	12	12	22	12	15	20

As shown in Table 4, FasTrak customers approaching the Bridge from I-80 and I-580 appear to experience a large travel time reduction during the PM peak, with less of a travel time savings for I-880. There also appears to have been an increase in the travel times for FasTrak customers during the 7 a.m. to 8 a.m. time period for I-80 and I-580. This may be due to more drivers switching to FasTrak (thus causing longer queues for the metering lights and causing more delay in the FasTrak lanes) or the low sample size mentioned previously. However, since the values of travel time change are statistically significant, more weight should be put on the notion that FasTrak patrons have seen some increase in travel times.

For HOV lanes, the number of floating car runs for each time period before and after the toll increase are presented in Table 6.

TABLE 6. Bay Bridge HOV Customer Floating Car Runs

Hour	April/May 2010			February/March 2011		
	I-80	I-580	I-880	I-80	I-580	I-880
5-6 a.m.	36	33	42	10	11	15
6-7 a.m.	25	31	31	22	7	10
7-8 a.m.	27	29	27	31	6	11
8-9 a.m.	25	25	26	13	7	10
9-10 a.m.	23	24	23	9	7	9
3-4 p.m.	26	38	41	9	12	14
4-5 p.m.	26	32	33	7	8	10
5-6 p.m.	25	25	33	5	9	11
6-7 p.m.	19	25	26	7	8	12

TABLE 7. Bay Bridge HOV Customer Travel Time Comparison

Hour	"Before" Mean TT (min)			Travel Time Change (min)			Standard Error (min)		
	I-80	I-580	I-880	I-80	I-580	I-880	I-80	I-580	I-880
5-6 a.m.	3.79	4.06	3.04	0.05	0.10	-0.04	0.07	0.11	0.06
6-7 a.m.	4.02	4.07	3.03	0.13	***0.30***	-0.10	0.09	0.11	0.07
7-8 a.m.	5.29	5.24	3.10	-0.43	***-0.73***	***-0.15***	0.29	0.30	0.06
8-9 a.m.	5.07	5.53	3.04	0.47	***-0.68***	-0.10	0.36	0.28	0.07
9-10 a.m.	4.18	4.58	3.10	0.21	-0.10	-0.15	0.20	0.32	0.07
3-4 p.m.	4.61	4.13	3.04	***-0.75***	0.12	0.00	0.21	0.09	0.11
4-5 p.m.	4.76	4.21	3.07	-0.45	0.10	***-0.17***	0.25	0.13	0.05
5-6 p.m.	4.74	4.16	3.01	***-0.39***	0.16	***-0.12***	0.17	0.13	0.06
6-7 p.m.	4.38	4.03	3.03	-0.41	0.24	-0.05	0.40	0.14	0.11

Note: Values that are statistically significant at the 5% level are bolded and italicized.

As seen in Table 7, there have been some minor changes in travel time for HOVs at some times of day. However, the HOV approaches appear to still be operating at or very near an uncongested state.

4.2 Changes in volumes by payment type and time of day

Over the last 10 years, traffic across the Bay Bridge has changed in response to population growth and economic activity, although traffic congestion at the Bridge during peak periods has moderated this change. The recession, gas price increases, and changes in population demographics and business activity have undoubtedly played a hand in these changes, and not simply the tolls. Here, however, we will focus only on the changes that can be observed in traffic by payment type and time of day. (See companion papers in other appendices on how other issues affect Bay Bridge travel).

MTC Data Analysis

We conducted two analyses of the changes on the Bay Bridge using data collected by BATA at the toll plaza by hour and payment type. The first analysis was to identify and document changes in volumes in September 2010, just a few months after the toll increase but past the summer months when travel patterns are very different. We then compared travel volumes in April 2011 to those in April 2010 to see how volumes may have changed nearly 10 months after the toll increase. This second analysis allows us to see whether initial volume changes hold steady or change months after the toll increase while travelers "settle in" to new peak toll schedule.

A sample of 5 days of traffic volume from September 2009 and 5 days from September 2010 at the Bay Bridge toll plaza by hour and payment type was provided by the Bay Area Toll Authority (the evening peak period only had 3 days of data, however). The data were analyzed to determine the changes, if any, in traffic volumes and whether the changes were statistically significant. Values that appear to be statistically significant at the 5% significance level are identified in Table 8 by bolding and italicization.

TABLE 8. Bay Bridge Volume Comparison from BATA Data
(September 2010 vs. September 2009)

	September 2009 (veh)				Volume Change (veh)				Percent Change			
	Total	FT	HOV	Cash	Total	FT	HOV	Cash	Total	FT	HOV	Cash
4-5 a.m.	2081	1218	19	843	***435***	***283***	***-9***	***161***	***20.9%***	***23.2%***	*	***19.1%***
5-6 a.m.	6179	3134	1173	1872	***-669***	***-142***	***-305***	***-222***	-	***-4.5%***	***-26.0%***	***-11.9%***
6-7 a.m.	9260	4388	2579	2293	-942	-227	***-424***	-290	-10.2%	-5.2%	***-16.4%***	-12.7%
7-8 a.m.	8674	3252	3926	1496	-182	286	***-531***	64	-2.1%	8.8%	***-13.5%***	4.3%
8-9 a.m.	9003	3871	3408	1724	***-450***	56	***-398***	-108	-5.0%	1.4%	***-11.7%***	-6.3%
9-10 a.m.	8253	4249	1771	2233	***-488***	116	***-390***	***-214***	***-5.9%***	2.7%	***-22.0%***	***-9.6%***
10-11 a.m.	7334	4302	132	2900	227	***486***	***-71***	-189	3.1%	***11.3%***	*	-6.5%
2-3 p.m.	6157	3389	72	2697	***473***	***488***	-20	5	***7.7%***	***14.4%***	*	0.2%
3-4 p.m.	6725	3442	789	2494	-350	87	***-279***	-158	-5.2%	2.5%	***-35.3%***	-6.3%
4-5 p.m.	7969	4432	995	2542	-293	144	***-333***	-105	-3.7%	3.3%	***-33.4%***	-4.1%
5-6 p.m.	8120	4676	1177	2267	***-518***	-65	-262	-191	***-6.4%***	-1.4%	-22.3%	-8.4%
6-7 p.m.	7228	4013	1104	2111	-7	254	-247	-14	-0.1%	6.3%	-22.4%	-0.7%
7-8 p.m.	5073	2866	132	2075	929	788	-84	225	18.3%	27.5%	*	10.9%
5-10 a.m.	41370	18894	12858	9618	-	88	-	***-770***	***-6.6%***	0.5%	***-15.9%***	***-8.0%***
3-7 p.m.	30042	16563	4065	9414	-	420	-	***-468***	***1.6%***	1.5%	***6.3%***	***1.8%***

* HOV Volumes occurring outside of HOV hours (5a.m.-10a.m., 3 p.m.-7 p.m.) are buses using the bus-only lanes (lanes 19 and 20)

Note: Values that are statistically significant at the 5% level are bolded and italicized.

As shown in Table 8, the change in the number of HOV vehicles played a significant role in the reduction in volumes across the Bay Bridge. Also, volumes are higher during the shoulders of the peaks and lower during the first and last hours of the peak. This is evidence of peak spreading, which is a benefit associated with congestion pricing. It also appears that most of the volume gains on the shoulders of the peaks have come from FasTrak customers.

A similar analysis was conducted using a sample of 8 days of traffic volume from April and May 2010 and 4 days from April/Early May 2011 at the Bay Bridge toll plaza by hour and payment type (see Table 9). By the later date, the data provided by BATA showed that during the AM peak period FasTrak users made up 71% of full fare patrons. Outside of the AM peak period, a lower proportion of customers use FasTrak. Further, the BATA data by lane and payment type show that the vast majority of FasTrak travelers use the FasTrak-only lanes. Again, it appears that there has been a significant drop in the number of vehicles in the carpool lanes during the morning and evening peak periods; whereas FasTrak volumes in other lanes have increased during the many of the peak hours. During the 4 a.m. hour, there has been an increase in total volume, while during the 5 a.m. hour, volumes drop steeply, indicating a shift in vehicles to the hour before the higher peak toll. The 10 a.m. hour shows an increase in total volume; however, it is not statistically significant. A statistically significant increase in FasTrak volumes and decrease in cash volumes results in a non-statistically significant change in total volume. Volume during the evening peak hours appears to have remained flat, but total volume in the 2 p.m. hour and 7 p.m. hour have increased significantly, mainly by FasTrak users.

TABLE 9. Bay Bridge Volume Comparison from BATA Data
(April 2011 vs. April/Early May 2010)

	April/Early May 2010				Volume Change (veh)				Percent Change			
	Total	FT	HOV	Cash	Total	FT	HOV	Cash	Total	FT	HOV	Cash
4-5 a.m.	2019	1162	30	826	***413***	***314***	-21	***120***	***20.4%***	***27.0%***	*	***14.5%***
5-6 a.m.	6040	3086	1108	1846	***-713***	-121	***-252***	***-340***	***-11.8%***	-3.9%	***-22.7%***	***-18.4%***
6-7 a.m.	8936	4291	2538	2107	-133	414	***-445***	-102	-1.5%	9.6%	***-17.5%***	-4.8%
7-8 a.m.	8598	3363	3804	1431	369	***710***	***-446***	105	4.3%	***21.1%***	***-11.7%***	7.3%
8-9 a.m.	8433	3688	3280	1465	194	***565***	***-462***	91	2.3%	***15.3%***	***-14.1%***	6.2%
9-10 a.m.	7899	4235	1761	1903	-289	228	***-442***	-75	-3.7%	5.4%	***-25.1%***	-3.9%
10-11 a.m.	7281	4332	70	2880	191	***546***	-3	***-353***	2.6%	***12.6%***	*	***-12.2%***
2-3 p.m.	5977	3388	54	2536	***696***	***601***	-4	100	***11.6%***	***17.7%***	*	***3.9%***
3-4 p.m.	6693	3519	785	2389	-169	125	***-311***	17	-2.5%	3.5%	***-39.6%***	0.7%
4-5 p.m.	7622	4352	883	2388	-116	186	***-237***	-65	-1.5%	4.3%	***-26.9%***	-2.7%
5-6 p.m.	7937	4779	962	2196	238	***406***	***-252***	84	3.0%	***8.5%***	***-26.2%***	3.8%
6-7 p.m.	6611	3869	881	1861	7	***198***	***-339***	***148***	0.1%	***5.1%***	***-38.5%***	8.0%
7-8 p.m.	4832	2861	63	1908	***669***	***610***	-8	67	***13.8%***	***21.3%***	*	***3.5%***
5-10 a.m.	39906	18664	12491	8750	-572	***1795***	***-2406***	-320	-1.4%	***9.6%***	***-16.4%***	-3.7%
3-7 p.m.	28683	16519	3511	8834	-41	***914***	***-1140***	185	-0.1%	***5.5%***	***-32.5%***	2.1%

* HOV Volumes occurring outside of HOV hours (5a.m.-10a.m., 3 p.m.-7 p.m.) are buses using the bus-only lanes (lanes 19 and 20)

Note: Values that are statistically significant at the 5% level are bolded and italicized.

Supplemental PEMS Data Analysis

To supplement the analyses, data from the California Freeway Performance Measurement System (PEMS) was downloaded at the detector stations closest to the toll plaza on the I-80/I-580 approach and I-880 approach. To combat seasonality and to ensure commonality with the data provided by MTC, the change in full-fare volumes from September 2009 to September 2010 was calculated. Only full-fare volumes were calculated as PEMS cannot accurately report HOV volumes due to the presence of an HOV lane without instrumentation in the approach. The analysis is summarized below in Table 10, with values that may be statistically significant at the 5% level bolded and italicized.

TABLE 10. Bay Bridge Full-Fare Volume Changes (September 2009 vs. September 2010)

Hour Starting:	Change in Volume (veh)			Standard Error (veh)		
	Total FF	FasTrak	Cash	Total FF	FasTrak	Cash
4-5 a.m.	***437***	***232***	***205***	43	18	35
5-6 a.m.	***-346***	***-213***	-133	88	50	64
6-7 a.m.	83	***-190***	***273***	124	81	77
7-8 a.m.	-221	-180	-41	227	127	139
8-9 a.m.	-36	-54	18	170	154	107
9-10 a.m.	-127	-71	-56	156	189	89
10-11 a.m.	60	-275	335	124	183	156
2-3 p.m.	***372***	***226***	***146***	90	50	48
3-4 p.m.	140	-29	169	150	32	148
4-5 p.m.	128	-9	136	160	85	158
5-6 p.m.	97	-143	241	168	106	171
6-7 p.m.	-78	-206	128	217	149	199
7-8 p.m.	***750***	195	***555***	231	101	232

Note: Values that are statistically significant at the 5% level are bolded and italicized.

Many results in Table 10 mirror the general trend of the full fare data from BATA. In the BATA data, the full fare changes are generally not statistically significant. This is mirrored in the PEMS data. For the total full fare payments, the main item that stands out are that traffic has shifted from the 5-6 am period to the 4-5 am period.

Mirroring the analysis done on the BATA data from April 2010 and April 2011, data was downloaded from PEMS for April 2011 at the same detector locations as in the analysis presented in Table 11. As seen in Table 11, there has been peak shifting in the early shoulders of the morning and evening peaks as the total volume has increased during the hour before the higher peak toll period, and decreased during the first hour of the peak periods.

TABLE 11. Bay Bridge Full-Fare Volume Changes (April 2010 vs. April 2011)

Hour Starting:	Change in Volume (veh)			Standard Error (veh)		
	Total FF	FasTrak	Cash	Total FF	FasTrak	Cash
4-5 a.m.	***376***	***213***	***163***	21	12	19
5-6 a.m.	***-256***	***-105***	***-151***	42	26	31
6-7 a.m.	296	5	***292***	145	125	84
7-8 a.m.	***524***	82	***443***	226	213	98
8-9 a.m.	***645***	338	***307***	207	223	111
9-10 a.m.	256	264	-8	144	176	121
10-11 a.m.	***416***	367	48	131	225	167
2-3 p.m.	***449***	***291***	157	111	40	82
3-4 p.m.	-162	-54	-108	100	42	68
4-5 p.m.	-124	8	-132	131	67	72
5-6 p.m.	***321***	***295***	26	113	57	71
6-7 p.m.	***202***	***175***	27	91	59	70
7-8 p.m.	278	***182***	96	162	71	104

4.3 Carpool Occupancy Violation Rates

The carpool occupancy violation rate was calculated from data provided by BATA for the carpool access lanes on the southern side of the toll plaza (Table 12). These data were collected 4 days total in April/May 2010 before the carpool toll/FasTrak requirement was instituted and 3 days in September 2010 after these changes went into effect. Data were collected in the carpool access lanes on the left side of the toll plaza to compare the number of autos violating the minimum occupancy requirement of 3 or more persons per vehicle. If it was too difficult to count the number of persons in a vehicle, the vehicle was not counted, which may affect the results.

TABLE 12. HOV Occupancy Violation Rate Changes (April/May 2010 vs. September 2010)

Hour Starting	April/May 2010	September 2010	*Change*	*Standard Error*
5:00 a.m.	3.89%	18.08%	***+14.19%***	2.85%
6:00 a.m.	5.88%	12.44%	+6.56%	2.75%
7:00 a.m.	4.54%	10.91%	+6.37%	2.69%
8:00 a.m.	5.00%	9.61%	+4.61%	1.72%
9:00 a.m.	4.97%	12.50%	+7.53%	3.40%
3:00 p.m.	7.70%	13.31%	+5.61%	5.19%
4:00 p.m.	5.91%	10.14%	+4.23%	3.45%
5:00 p.m.	7.49%	11.94%	+4.45%	3.65%
6:00 p.m.	6.57%	12.56%	+5.99%	3.98%

As shown in Table 12, the hourly violation rate appears to have increased somewhat between April and May 2010 and September 2010. However, since there are low sample sizes, the only change that is statistically significant at the 5% level is the change for the 5 a.m. hour.

Data also were provided from three days in January 2011 from 7:30 a.m. to 9:30 a.m. The data were averaged over the 5-minute periods that data was provided, and that average was compared to the average from the April/May 2010 data (averaged over the same time period using the 5 minute data periods). This analysis is summarized in Table 13.

TABLE 13. HOV Occupancy Violation Rate Changes (April/May 2010 vs. January 2011)

Time period	April/May 2010	January 2011	*Change*	*Standard Error*
7:30 a.m.-	4.98%	8.67%	***+3.69%***	*0.71%*

As seen in Table 13, there has been a statistically significant increase in the 5-minute average occupancy violation rate from April/May 2010 to January 2011. This finding is consistent with the previous analysis comparing the April/May 2010 data to September 2010 in which the violation rate is higher during the heart of the morning peak period.

Also, since the samples above are only from the left-side HOV lanes, the sample may not accurately reflect the HOV violation rate in the HOV lanes on the right side of the plaza (which operate at higher speeds, making counting the number of persons in each vehicle more difficult).

4.4 Changes in Metering Lights Operations

The metering lights at the SFOBB are manually operated by the Caltrans TMC in Oakland in response to traffic conditions on the bridge. Typically, they are activated at the onset of congestion. Therefore, the operation of the metering lights is affected by changes in traffic on the bridge due to the implementation of congestion pricing. The hours of operation of metering lights "before" and "after" the toll increase are shown in Table 14.

TABLE 14 Metering Lights: Hours of Operation (in hrs and min & % peak period)

	AM Peak	PM Peak
Fall 2009 Average Duration (h:mm)	3:30	1:18
	3:37	0:46
Change (min)	+7.5	-32.2
Standard Error (min)	5.08	17.76
2009 % of Peak	70.09%	32.66%
2010 % of Peak	72.58%	19.23%
Change	+2.49%	-13.43%
Standard Error	1.7%	7.40%

As can be seen in Table 14, the changes in average duration and percent of peak are not statistically significant at the 5% level of significance and thus there is no change in the duration of meter operation. The activation and deactivation of the metering lights is typically reported on by the media in their traffic reports and through 511, and travelers may choose the time they travel and/or their mode of travel based on when the meters are active. Thus, the finding of a statistically insignificant change in metering duration may indicate that any changes in flows and travel times can be attributed to the implementation of congestion pricing.

5. KEY FINDINGS AND DISCUSSION

Our analysis reveals several key findings on bridge volumes and travel times since the July 2010 peak toll increase. We also discuss data limitations and needs as well as provide recommendations for future analyses.

5.1 Bridge Volumes

BATA volume analyses indicate the early-morning peak shoulder and the evening peak's shoulders provide evidence that peak spreading is occurring – that motorists are changing the time they travel to avoid the higher toll rate. For example, there has been an increase in total volume during the 4 a.m. hour when the toll is at $4, followed by a steep drop in volumes during the 5a.m. hour when the toll increases to $6.

BATA volume data has shown that FasTrak volumes have increased during the many of the peak hours, whereby FasTrak patrons now make up 71% of full fare patrons during the AM peak period. Further, in examining the BATA data by lane and payment type, the vast majority of FasTrak travelers use the FasTrak-only lanes.

There also has been a significant drop in the number of vehicles in the carpool lanes during the morning and evening peak periods since the institution of the carpool toll and FasTrak requirement.

5.2 Travel Times

Cash/FasTrak lane travel times have sharply decreased and these travelers are experiencing faster trips on average. FasTrak customers also appear to experience a large travel time reduction during the PM peak on I-80 and I-580, with less of a travel time savings for I-880. These travel time savings range from 2 minutes to 6 minutes. However, there also appears to have been an increase in the travel times for FasTrak customers during the 7 a.m. to 8 a.m. time period for I-80 and I-580. This may be due to more drivers switching to FasTrak (thus causing longer queues for the metering lights and causing more delay in the FasTrak lanes).

5.3 Metering Light Operations

Statistical tests on the metering light flow rate data show that there has been no sy significant change in meter flow rate. Therefore the changes in travel times can reasonably be attributed to the pricing changes on the bridge.

5.4 Data Limitations and Needs

A limitation in the analysis is that the floating car data sources and MTC volume data consist of small sample sizes, which has an effect of not tempering the variance of the data. For continued analysis of volumes and travel times, more data points need to be produced; that is, data collection should be expanded to allow for a more sound representation of the volumes and travel times.

The PEMS system also is lacking with respect to the number of sensors in the Bay Bridge approaches. There are no sensors from West Grand Avenue until after the metering lights for the Interstate 80/580 approach and from Maritime Street until after the metering lights for the Interstate 880 approach. This means that delays due to the queue for the metering lights and the toll plaza cannot be quantified via PEMS; the quantifying of these delays would be helpful in the analysis of traffic approaching the Bay Bridge and traffic through the queuing area. More sensors need to be added to the

HOV bypass lanes as the current sensor network cannot correctly measure HOV volumes. A more robust and dense sensor network can aid in the expansion of data collection for volumes and travel times.

Another change to the toll structure that may impact volumes across the Bay Bridge is the increase in multi-axle vehicle tolls that occurred on July 1, 2011. Increasing the multi-axle toll may reduce the number of trucks on the Bay Bridge; doing so may allow for better traffic movement on the incline section of the Bay Bridge as trucks travel slower on steep upgrades when compared to the general traffic stream. Further analysis should be completed with regards to this potential change in vehicle mix.

In addition, FasTrak transponder/511 data does not automatically sort out HOVs (HOVs using the bridges now must use a FasTrak transponder to claim the toll discount and thus their travel is captured by the 511 system). A classification system needs to be developed to allow for the accurate representation of full-fare drivers and HOV drivers. This also could be used on other freeway segments in the Bay Area to determine travel time savings for HOV versus mixed-flow lanes on the freeways and to display travel time data on the changeable message sign network. For this analysis, transponder travel time data cleaned of HOVs could have yielded a check on the floating car travel time runs.

6. REFERENCES

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(2) San Francisco Bay Crossings Study. Oakland, California: Metropolitan Transportation Commission, 2002.

Appendix B

Variable Pricing on the San Francisco-Oakland Bay Bridge: Sorting Out Toll Effects from Other Factors

Variable Pricing on the San Francisco-Oakland Bay Bridge: Sorting Out Toll Effects from Other Factors

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1. INTRODUCTION

The raising of bridge tolls on the San Francisco-Oakland Bay Bridge on July 1, 2010 provides one of the few U.S. examples where true peak-load pricing is now being applied on a major highway facility, in this case a bridge crossing. The toll increase introduced time-of-day pricing on the bridge facility. This occurred through raising bridge tolls from $4 to $6 during peak hours (5AM-10AM and 3PM-7PM) and retaining the previous $4 toll for all other periods, except weekends when a $5 toll is charged. Rush-hour motorists thus ended up paying a 50 percent surcharge relative to what they previously paid and relative to those who travel during non-peak weekday hours. Also the practice of allowing free passage to carpoolers, motorcyclists, and vehicles with clean-air decals ended on July 1, 2010 when a $2.50 levy was charged to vehicles using the bridge's HOV (High-Occupancy Vehicle) lanes. Hybrid vehicles with clean air stickers were allowed to drive solo in HOV lanes, but they still had to pay full fare ($4). With the toll increase, they now pay $2.50, thus incurring a toll decrease. Given the differentiated nature of toll charges that were introduced, the generic term "variable pricing" perhaps best expresses the Bay Bridge's new pricing regime.

This report investigates the influences of higher peak tolls and variable pricing on traffic volumes on the San Francisco-Oakland Bay Bridge. Regression equations are estimated that partial out the influences of the toll charges on traffic volumes controlling for other factors that could explain variation in demand, such as rising gasoline prices and unemployment levels in the region. Predictive models are presented for explaining changes in peak-period traffic on HOV lanes (i.e., carpools, motorcycles, and qualified low-emission vehicles) and on all lanes (e.g., all motorized traffic on all lanes) as well as total monthly traffic (i.e., peak and off-peak weekdays plus weekends). An effort was also made to apportion changes in traffic to various factors like rising gasoline prices and unemployment as well as the availability of BART as a substitute mode vis-à-vis higher tolls in accounting for variations in Bay Bridge traffic volumes over the time series. Particular attention is given to sorting out factors that help explain the effects of charging a $2.50 toll to carpools given that these vehicles could previously cross the Bay Bridge for free during peak hours.

2. DATA AND TRENDS

A time-series database was constructed with months being the unit of analysis. Before-and-after data were compiled over the 29-month period of January 2009 to May 2011 – i.e., 18 months prior to the toll hike and 11 months after the increase. Collected data comprised variables that theory holds might explain month-to-month variations in bridge traffic, including: bridge tolls; incidences that could influence traffic volumes (e.g., bridge closures; bridge accident levels; air pollution episodes when the use of public transit and alternative modes are actively promoted); and exogenous factors, notably regional fleet-averaged median gasoline prices and unemployment rates. In addition, because the Bay Area Rapid Transit (BART) heavy-rail service operates through a tube along the Bay Bridge corridor and thus represents a substitutable mode, monthly data on BART service levels (e.g., the number of rail-car units), average fares, and ridership were also compiled. Data for other variables that might sway bridge traffic volumes, like monthly attendance at the AT&T sports stadium near the bridge's western terminus in San Francisco, were collected as well.

Before presenting the model results, it is useful to track trends for some of these variables over the 29 month period. Figure 1 indexes monthly trends for: peak total vehicles (passenger cars on regular lanes, multi-axle vehicles, and all vehicles using HOV lanes); peak vehicles using HOV lanes; and total vehicles (i.e., all vehicles for all hours of the day and days of the week during the month). The graph shows that the toll hike was accompanied by a precipitous decline in traffic using the HOV lane, which fell from 367,473 vehicles in June 2010 to 270,210 in July 2010 – more than a 25 percent drop in one month. Total peak-hour traffic volumes, however, generally held their own for the first few months following the toll hike. Moreover, total Bay Bridge traffic volumes (peak and non-peak) actually rose the first few months after the toll increase, suggesting some motorists switched their times of travel to the edges of the off-peak (e.g., before 5AM or after 10AM in the morning) to save $2 in the westbound direction (which is the only direction for which tolls are collected; eastbound bridge traffic crosses for free). While non-HOV Bay Bridge traffic tended to remain stable several months following the toll hike, by late Fall 2010, all traffic volumes began to taper, reaching a particularly low point in February – partly due to fewer days in the month but more likely due to the lingering effects of the economic recession and steadily rising gasoline prices.

Regional trends in these two important exogenous variables – gasoline prices and unemployment rate – are shown in Figure 2. Soon after the average bridge toll rose by nearly 27 percent in one month (June to July 2010), the region's average gasoline price began trending upward, reaching nearly $4.20 per gallon for regular unleaded in Spring 2011, among the highest rates in the nation. Gasoline prices more than doubled over the 29 month period shown in Figure 2. The San Francisco Bay Area's unemployment rate, while still fairly high at over 10 percent in Fall 2010, had largely stabilized following the toll increase, suggesting its influence on traffic volumes was likely not as strong as that of rising gasoline prices. Figure 2 also shows that BART ridership remained fairly flat over the 29 month period, showing some patterns of seasonality (e.g, dips in December). While factors like rising gasoline prices and bridge tolls might have spurred some travelers to take BART, the economic recession could have had a counter-balancing effect, resulting in stable ridership figures.

3. MODELING DEMAND IMPACTS

Higher bridge tolls should curb the demand for motor-vehicle travel and peak surcharges should exact an even more pronounced effect on peak-period travel. Since carpools and other users of the HOV lane previously traveled for free, the impacts of a new bridge toll on this group, bridge officials predicted, would be particularly strong, which is suggested by trend lines in Figures 1 and 2.

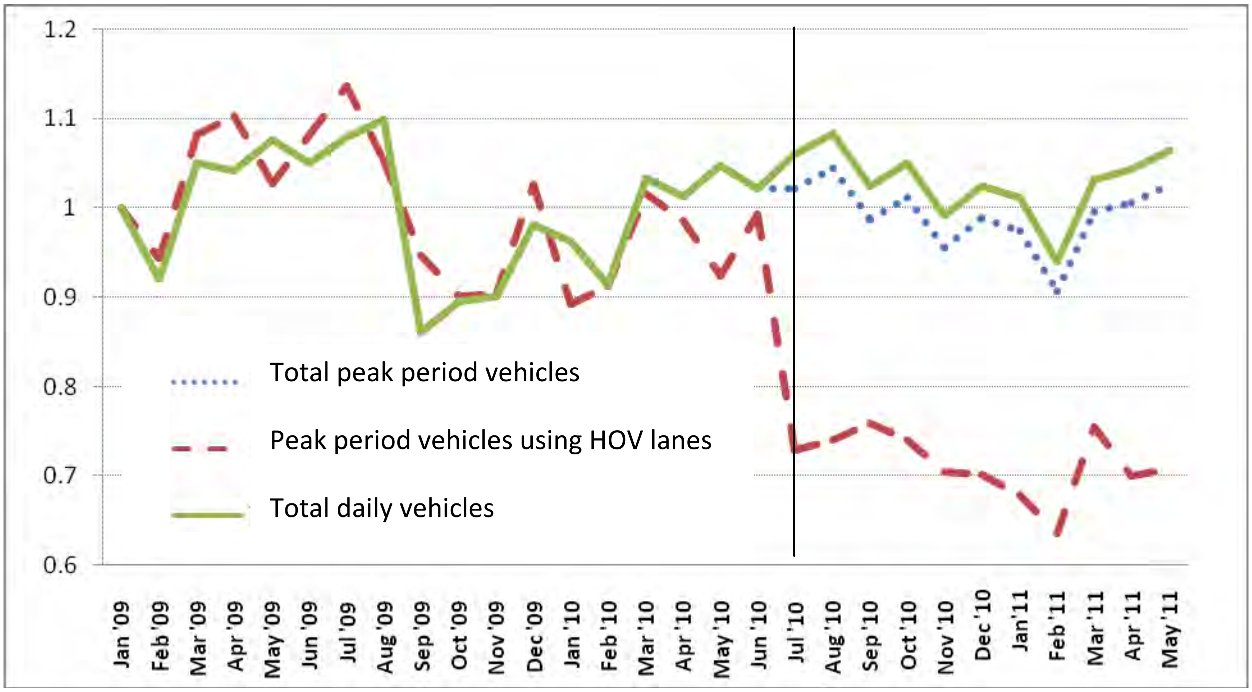

FIGURE 1 Trends in Bay Bridge Traffic Volumes: January 2009 to May 2011. All monthly values expressed as a proportion of January 2009 values.

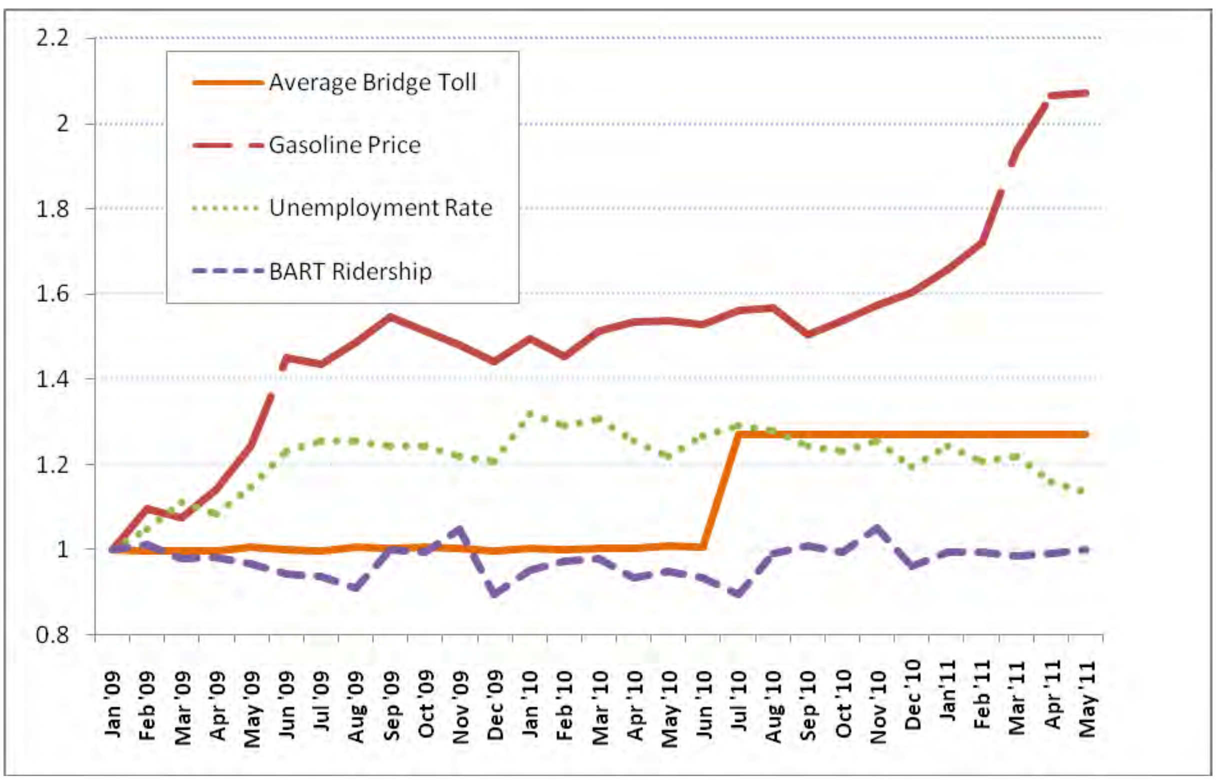

FIGURE 2 Trends in Factors Possibly Influencing Bay Bridge Traffic Volumes: January 2009 to May 2011. All monthly values expressed as a proportion of January 2009 values.

In estimating a predictive model, it is necessary to separate out the influences of higher bridge tolls and peak-load pricing on traffic volumes from other factors that also influence travel over time. These include not only exogenous factors like gasoline prices and unemployment rates, but more endogenous ones as well – i.e., they are within the sphere of public policy influence. Perhaps most notable is the presence of a high-speed heavy rail service along the trans-bay corridor, BART. Accordingly monthly data were compiled on BART service levels (expressed in rail-car units), average fares, and ridership (stratified by peak, non-peak, and total hours) for train services operating through the trans-bay tube. Additional variables compiled that could influence travel demand along the trans-bay corridor included: number of "Spare the Air" days each month (when various media actively encourage travelers to take public transit or share rides because of high air pollution levels); monthly attendance at AT&T stadium (home of the San Francisco Giants) near the bridge's western terminus; number of days of bridge lane closures during the 5AM to 10PM period; and an adjustment for number of days in each month [relative to a value of 30; thus with 31 days, the month of January was assigned a value of 1.033 (i.e., 31/30) while February was assigned a value of 0.933 (i.e., 28/30)].

Because of the limited number of time series data points, particular care had to be given specifying models to allow key predictor variables of interest to be studied while at the same time minimizing the inefficiencies introduced when predictors are highly correlated amongst themselves. For example, rising gasoline prices likely had a hand in reducing business transactions and thus employment rates, which from Figure 2 appears to have been the case during the first part of the time series.

The models of Bay Bridge traffic volumes presented in this paper were estimated by initially including available endogenous and exogenous variables in the equations, as outlined above, guided by traditional utility-based theories of travel demand. Thus variables on bridge tolls and service levels, BART fares and service levels, incidences (e.g., spare-the-air days; bridge closures), and various statistical controls (e.g., gasoline prices; unemployment rates; days-in-month adjustment) were initially included in all models. In part due to the relatively small number of time-series data points but also due to the presence of statistical problems like multi-collinearity, highly insignificant variables were then purged from the initial model.

Because the Bay Bridge and BART are alternative, substitutable connectors of Oakland and San Francisco, economic theory holds changes in prices and service levels should have reciprocal effects on demand for both options. For example, shifts from motorized travel to BART in response to the higher bridge tolls might be expected to prompt BART managers to run more trains during the peak which would further influence mode choice. However the trans-bay corridor is really not a privately-run, competitive marketplace, with agents seeking to maximize profits, but rather a corridor wherein prices and transit service levels are governed by public institutions. Strapped for funding, BART did not intensify services in anticipation of mode shifts from the higher and time-differentiated bridge tolls. In fact, the monthly number of rail-cars passing through BART's trans-bay tube fell by more than 4 percent during the first six months of the Bay Bridge toll hike (July 2010 to January 2011). Instead of service expansion, peak rail services were marked by more crowded trains. While monthly data on number of rail-cars (for all of BART and for trans-bay services) and mean BART fares were compiled, these variables were highly insignificant for all models. In terms of model estimation, moreover, prices, service levels, and demand did not simultaneously influence each other, as in the case of private transportation service-providers, thus there was no need to econometrically estimate models using instrument variables or structural equation modeling. Rather ordinary least squares (OLS) estimation was used. Because the presence of BART as a potentially cheaper mode did influence Bay Bridge traffic following the toll increase, monthly ridership was used as a predictor variable to reflect the relative drawing power of BART as a substitutable mode. Thus ridership, not service levels, was employed to express the relative influences of BART's presence on Bay Bridge traffic volumes over the time series.

Lastly, a secular trend variable (January 2009 = 1, February 2009 = 2, etc.) was initially applied to models. Because a number of other controls (e.g., average gasoline prices) were similarly trending upwards over the time series, this variable was unnecessary and thus omitted in the final models.

4. IMPACTS OF TOLL ON HOV TRAFFIC DURING PEAK PERIODS

For carpools, motorcyclists, and other HOV-lane users traveling during peak hours, going from free passage on June 30 2010 to a $2.50 toll on July 1 2010 marked a stark change in the treatment of these "small footprint" travel modes. There was perhaps more political sensitivity to a possible public backlash to this new toll than there was to any other part of the new toll regime, including differentiating tolls by time-of-day and day-of-week.

Table 1 presents the estimated model that yielded the best statistical fit while also producing results that matched theory and expectations. Because a log-log model was estimated, coefficients can be interpreted as point elasticities. It should be noted that the variable "HOV Toll" could not be expressed in logarithmic form since there was no toll prior to the July 2010. In the log-log model, the toll applied to HOV lanes was treated as a binary event – from a free service to a tolled one -- using a 0-1 dummy variable, with the coefficient treated and interpreted as an elasticity like other variables in the model. Overall, the model in Table 1 explained 92 percent of the variation in peak HOV-lane traffic over the 29-month period.

Carpools and other vehicles using the bridge's HOV lane were moderately sensitive to the exaction of a $2.50 toll. The estimated elasticity of around -0.30 is in line with the short-term elasticities recorded for time-of-day road pricing schemes abroad and in Southern California (Litman, 2011). The imputed price elasticity -0.30 is considerably higher than the -0.15 figure estimated for a Golden Gate Bridge toll increased in 1992 for all times of day and the -0.05 value estimated for the Bay Bridge when the toll rose from $0.75 to $1.00 in 1988 (Harvey, 1994; Wilbur Smith, 2000).

TABLE 1 Estimated Regression Model of Factors Influencing Peak-Peak High-Occupancy Vehicle (HOV) Volumes, January 2009 to May 2011. Dependent Variable = HOV Traffic Volume. All variables expressed as natural logarithms except HOV Toll.

	B	**Beta**	**t**	**Prob.**
HOV Toll ($)	-.296	-.828	-9.590	.000
BART Peak Ridership	-.652	-.148	-2.056	.052
Unemployment Rate (percent of workforce)	-.199	-.074	-0.921	.367
Gasoline Price (mean, $)	-.113	-.109	-1.109	.279
Spare Air Day (0/1)	.041	.119	1.846	.078
Number of days in month (relative to 30)	.662	.118	1.821	.082
Constant	20.645	--	4.984	.000
Summary: N = 29 F = 41.00; prob. = .000 R^2 = .918				

Table 1 also reveals that although less statistically significant, the presence of BART (as represented by the proxy variable "BART Peak Ridership") appeared to influence the bridge's HOV traffic volumes during the peak period. So did rising regional gasoline prices and unemployment rates, which depressed HOV-lane traffic over the time series (although based on the elasticities and beta coefficients, not as much as the HOV toll itself). Incidences of poor air quality, when Spare the Air public announcements encourage motorists to share rides or take alternative modes, appeared to boost HOV-lane usage.

BATA's board asked for estimates of how recent losses in HOV-lane traffic might have been distributed among various factors like the introduction of a toll, the availability of BART, escalating gasoline prices, and rising unemployment. This was done using the standardized coefficients, or beta weights, in the predicted model. Beta weights reflect the relative explanatory power of predictor variables. They allow factors influencing HOV-lane traffic over the time series to be apportioned. The following formula was applied for this purpose:

$$P_i = \frac{\beta_i}{\left[\left(\sum_{j}^{k} \beta_j \right) / R^2 \right]} \qquad (1)$$

Where:

P_i = Proportion of variation explained by variable i

β = Beta weight (standardized regression coefficient)

R^2 = Coefficient of Determination of model (proportion of variation explained by variables in the equation)
K = Number of explanatory variables in model
j = Summation index , where j = 1, 2,….K

The formula states that the share of variation in Bay Bridge traffic explained by variable i represents its beta weight relative to the sum of all beta weights in the model, adjusted for the share of total variation explained by the model. For purposes of creating a pie chart that apportioned the loss in HOV-lane traffic over the time series, an "other" category was created that represented the influences (based on beta weights) of the "Spare Air Day" and "Number of days in month" variables along with the share of variation in the dependent variable unexplained by the model (i.e., $1 – R^2$). This approach assured that the influences of key variables of policy interest – i.e., toll, BART, gasoline prices, and unemployment rates – plus a catch-all category of "other" summed to 100 percent.

Figure 3 presents the resulting pie chart. Overall, it is estimated that around 54 percent of the HOV-lane traffic losses were due to the introduction of a $2.50 toll. BART, I estimated, absorbed around 10 percent of the lost HOV-lane traffic (in its role as a substitutable mode along the trans-bay corridor). Smaller shares of the traffic losses were due to rising regional gasoline prices and unemployment. Nearly one-quarter of the changes in HOV-lane traffic were due to other factors like Spare the Air incidences and variables not explicitly accounted for in the model (including possible route shifts of former Bay Bridge motorists switching to other, albeit typically more circuitous, route crossings).

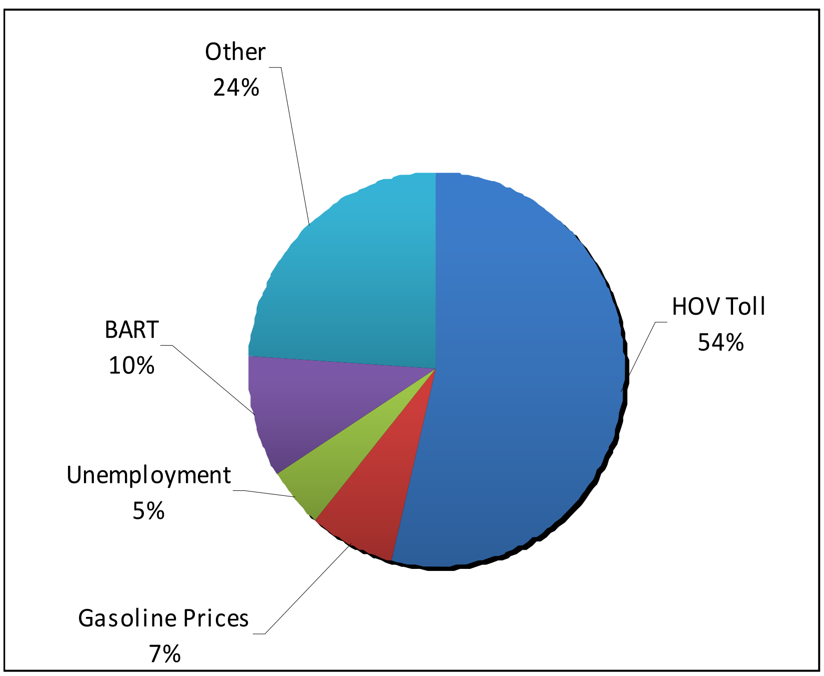

FIGURE 3. Estimated Effects of Key Factors Influencing Peak-Period HOV-Lane Traffic Volumes, January 2009 to May 2011.

5. IMPACTS OF TOLL ON TOTAL PEAK TRAFFIC VOLUMES

What effects did higher tolls have on all traffic crossing the bridge during peak hours – i.e., vehicles using both the HOV lanes and regular (non-HOV) lanes? Table 2 presents the best fitting, most interpretable model, again using a log-linear specification and OLS estimation. It is noted that a separate model was also estimated for predicting impacts on peak-period non-HOV traffic (e.g., non-carpools and multi-axle vehicles using regular lanes), however the results were quite similar to those in Table 2 and thus are not presented here.

The estimated short-term price elasticity of -0.233 indicates most motorists were willing to absorb the higher bridge toll, which is again consistent with findings of past research that peak-period travelers are fairly price insensitive. Those priced off the bridge were presumably previously making more discretionary or lower value-added trips. Some no doubt shifted to the lower-priced shoulders of the weekday peak (e.g., prior to 5AM and after 10AM). And some opted for alternative routes. BART also appears to have attracted some former peak-period motorists (with again BART ridership serving as a stand-in metric for the availability of trans-bay rail service as an alternative mode).

The relative influences of the variables in explaining changes in total peak-period traffic on the Bay Bridge were estimated, applying the beta weights and goodness-of-fit statistic in Table 2 to equation 1. The pie chart in Figure 4 reveals that other factors not explained by the model (including possible route shifts) had the dominant influence on changes in total peak-period bridge traffic over the 29 month period. The bridge toll itself was estimated to account for 17 percent of the changes in peak-traffic volume, followed in relative importance by the presence of BART as an alternative mode and rising gasoline prices.

TABLE 2 Estimated Regression Model of Factors Influencing Peak-Peak Total Traffic Volumes, January 2009 to May 2011. Dependent Variable = Total Peak-Period Traffic Volume, including multi-axle vehicles and motorcycles. All variables expressed as natural logarithms.

	B	Beta	t	Prob.
Average Toll ($)	-.233	-.403	-2.399	.031
BART Peak Ridership	-.520	-.306	-1.339	.032
Gasoline Price (mean, $)	-.072	-.179	-1.125	.272
Bridge Closures (0/1)	-.075	-.340	-2.122	.014
Number of days in month (relative to 30)	.824	.384	3.092	.005
Constant	21.040	--	7.692	.000
Summary: N = 29 F = 0.96 ; prob. = .000 R^2 = .684				

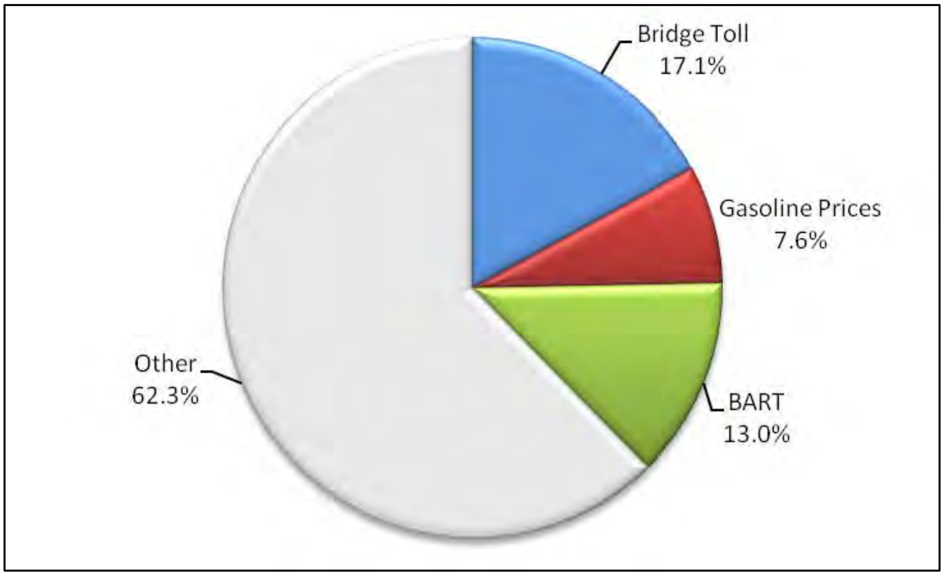

FIGURE 4 Estimated Effects of Key Factors Influencing Peak-Period Total Traffic Volumes, January 2009 to May 2011.

6. IMPACTS OF TOLL ON TOTAL MONTHLY TRAFFIC VOLUMES

A final model was estimated that examined the influences of higher tolls on total monthly Bay Bridge traffic volumes. A standard linear model best fit the data and provided the most interpretable results. The resulting model, shown in Table 3, explained 73 percent of the variation in total monthly traffic volumes over the 29 month period.

Table 3 reveals that every dollar increase in average toll over the time series was associated with a loss of 103,600 motorized vehicles crossing the bridge each month, all else being equal. The estimated mid-point line elasticity is -0.119, derived from multiplying the regression coefficient (-103.6) by the ratio of mean values for the explanatory variable [average toll ($4.228)] and dependent variable [total monthly traffic (3,684, expressed in 1000s)]. The relationship between average toll and monthly traffic volumes, however, was not statistically significant at the 5 percent probability level. Among variables measuring attributes of BART services, the best predictor was average BART adult fare level. Higher BART prices for trans-bay trips appeared to induce more bridge travel, although the relationship was not statistically significant. Higher unemployment and bridge closures cut into monthly bridge traffic volumes. Events at AT&T park had a stimulating effect. Most high-attendance stadium events do not occur in the peak period thus while AT&T Park attendance did not enter into the peak-period models as a significant predictor, for the model of totally monthly traffic, which encompasses non-peak and weekend periods, it did. Lastly, because of the insignificant of average tolls and the absence of key variables like average gasoline prices and BART ridership from this model, no attempt was made to create a pie chart that apportions impacts among explanatory variables.

TABLE 3 Estimated Regression Model of Factors Influencing Total Monthly Traffic Volumes (in 1000s) on San Francisco Bay Bridge, January 2009 to May 2011. Dependent Variable = Total Monthly Bay Bridge Traffic Volume, including motor vehicles, multi-axle vehicles, and motorcycles.

	B	Beta	t	Prob.
Average toll ($)	-103.60	-.241	-1.208	.240
BART, average fare ($)	2,032.73	.335	1.261	.220
Unemployment Rate (percent of workforce)	-122.62	-.351	-2.029	.055
Attendance at events in AT&T Stadium, in 1000s	0.324	.366	2.652	.015
Bridge Closures (number of days in month)	-84.73	-.499	-4.375	.000
Number of days in month (relative to 30)	2,537.81	.363	2.997	.007
Constant	-4,358.36	--	-0.936	.359
Summary: N = 29 F = 10.14; prob. = .000 R^2 = .734				

7. CLOSE

The introduction of higher charges for crossing the San Francisco-Oakland Bay Bridge during peak periods is one of the few examples of peak-load pricing of a busy highway corridor in the U.S. today. Economists have long touted the virtues of peak-period tolling as an efficient way to ration road space and relieve traffic congestion. While studying the impacts on traffic conditions was not the focus of this particular working paper, the results did suggest that the higher tolls had an appreciable effect on bridge traffic volumes.

For the most part, the empirical results matched expectations. Most motorists and carpoolers appeared willing to absorb the higher toll charges however the price increases were not inconsequential, particularly for HOV-lane travelers. Bridge tolls exerted far stronger influences on Bay Bridge carpool traffic volumes than other factors, like economic conditions and gasoline prices. The estimated short-term elasticity of around -0.30 suggests significant shares of vehicles using the HOV lane during peak periods forewent travel, switched routes, or shifted to transit. Using the apportionment method presented in this paper, over half of the loss in carpool traffic was attributed to the introduction of an HOV-lane toll while less than 25 percent of the loss traffic, I estimated, switched over to BART or was due to rising unemployment or gasoline prices.

Regular (non-HOV-lane) traffic appeared to be less sensitive to the higher peak-period bridge tolls. In difficult economic times, motorists appear willing to absorb higher fees for essential travel like the journey-to-work. These findings are generally consistent with those reported for other time-of-day road pricing schemes introduced in the U.S. and abroad.

The results presented in this paper reflect just 29 months of time series data and only 11 months of post-toll-hike observations. Accordingly, they gauge short-term impacts. It will be important to monitor trends and relationships over time. Ideally, follow-up work will be conducted to measure intermediate-term (e.g., 24-to-36 month) and longer term (e.g., 48-to-72 month) impacts. Such knowledge should be of value in informing future tolling decisions on the Bay Bridge and other natural corridors where congestion pricing is being considered.

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Appendix C

Energy and Environmental Impacts of Congestion Pricing on the San Francisco-Oakland Bay Bridge

Energy and Environmental Impacts of Congestion Pricing on the San Francisco-Oakland Bay Bridge

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Working Paper

November 2011

Statement of the Problem

On July 1, 2010, the Bay Area Toll Authority (BATA) raised the light-duty vehicle toll on the San Francisco-Oakland Bay Bridge from $4 to $6 during weekday peak periods (5-10 a.m. and 3-6 p.m.), leaving the off-peak weekday toll unchanged. Weekend tolls were set at a flat $5 and a new $2.50 toll was instituted on carpools, which previously crossed the bridge free of charge. While BATA's principal reason for increasing the toll on the Bay Bridge and six-other state-owned bridges was to help pay for earthquake retrofits, the Bay Bridge toll schedule was specifically designed to serve as a mild form of congestion pricing. It was hoped that the 50% surcharge for peak period travel would induce a portion of the bridge users to schedule their travel off-peak, switch to transit, or otherwise cut back on their peak period use of the facility, reducing congestion and related energy use and emissions.

This paper develops first-cut estimates of energy consumption and emissions changes resulting from the new toll schedule, using data available from BATA and surveys conducted at UC Berkeley as part of an independent evaluation funded by BATA.

Background on Congestion and Emissions

The dominant air pollutant emissions from transportation that are regulated under the Clean Air Act are volatile organic compounds (VOC, also called hydrocarbon emissions or HC), oxides of nitrogen (NOx), carbon monoxide (CO), and particulate matter (PM). Motor vehicles emit pollutants from the tailpipe while a vehicle is operating. They also emit VOCs through evaporative processes and during refueling. Ozone (O3) is a regulated air pollutant (as an element of smog) but is not directly emitted; rather, O3 and other components of smog are the result of photochemical reactions involving VOC and NOx in the presence of sunlight.

Greenhouse gas emissions, including CO2, are regulated in California under AB32; in addition, SB375 requires regional transportation and land use planning and provides incentives for greenhouse gas reduction (CARB, 2011). In the last few years the federal government also has initiated CO2 emissions regulations affecting many sectors of the economy including transportation (US EPA 2011a, 2011b).

It is well settled that motor vehicle emissions and energy use vary with vehicle type, age, and condition, emissions control technologies, fuel type, ambient temperature, wind speeds, mixing layers, driving conditions including engine temperature, facility design, and traffic levels, and driving practices. Further, the type of emissions that are problematic vary with temperature and phase of use. CO and NOx are products of combustion and their emissions vary with engine temperature and efficiency. VOC emissions are products of combustion, evaporation, and leaks and spills; they occur during operation, when the vehicle is parked, and when it is refueled. VOC emissions occur in high quantities during start-up, when the engine is not operating efficiently and the catalytic converter used to reduce emissions is not fully warmed up ('cold starts"), but also occur when the engine has been turned off but fuel continues to evaporate ("hot soaks") and when the vehicle has been parked overnight and the next day the temperature begins to rise again ("diurnal emissions"). In addition, VOC emissions are high during heavy accelerations and at high speeds. Particulates, especially those under 2.5 microns, are heavily associated with diesel engines, but fine particles also are emitted by other motor vehicles. CO_2 are emitted as a product of efficient combustion and CO_2 and other greenhouse gases can also form from carbon that enters the atmosphere from leaks, spills, and partial combustion of carbonaceous materials, among other mechanisms.

Emissions can vary by a factor of 10 or more depending on the age, make and model, and condition of the vehicle. A number of vehicle technologies have been added to vehicles over the past several decades to reduce emissions, including catalytic converters, particle traps, gas caps and tanks that reduce evaporative emissions, and computer-controlled fuel injection and combustion processes. Low carbon fuels and energy efficient motor vehicles including hybrid and electric vehicles also have lowered petroleum consumption and reduced emissions.

Driving conditions can make a difference in emissions of as much as 20% (Barth and Boroboomsomsin, 2009). It has been understood for many decades that the stop-and-go driving and idling that characterizes motor vehicle travel under heavily congested conditions is a significant source of air pollutant emissions and energy consumption. It also has been understood that high speed driving is not fuel efficient and that pollutant emissions are higher at high speeds. This is part of the reason why efforts have been made over the past 30 years to smooth traffic flows and limit very high speed driving, both in the US and in other countries with high auto ownership and use (EU, Australia, Japan).

Some have worried about a rebound effect from traffic flow improvements, i.e., that the improved conditions will lead to more driving. In addition, a little moderate congestion that brings average speeds down from a free-flow speed over 70 mph to a slower speed of 45 to 55 mph can reduce emissions, but if congestion mitigation raises average traffic speed to above about 60 or 65 miles per hour, it can increase CO_2 emissions (Barth and Boroboomsomsin, op cit). However, there is broad consensus that smoothing the stop-and-go pattern of traffic so that cars move at a relatively constant speed will reduce energy use and emissions per mile driven. Indeed, this was the basis for the fuel-efficient traffic signal timing program initiated by the California Energy Commission in the early 1980s, which reduced emissions in the affected arterial networks by 2-8% depending on initial conditions (Deakin, Skabardonis, and May, 1986), as well as the many ramp metering efforts implemented in California and elsewhere from the 1960s forward.

Energy and Emissions Modeling

A variety of models for estimating energy and emissions are available, from simple spreadsheet models to detailed and complex models that account for vehicle fleet composition, traffic speeds, and the types of facility used for travel. The more complex methods are better capable of accounting for specifics such as the mix of vehicles in the fleet and facility types, but also require more data, expertise, and time to run.

Studies done over the last 15 years to update the emissions models as well as to evaluate their accuracy also have identified the need for further refinements, especially for cold starts, hot soaks, and high-speed travel (e.g., Barth et al. 1996, Singer et al., 2006, Barth and Boriboonsomsin, 2009), and improvements are in fact being made. The US Environmental Protection Agency (EPA) has released new emissions models (MOBILE6, MOVES) and continues to refine them. For example, the emissions models developed by the U.S. EPA have for decades been based on driving cycles that, for urban areas, attempt to represent an amalgam of slow speeds, stops, and delays as well as at higher speeds such as occur on uncongested freeways. Because the aggregate driving cycle approach did not lend itself easily to corridor level analysis or studies of specific facilities, the MOVES model takes a disaggregate approach. Both EPA and its state counterpart, the California Air Resources Board (CARB), recognize that different models and levels of detail are appropriate for regional analyses and for project evaluation.

EPA's MOVES model (EPA, 2001) allows the user to specify the air pollutants, vehicle operating characteristics, and road types to be investigated. The model then performs a series of calculations, including cold start and extended idle, and provides estimates emissions for each calculation step. It can be run with user-provided data inputs or with "default" data that are based on Census Bureau vehicle surveys, Federal Highway Administration travel data, and other federal, state, local, industry and academic sources. CARB's EMFAC and URBEMIS models likewise provide both regional and more locally-oriented modeling approaches that can be used with local data or default values.

Because the specifics can make a large difference in the results, estimates of emissions preferably should be based on the characteristics of the vehicle fleet in use in the area being studied, as well as the actual patterns of use (trips made by time of day, trip length, speeds traveled, stops and delays, parking duration, etc). However, for many studies the level of effort for using the advanced methods and local data is beyond available resources, and simpler sketch planning methods are used to produce estimate of emissions and energy use.

Expected Impacts of Congestion Pricing

Congestion pricing can increase average traffic speeds and smooth traffic where there is slow, heavily-congested traffic. However, in some conditions it might also increase speeds and accelerations so that emissions increase. Therefore a context-specific analysis is desirable.

In case of the Bay Bridge, a multitude of travel responses are available in response to congestion pricing. Travelers could choose to drive and pay the higher toll in return for a somewhat faster trip. Indeed, not only those who used the bridge before the toll increase but others who avoided it because of the unreliable and difficult travel conditions might opt to drive if the toll allows them to buy time. Drivers also could shift to the off-peak periods Monday through Friday and save $2 per round trip, or move certain trips to the lower-toll weekends and save $1. A few could switch to the San Mateo bridge, the only plausible alternative route for Bay Bridge travelers.

Some drivers might choose to cross the bridge less frequently. Workers who commute across the bay might cut their travel by 20% by going to a four day workweek; they also could reduce their transbay travel by telecommuting. Travelers crossing the bay for other trip purposes might consolidate trips (planning a night at the opera after a day at the spa, or going shopping after a medical appointment), reducing transbay trips but not activities. Still others might choose social-recreational or personal business destinations that do not require a trip across the bay. Some might simply eliminate trips, perhaps substituting teleshopping for an in-person trip or holding a business meeting by webinar.

Drivers also could switch modes. They could decide to carpool to share costs; two person carpools would pay the full toll, but could divide it, while carpools of three or more could not only share costs but could take advantage of the time-saving HOV lanes at the toll plaza. Or drivers could switch to transit, using BART, transbay buses, ferries, or a combination of these modes. Some of carpoolers and transit users would walk to the pickup points and their destinations, while others would use a motor vehicle to get to a transit station or park and ride lot, and a few would ride in employer-provided vans or community shuttles to reach their destination.

Some travelers could change residential locations or workplaces or if they found themselves needing to look for a new home or job, and as a result might no longer need to cross the Bay - or if the toll was a sufficient deterrent to travel (or "last straw" on top of other commuting difficulties) so that they felt a move was necessary. While moving might seem like a drastic step, over 12% of the population, or about one in eight Americans, moved between 2009 and 2010, the latest year available, with a much higher share of movers among urban renters and lower income populations (U.S. Census Bureau, 2011a, 2011b). While better housing and job changes are the principal reasons for a move (US Census, ops. cit.), once a move is being considered, travel times and costs have long been recognized to be to factor in choosing specific locations (Weisbrod, Ben Akiva, and Lerman, 1980).

Travelers also could choose (or be compelled by circumstances) to make a combination of these moves - for example, a person could decide to use transit part time, to telecommute part time, to drive off peak some days and during the peak hours others, to link social-recreational trips with work trips rather than going on a separate outing, to shop after work or during the lunch hour rather than on the weekends, and to look for a new apartment closer to work when the lease runs out. Multi-day surveys indicate that many travelers do, in fact, use a variety of modes and link trips when costs increase. Evidence from travel surveys conducted as part of the evaluation of the Bay Bridge toll increase confirm that such behavior is happening.

It is not likely, of course, that a toll increase of only a dollar or two would by itself spark widespread changes of this sort. However, the toll increase is happening in the context of an uncertain economy, volatile gasoline prices, and transit service restructuring, factors that together can lead to significant overall changes in costs and affordability, and spark reconsideration of travel choices.

Analysis

The best method for analyzing these complex changes would be to use an advanced, disaggregate travel demand model (or land use-travel-activity model) plus an advanced emissions model, complemented with data collection and surveys to measure actual changes and dig deeper into their causes. The travel demand model would be used to represent and capture and sort out the variety of responses available to travelers; a disaggregate form of the model would allow consideration of changes by income group and location rather than by zonal averages.

Modeling the travel impacts of this complex set of changes would be a stretch for even the most advanced travel demand models, had they been available for use. For this study, they were not. While models that can handle many elements of these travel and activity issues are available for the Bay Area, their application was far beyond the time and resources available in this study. In addition, some of the data elements that would be desirable for a detailed analysis of emissions, such as the specifics of the vehicles used by travelers crossing the bridge, were not available. (This information could be obtained by filming and creating a database of license plates, and obtaining year, make, model, and registration zip code from the Dept. of Motor Vehicles; but this approach was not feasible within the resources available to the study.)

To develop first approximation of emissions changes, data on emissions as a function of speed were used along with speed estimates based on floating car studies commissioned by BATA. CO2 speed - emissions relationships were taken from research conducted in California (Barth and Boroboomsomsin, 2008.) Figure 1, from their work, shows two curves for emissions vs. speed for CO2. The steady-state speed curve in Figure 1 is the approximate lower bound of CO2 emissions for any vehicle traveling steadily at that particular speed, while the real-world activity curve accounts for the accelerations and decelerations which occur in actual on road driving and increase emissions. (The activity curve is based on measurements from instrumented on-road vehicles in Los Angeles.) Vehicles traveling at very low average speeds accelerate and decelerate frequently, and also do not travel far, so the grams emitted per mile are high. As speeds increase, emissions decline up to a point, after which the higher engine load and frequent heavy acceleration episodes associated with high speed driving increase emissions again.

CO2 emissions track energy use - a gallon of fuel burned emits 19.4 lb. of CO2 - so a similarly U-shaped curve applies to fuel consumption vs. speed. Speeds in the 45-55 mph range result in relatively good speeds with low emissions, which is why speeds were set at 55 mph on freeways in earlier decades when energy conservation was being promoted.

For other key pollutants, the emissions-speed curves shown in Figure 2, for hydrocarbons (VOC), carbon dioxide (CO), and oxides of nitrogen (NOx), respectively, were used. The relationships were plotted using the US EPA's MOBILE 6 emissions model (SEMCOG, 2004). California uses its own slightly different emissions model EMFAC, and EPA's new MOVES model also produces slightly different results; however, the shapes of all the emissions-speed curves remain similar across models. The figures therefore are adequate to illustrate speed-emissions relationships at a first-approximation level of accuracy. Note that VOC and CO emissions decline with increasing speeds up to about 60 mph (after which emissions, not shown on the graphs, go up). NOx emissions decline to about 30 mph and then increase sharply.

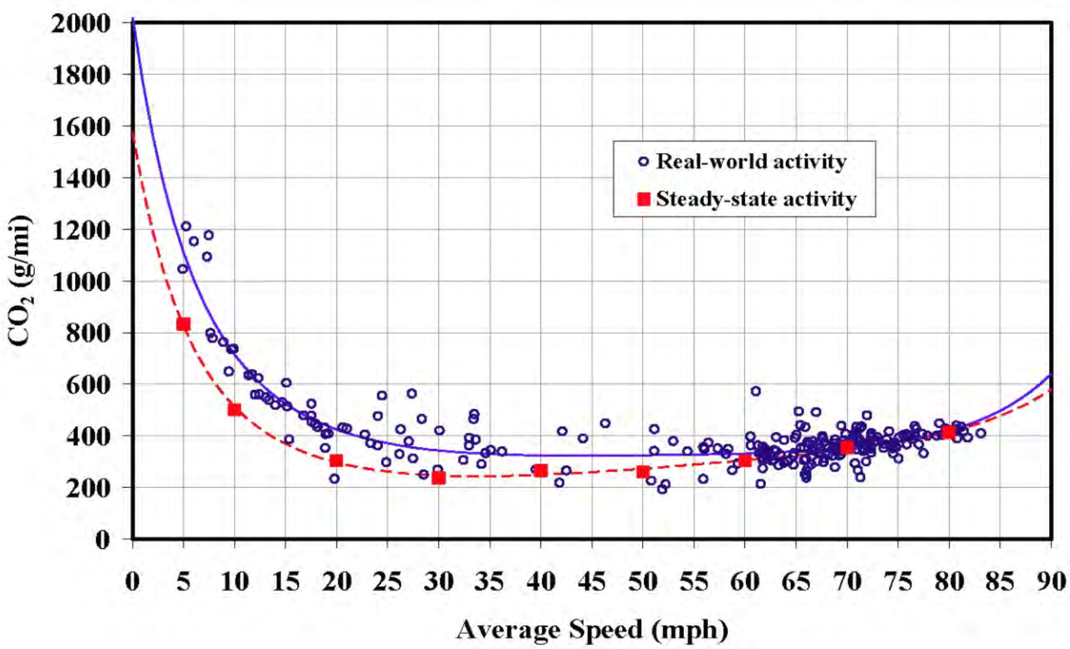
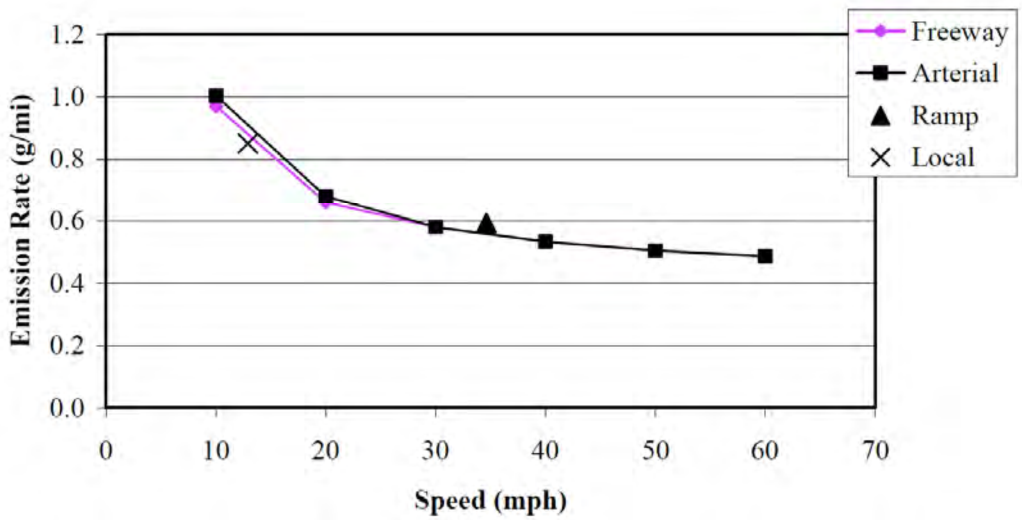


Figure 1. CO2 versus Average Speed (Barth and Boroboomsomsin, 2008).

Mobile6 VOC Emission Rates and Speed by Facility Type (Year 2010)



Mobile6 CO Emission Rates and Speed by Facility Type (Year 2010)

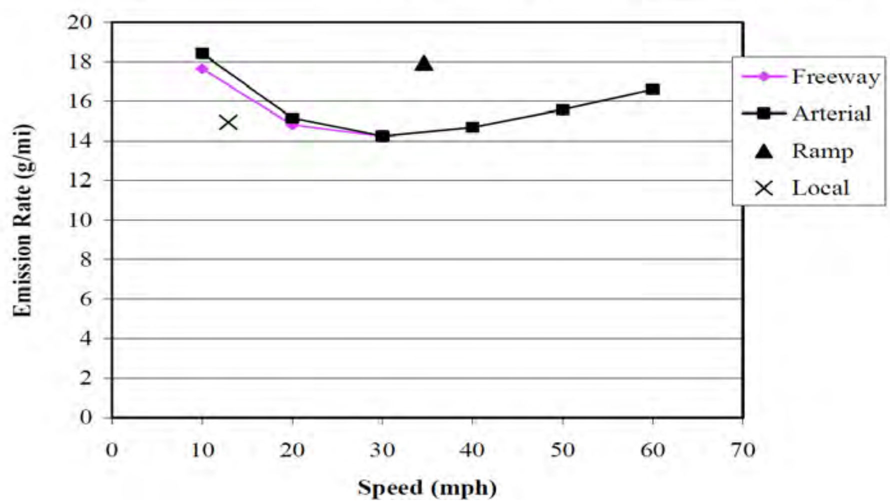


Figure 2: Emissions Rates as a Function of Speed for VOC, NOx, and CO2

Source: SEMCOG, 2004, based on runs of US EPA's MOBILE6 emissions model

To measure travel time changes before and after the new toll schedule on the Bay Bridge, BATA assembled FasTrak data for a period before the toll increase, and hired consultants to conduct a number of floating car runs. The data and methodology used by BATA and its consultants are reviewed in greater detail in a companion working paper (Barnes et al., 2011). Separate measurements were made for HOV lanes, FasTrak lanes, and cash lanes. From these travel time data we can estimate average speeds to the metering lights by lane type used, for all three approaches to the Bay Bridge: . I-80 from University Avenue in Berkeley (~ 4 mi.) , I-580 from Grand Avenue in Oakland (~ 4 mi.) and I-880 from Union Street on-ramp in Oakland (~3 mi.).

The data show that speeds in each of these study sections was very low before the toll increase. Before the toll increases, for example, it took almost 15 min for Fastrak users to get from the University Avenue-I-80 to the metering lights between 7 and 8 am; from the I-580 approach it took over 12 min. Since these are each about 4 mile distances, the average speed was about 16 mph from the University Avenue along I-80 and about 20 mph from Grand Ave. via I-580. Such low speeds, as shown in Tables 1 and 2, are associated with very high emissions of all sorts. After the toll increase, the speeds for FasTrak vehicles along certain approaches improved, except between 6 a.m. and 8 a.m. Speeds in cash lanes increased the most during the worst time period (7-8 a.m.) for travelers coming from all three freeway approaches – again a speed improvement change that produces a significant reduction in emissions. As Figures 1 and 2 show, all pollutants decline substantially with freeway speed increases. Speeds in HOV lanes were in the 50-60 mph range before the toll increase and did not change significantly for most times of day after it.

Because there is a high variability in traffic in the Bay Bridge corridor by time of day, day of week, and season, not all of the times for which floating car studies were available produced statistically significant results. The examples provided above are statistically significant, however. (see Barnes et al, 2011 in Appendix.)

Not all of the time savings is due to the toll, and therefore not all of the pollutant emissions are attributed to it. However, as the Cervero paper in this overall report's Appendix indicates, the toll has contributed to a reduction in travel times, congestion, and emissions. Focus groups and surveys conducted with Bridge travelers also support this conclusion.

Discussion

This analysis shows that when significant congestion exists and leads to very long delays, even a modest toll and improvement in travel time can result in significant reductions of emissions. A first estimate analysis indicates that during the peak hour on the bridge, reductions of CO_2, VOC, CO, and NOx were all significant.

Data limitations do not allow for a more detailed analysis as part of this study. However, future studies could use the technology available on the bridge or readily available in the region to carry out more elaborate investigations of travel times, speeds, and emissions as they relate to tolls. Using FasTrak information and /or video license plate methods coupled with surveys would allow future analyses to document how travel choices and emissions vary with price, by trip purpose and origin-destination pattern. Equity analyses could be added by collecting information on the socioeconomic characteristics of the travelers. A more fine-grained analysis could provide insights into how to set prices in the future to maximize both revenues and social benefits.

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Appendix D

Transbay Travelers' Responses to Congestion Pricing on the San Francisco-Oakland Bay Bridge

Transbay Travelers' Responses to Congestion Pricing

on the San Francisco-Oakland Bay Bridge

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Statement of the Problem

The San Francisco–Oakland Bay Bridge, which connects San Francisco and the East Bay, is a heavily traveled toll bridge facility. For two decades or more, delays at the toll plaza have averaged 20 to 25 minutes and sometimes more on the bridge's westbound approaches during the morning commute.

On July 1, 2010, the Bay Area Toll Authority (BATA) raised tolls on all state-owned bridges in the region, in order to cover the costs of earthquake retrofits. For the Bay Bridge, BATA introduced a mild form of congestion pricing in order to encourage peak-period transbay travelers to switch the time of day or mode of travel.

The toll previously was a flat $4 for non-carpool single-axle vehicles on all state-owned bridges in the region. BATA increased the Bay Bridge toll, which is collected westbound only, to $6 during the peak periods (5-10 a.m. and 3-7 p.m.) on weekdays. This amounts to a 50% toll increase for peak period weekday travel. The weekday off-peak toll was left at $4 and Saturday and Sunday tolls were set at $5 throughout the day. On other state-owned bridges in the region the regular toll was set at a flat $5.

As part of the new toll schedule, a peak period toll of $2.50 on carpools with three or more occupants was introduced on all state-owned bridges, In addition, carpools of three or more passengers may use the toll plaza carpool lanes only if they pay the carpool toll using California's electronic toll tag, FasTrak. Carpools of three or more previously travelled toll-free on the state-owned bridges, and did not need FasTrak to use the carpool lanes.

Estimates developed by consultants for BATA predicted that average delay at the Bay Bridge toll plaza would decline from 27 minutes to 23 minutes, a 23% reduction or average four minute savings in the morning peak period. For the evening peak period, the consultants estimated that delay would decline from 10 minutes to eight minutes, a two minute, 18% delay reduction. (Cambridge Systematics, 2009.) Data collected after the toll increase show that delay was reduced mostly because of a sharp decline in carpool traffic that immediately followed the institution of a toll and required use of FasTrak (BATA, 2010; BATA, 2011). The decline in carpools has persisted for nearly a year.

Travel demand models can be used to evaluate price changes, but running the region's formal travel demand models was not feasible within the resources available for this evaluation. Price elasticities can be used to consider the likely change in travel with respect to a price increase, but their application requires careful assessment, especially when applied to a single corridor where traveler incomes and travel choices are not necessarily the regional average. Typical price elasticities for urban travel are in the -.1 to -.3 range: a doubling of cost leads to a 10-30% reduction in demand. However, a toll increase is only one element of travel cost, and the total out-of-pocket cost can vary substantially depending on distance traveled and parking costs incurred. For example, a Bay Bridge traveler living 25 miles from work might pay $8 round trip in operating costs (mostly for fuel) and $16 in parking costs. With a $4 toll, the daily commute cost would be $28. A $2 increase in the toll to $6 would bring the total cost to $30, a 7% increase in total daily costs. However, if the same traveler did not have to pay for his parking, daily costs would be $12 before the toll increase and $14 after it, a 17% increase. For a traveler whose round trip was only, say, 25 miles, the cost of driving plus the toll would be about $8 before the toll increase, $10 after, a out-of-pocket cost increase of 25%. Furthermore, price is also relative to income, and sensitivity to price changes depends on trip purposes and available alternatives. In a complex corridor such as the Bay Bridge, then, elasticities and simple models provide useful information, but the results are likely to be approximate, especially when applied to travelers who may not be "average".

Because of these complexities, several different research approaches are being used in this study to examine travel behavior. The purpose of this paper to is examine reactions to congestion pricing as expressed by transbay travelers in surveys and focus groups on the topic. The surveys and focus groups were designed to assess knowledge, attitudes, and responses regarding the new pricing strategy, and to provide greater insights into factors in addition to time and cost considerations that may have affected their travel choices in the Bay Bridge corridor.

We first provide background information on traveler behavior and responses to changes in the conditions of travel. We also relate this extensive literature and body of work to the Bay Bridge corridor. This discussion then frames and guides our study approach and detailed analysis of the surveys and focus groups provided below.

Background on Travel Behavior and Responses to Change

Traveler responses to changes in the conditions of travel are affected by many factors, including the traveler's personal characteristics and those of the household, the other travel options available to the traveler and considered by him or her, and whether alternative destinations are available for the trip. Traveler responses are also affected by psychological, social and environmental factors, such as concerns about personal safety, reactions to crowding, attitudes about the environmental soundness of various modes, and status assessments of various modes.

Among the personal characteristics that have been shown to affect travel choice are age, sex, mobility impairments, employment status, work hours, and occupation of the traveler. Household characteristics also have a strong influence on household members' travel and include household size, number of workers, presence of young children, number of licensed drivers, and number and types of vehicles available to the household members. Along with auto ownership, home and work locations heavily shape what travel options are available to the individual; they frequently anchor and delimit other trip-making, especially during the workweek. The locations of schools, shopping and services of various types also shape where, how, and how often trips are made and the travel options that can be used. In addition, the traveler's knowledge and impressions of the modes of travel available for a particular trip or in a particular area can affect whether they are seriously considered.

In thinking about what mode(s) of travel to use, the amount of time it takes to make a trip by a particular mode is a very important determinant of choice for nearly all travelers. Furthermore, travelers experience and respond to different uses of time very differently; time spent gaining access to a mode, e.g. walking to a bus stop and waiting for the bus, or walking to a store from a central parking garage, has been found to be 2-3 times as onerous as time spent in the vehicle. Likewise, time spent making transfers among lines or modes is at least twice as onerous as in-vehicle time.

Out-of-pocket travel costs are also a very important determinant of travel choices. For automobiles, these costs include fuel and some maintenance costs, as well as tolls and parking charges. It is not always a simple matter to determine an individual traveler's costs, however. When multiple travelers share a ride, the costs may be shared among all occupants, or may be absorbed by the driver. Travel costs also may be subsidized or reimbursed; for example, drivers may have a company car, a employer-provided transit pass, or a commute allowance; trips made for business purposes may be paid for by an employer or deducted as a business expense; parking may be provided free or at a discount by employers, retailers, and local governments. Thus simply knowing typical costs for travelers between an origin and a destination often will not tell the whole story.

Uncertainties and time constraints over the full course of the day have been shown to be important elements in travel choices. For example, it might appear that a traveler could take transit to work in the morning. However, if the traveler frequently has to work late, past the hours that transit service is available, transit use in the morning would become far less attractive. Likewise, a traveler might be able to carpool to work and home again, but if the traveler must pick up a child from daycare on the way home, carpooling may not be an option.

Travel time and costs, considered from the perspective of the travelers' activity schedule and total daily time budget, explain much, but not all, of mode choice. Psychological and social factors also shape what choices travelers are willing to consider. Individuals who are concerned about safety in parking lots late at night may not be willing to drive to work when they know they have to work late. Individuals who have never used transit may not even consider it when deciding how to get to work, even if its time and costs are better than the alternatives. Individuals' opinions about the status of a particular mode and the kinds of individuals who use it also can be a strong influence on choice. Habit also plays a role; once an individual has gotten used to a particular way of traveling, he or she is likely to continue to use it until a significant change - personal or household change, or change affecting the mode normally used - occurs. Such personal and household events as a household move, a new job, going off to school, getting married or divorced, adding a child to the household, or having children grow up and move out are the sorts of major changes that can result in a rethinking of travel choices and a trying out of different options. Habits can be re-established if the experiences are repeated and are positive, especially if they are reinforced by peers or authority figures. On the other hand, a single powerfully negative incident, such as being involved in a crash or witnessing an assault in a parking lot, may be enough to cause some individuals to abandon a previously preferred travel mode.

While breaking a habit can be precipitated by a significant change or incident, most changes do not rise to that level. Even so, adjustments to changes can take time. For example, if a transit system converts from a cash system to prepaid cards only, or a toll facility requires all users to have an electronic toll tag, some may use other routes or modes or defer discretionary travel until they get around to obtaining the payment media. It is important to distinguish the temporary instabilities caused by a change as people adjust to and accommodate it from the changes that will be permanent.

Changes in service levels, prices, or rules and regulations may result in short-term confusion, while people learn about the new conditions and adjust to them. For example, traffic calming studies have found that in the first several months after the change, violations, some intentional and others not, can be high, but usually decline after the first few months. Changes in conditions also can precipitate "opposition" behavior, especially if those affected believe the change was unfair or that they were not adequately consulted. For example, a rise in transit fares may lead some people to stay away for a while, even if transit still remains their best option from a time and cost perspective. The installation of parking meters may lead some shoppers to try other shopping districts or to protest by not paying the meters and protesting fines. In many instances such protest behavior subsides after a short period and travelers return to previous patterns.

Implications of Travel Behavior Literature for Bay Bridge Travelers

The findings on travel behavior have significant implications for the Bay Bridge congestion pricing changes. The new tolls and the requirement that carpools pay a discount toll can be expected to have not only an economic effect on travelers, but also psychosocial impacts. Reactions are likely to vary depending on the traveler's personal and household circumstances, residential location, destination(s) for which travel is being made, and trip purposes. Attitudes toward the changes in pricing and regulation also may vary from support to indifference to opposition. These responses also may vary over time as travelers react to new rules and prices, observe changes in the corridor, consider and in some cases try out alternatives, and eventually settle back into a travel routine.

A willingness to spend $2 extra to save 4 minutes implies that time is valued at the margin at about $30/hr. This is a high value of time but not an extraordinary one. For work trips, which are a significant portion of peak period travel across the Bay Bridge, value of time is often compared to the wage rate and has been found to be valued at half to two thirds that rate. A $30 value of time would thus imply a wage rate of $90,000 to $120,000, which is not out of line with wages reported for the area and among peak period San Francisco-bound auto drivers. Values of time are typically considerably less for other common trip purposes such as shopping but can be equally high or even higher for trips with high monetary implications or high time sensitivity, such as travel to the airport, to some business meetings, to school, and to medical appointments.

An increase in peak period tolls will simply lead to higher costs for some travelers but it can trigger other, more cost-sensitive travelers to reconsider their options. Some may decide to take transit instead of a car or carpool. Some may decide to carpool rather than drive alone. Some may shift trips to before or after the peak period to avoid paying the higher toll. A few travelers have may decide to take another route with a lower toll (e.g., in this case, to go to SFO from Oakland via the San Mateo Bridge rather than the Bay Bridge).

Travelers with discretion over their trip frequency have the flexibility to choose to travel across the tolled facility less frequently and consolidate trips when they do (e.g., plan a full day's outing to the museum, shopping, and a restaurant in the city rather than making three separate trips.) Some travelers may choose other locations for their activities (e.g., work at home one day a week rather than commuting five days, shop in Walnut Creek rather than San Francisco; dine out in Berkeley instead of in the city.)

If the toll increases shift some drivers to other modes, times of day, or destinations, or reduce the frequency of certain transbay trips, peak period traffic conditions may improve enough to lead some travelers who are currently on other modes or are traveling at other times of day to switch to driving, or to making their driving trips during the peak now that it is less congested. Shifts back into peak period auto driving would in turn offset some of the travel reduction that the toll precipitated among less time sensitive, more cost sensitive drivers. On the other hand, changes in congestion at the bridge may not be sufficient to alter some time-sensitive travelers' behavior. Because there are bottlenecks at other locations on the freeway system and high variability in travel times for most travelers, a small change in travel time at the bridge may not stand out to drivers who hit several congestion points along the way, or may be noticed only after a considerable number of trips have been made.

The situation is especially complex for Bay Area carpoolers, who have enjoyed both a cost savings and a significant time savings by using designated carpool lanes that bypass queues and can save carpoolers 20 minutes or more. If congestion pricing works as anticipated and reduces congestion in the non-carpool lanes, some carpoolers might decide to drive alone or just with one other person, particularly if it is a family member or co-worker, rather than “lose time” picking up and dropping off a third passenger. This would lead to an increase in traffic (and possibly in average vehicle occupancy) in the regular lanes but a drop in carpool lane usage. On the other hand, if drivers in the regular lanes decide that the toll is now too high, they may decide to take up carpooling. Shifts in both directions are plausible.

A further complication in the Bay Bridge case is related to the new carpool FasTrak requirement. Previously, carpools could use the carpool lanes without this device. Now that they must pay a toll, they must also have FasTrak; the carpool lanes are FasTrak only so that there is no delay (since the FasTrak lanes process cars several times faster than cash lanes.) This has meant, however, that some travelers who did not previously have FasTrak have had to obtain it. Many have done so, but some delayed for a while and for others this requirement appears to have been enough of a barrier that they reconsidered their mode choice. A recent study (511 Rideshare, 2011) suggests that about 83 percent of current casual carpool drivers had FasTrak before the new tolls went into effect, but no information is available about what that percentage was in earlier years. It t is possible that some drivers who did not have FasTrak have ceased offering casual carpool rides now that FasTrak is required.

Yet another complication is the effect on cost-sharing among carpoolers. Three or more people must be in a vehicle to qualify as a carpool across the Bay Bridge (but two is sufficient on many carpool lanes and across some of the other bridges in the region.) Since relatively few peak period vehicles, contain three people, many 3+ person carpools must be actively arranged. In the Bay Area, this happens in two ways: conventional carpool groups are established at workplaces or through rideshare matching services and the members ride together on a regular basis; and “casual carpools” are formed through the travelers' own initiative: drivers pick up ride-seekers who wait for the next available ride at designated areas in several East Bay cities. Before the carpool toll went into effect, organized carpools generally had an established cost sharing practice, but most casual carpoolers rode for free. Since the toll was instituted, most casual carpool passengers offer the driver a contribution toward the toll, though both the amount and the willingness of drivers to accept a payment vary with pickup location. However, paying for carpooling has been controversial, and there is considerable evidence that the carpool toll has reshaped the social dynamics of casual carpools and has led to situations that are uncomfortable for some. The new social dynamics triggered by the toll for carpools may be at least as important in affecting carpooling rates as the new toll itself.

Traffic counts on the Bay Bridge indicate that total traffic is up slightly. Analyses of traffic changes during the peak periods found statistically significant differences for some times of day (see Appendix A). However, efforts to model changes in monthly traffic as a function of tolls, fuel costs, unemployment rates, etc. found that the toll per se did not produce results that were significant at the 5% level. Predictive modeling attributes about half of the reduction in HOV lane use to the existence of a toll and the rest to other factors including fuel prices, days when the bridge was closed, etc. (Note that since the HOV toll was modeled such that its existence and not the specific price is what is represented.) (see Appendix B).

The reasons for such significant reductions in carpooling are hard to understand as a matter of cost alone. Simple price analysis shows that for HOV passengers, alternative means of crossing the Bay are significantly more expensive than carpooling. For example, a casual carpool passenger today pays $1 - 1.25 plus access costs for the westbound trip; previously only access costs were paid on the westbound trip. All available transit fares are more costly than the toll increase. For carpool drivers, the previous toll was zero, the current toll for carpool drivers is $2.50 if the driver pays it all - but if passengers pay $1 each, the driver's added cost is $.50 and if passengers pay $1.25 the difference is zero. The time differential remains significant, although not as significant as before the toll increase.

It is not entirely clear why so many have abandoned carpooling given the availability of continued time savings compared to the regular driving lanes, the higher costs of all alternatives, and the modest per-person costs under any of the cost alternatives. Most likely, the changes are due to a variety of factors, including but hardly limited to the tolls.

Losses in casual carpooling do not explain the observed reduction in HOV lane usage, if recent studies for the 511 ridesharing organization are correct: Casual carpooling formation rates are down about 9%, according to a study done in spring 2011 (511 Rideshare, 2011). Such a reduction falls far short of explaining the much greater reductions in HOV lane usage at the Bay Bridge. The data presented exhibit a high variance in the decline in carpool formation among the sampled sites, and unsampled sites also do not account for changes in carpools. Also, the counts themselves could have a high (but unreported) variance, since they were done for only a few hours at each site. Alternative explanations for fewer carpools and a precipitous decline in carpooling also are plausible, and include the possibility of a sharp reduction in organized carpooling once costs increased, or even a reduction in violation rates once carpool lanes were equipped with FasTrak readers.

The limitations of available data and models and the difficulty in understanding why the HOV lane changes were as drastic as they were all suggest a need for supplementary investigations. Hence, we carried out surveys and focus groups to provide insights into the underlying reasons behind the observed changes.

Data and Methods

Surveys and focus groups of transbay travelers were conducted to explore the reactions and reasoning regarding the complex set of issues and responses surrounding the Bay Bridge pricing changes. The surveys and focus groups were also intended to supplement and assist in interpreting the findings from the other data sources and analysis methods.

To gather information about transbay travelers' behavior, perceptions and responses to pricing, a baseline, "before", survey was designed by UC and BATA and conducted by BATA in June 2010. A total of 5,313 travelers responded to this survey. A second "after" survey was conducted a year later, in June 2011. A total of 5,004 travelers responded to this survey. In addition, a survey of transbay travelers who had volunteered to participate in this research was carried out. A total of 1,092 travelers responded to this survey. Finally, sixteen focus group meetings of transbay travelers were held to explore key issues and traveler reactions in depth.

Before and After Surveys

BATA distributed the "before" survey to those who responded to an invitation to participate issued through the FasTrak email list. This lists consists of FasTrak holders who had agreed to be contacted for surveys. BATA also prepared paper flyers announcing the survey and inviting participation, and asked Caltrans toll collectors to distribute the flyers to those who used the cash lanes. However, this was not part of the toll booth workers' official job description, and many toll booth workers felt it was too difficult to do. As a result, many paper flyers were simply discarded by the toll booth workers rather than distributed. HOV lanes were also omitted, since HOV lane users do not stop at the toll plaza and were not previously required to have FasTrak. As a result, cash lane users and HOV lane users were not contacted for the survey unless they also were sometime users of FasTrak or happened to use the cash lanes and get a flyer at the time of the survey. A question in the survey asking about modes used allowed a modicum of analysis of carpoolers and cash lane users and partially compensated for the limitations of the sample design.

The request to participate was emailed to 80,000 FasTrak holders and to an unknown number of cash toll payers. An on-line survey was distributed to those who responded to the request. 5,313 responses were received, 5,148 from the FasTrak solicitation email and only 165 from the paper flyers for which an unknown number were actually distributed.

The “before” survey gathered information on current travel behavior (including mode and time of travel, trip purpose, origin and destination and whether auto travelers paid for parking) as well as on socioeconomic and demographic characteristics of the traveler, such as income, ethnicity, age, and job sector.

The following June, a second "after" survey was designed by UC and BATA staff and administered by BATA. A modified sampling procedure was followed. No attempt was made to survey cash lanes in light of the failed attempt to distribute invitational flyers in the 2010 survey. A special effort was made to contact the 3,981 respondents from the 2010 survey who had agreed to be contacted later. 22,798 FasTrak holders who had made a transbay trip within the morning and evening peak periods were contacted; because by June 2011 this included travelers who used HOV lanes as well as travelers in the full toll lanes. The “after” survey asked once more the core socio-demographic and travel questions, and supplemented these with additional questions about changes in travel behavior and stated preferences.

Focus Groups

The before and after surveys were supplemented by 16 focus group meetings. Focus group participants were recruited by email from a list of volunteers from previous surveys, recruitment invitations sent out by BATA to FasTrak users and other survey respondents, and by paper flyers distributed by UC researchers at selected casual carpool locations.

The focus groups were held in downtown San Francisco, downtown Oakland, downtown Berkeley, Walnut Creek, and Vallejo. A total of 150 participants took part in these meetings. The groups were comprised of drivers who use the full fare lanes, carpoolers and casual carpoolers, BART riders (almost all of whom also drive at least once a week), former casual carpoolers who have taken up other modes, and transbay travelers who routinely use several different modes in any month.

The focus group discussions were 45 minutes to an hour in duration. During each focus group, participants discussed their transbay travel, both for work and other purposes. They were asked whether and if so, how their travel had changed since the toll increase. They discussed their views about the impact of congestion pricing on travel and bridge operations, and general perspectives on other transport modes available in the corridor. The discussions also explored the participants' knowledge about transportation alternatives, their costs and travel times, and their other salient characteristics, their attitudes toward the various alternatives, and their behavior in light of their viewpoints.

Each participant was offered a light meal during the meeting and was given a $50 gift card at the conclusion of the meeting.

UC Recruitment Survey

The focus groups produced an outpouring of interest. The UC Berkeley research team received emails from 1,825 respondents who expressed interest in participating in the research. While the resulting sample is not random, a comparison with Census data for the Bay Bridge commute shed shows that it is reasonably representative of the adult commuting population. The UC researchers thus decided to accept the volunteers' offer to participate in the research.

UC Berkeley researchers sent out a link to an email survey to the 1,825 volunteers, offering the incentive of being entered into a drawing for a $50 American Express gift card. Of the 1,825 volunteers, 1,092 responded to the survey (a 60% response rate). Of the 1,092 responses to the survey, 954 provided responses to key questions and were retained in the sample. The resulting responses were again compared to regional demographics and were reasonably representative of adult commuters, though there was less ethnic and racial diversity among the survey respondents than in the commuter population.

Findings

The before-after surveys, the UC survey of volunteers, and the focus group surveys and discussions each provided rich insights into transbay travelers' responses to the Bay Bridge toll changes. For the most part, the results from these different methods also were consistent with one another. We have combined the responses from these sources to highlight key findings on the following issues:

- awareness of new toll schedule and reasons for it; reactions to it
- knowledge of how transportation is funded and attitudes toward tolls as a funding source
- perceptions of changes to congestion levels on the bridge approaches after the toll increases
- changes in travel behavior due to toll increases
- importance of travel time reliability in choosing a mode
- potential for using transit and shifts to transit
- parking -- location and amount of payment
- impact on casual carpools

When there were differences in findings over time or when only one source produced a finding reported here, we identify the source and the timeframe; otherwise the findings stem from all the sources taken together.

Awareness of new toll schedule and reasons for it; reactions to it

From both the focus groups and the UC surveys we found that there was a fairly widespread lack of understanding of the reasons behind the toll increase.

Few focus group participants knew how the bridge was paid for or what the justification for a higher toll was. Many also thought the "bridge had already been paid for" and thus did not understand why the tolls were being raised. They had not seen media coverage of the reasons for the increases. A few who had did not understand why tolls were being raised on all bridges if retrofits were not needed on all of them.

In addition, very few participants understood that a higher toll during the peak was a way to reduce congestion and decrease travel times during peak periods. Some argued that it would be fairer to simply raise the toll to $5 at all times of day, instead of "penalizing people who have to drive to and from work during the peak hours". Others, however, thought that driving during peak periods was a bad social and environmental move, and that therefore it was fair to charge those who did drive then a higher toll, as long as there were other ways to cross the Bay that were reasonably available and affordable.

The toll on carpools was the most puzzling change in policy from the participants' perspective. Instead of being seen as a $3.50 discount from the standard $6 peak period toll, the $2.50 carpool toll at least initially was widely viewed as a new toll (penalty) for carpools, with an added burden that FasTrak was now required. About half of the focus group participants were of the opinion that carpools should not be tolled during the peak periods because they delivered many social benefits, and felt that this behavior should be rewarded with both time savings and cost savings. Many in this faction also thought that carpooling was a more environmentally sound mode than driving alone, and should be rewarded for that. Some further commented that carpools helped students, low income workers, and others on a tight budget to travel affordably, and argued that carpool drivers deserved credit for that. This perspective was not shared by all, however, with other participants arguing that the HOV lanes and other priority treatments provided carpoolers sufficient reward and that all cars should pay to use the bridge.

That said, there was a general attitude of "resigned acceptance" to the toll among the Bay Bridge commuters in our focus groups and surveys including carpoolers (Note, however, that the number of commuters still carpooling had declined substantially.) Most respondents saw the new tolls as "not worth fighting about". Indeed, some participants commented that "everything else is going up - why not tolls?" Increased tolls along with higher transit fares for the AC Transit, BART and Muni seemed to many of our respondents to be "par for the course."

Awareness of what the new tolls were costing drivers was mixed. Many drivers had carefully calculated their out of pocket costs for transbay travel, but a significant minority reported that they "didn't pay attention" to monthly expenses that were under $100 or $150 ("coffee money amounts", as one driver put it.). Several said that while they knew that the toll had gone up during peak hours, they didn't really think about it, since their FasTrak is billed automatically and they do not look at the statements each month.

Knowledge of how transportation is funded and attitudes toward tolls as a funding source

As the participants' comments on the reasons for the toll indicate, our research reveals knowledge gaps among Bay Area travelers on how transportation is funded and the role that tolls play in bridge funding. Knowledge about the costs of maintaining and operating transportation infrastructure and services was also low. Nor did participants provide strong recommendations on how revenues should be raised to fund transportation services. There were comments on whether government was spending the revenues it does have wisely and whether it could be more efficient, and also a number of comments that every level of government as well as travelers should contribute funds, to "spread the costs widely".

The research also found that there are mixed feelings about using tolls to fund transportation, but fairly solid acceptance that tolls can play a part. The UC survey asked respondents whether they agreed or disagreed with the following statement: “The higher toll is a good way to pay for bridge improvements.” Of the 813 survey participants that responded to the statement, just over half (409) agreed. Of those that agreed, income was not a significant factor. Instead, the best explanation of support or opposition was frequency of bridge use. As shown in the Figure 1, the less frequently that people cross the bridge, the more likely they are to believe that the increased toll is a good way to pay for bridge improvements. Only 35% of frequent crossers agreed.

Support for using a toll to pay for bridge improvements also was slightly higher among solo drivers than among carpoolers (Figure 2), but both groups had support levels in the range of 50%. Together with the response based on frequency of bridge use, this response suggests that the question may have stimulated a response based on both self interest and a sense of fairness whereby travelers who use the bridge less are more inclined to support higher tolls presumably so that other more frequent bridge users would pay for these facilities.

Respondents also were asked the extent to which they agreed to the statement: “Periodic toll increases are to be expected as costs go up.” Of the 941 people answering the question, 46% agreed or strongly agreed, and another 21% were neutral. Only 33% disagreed or strongly disagreed with the statement. The responses to this question are similar to the “resigned acceptance” of the higher toll that was found in the focus groups.

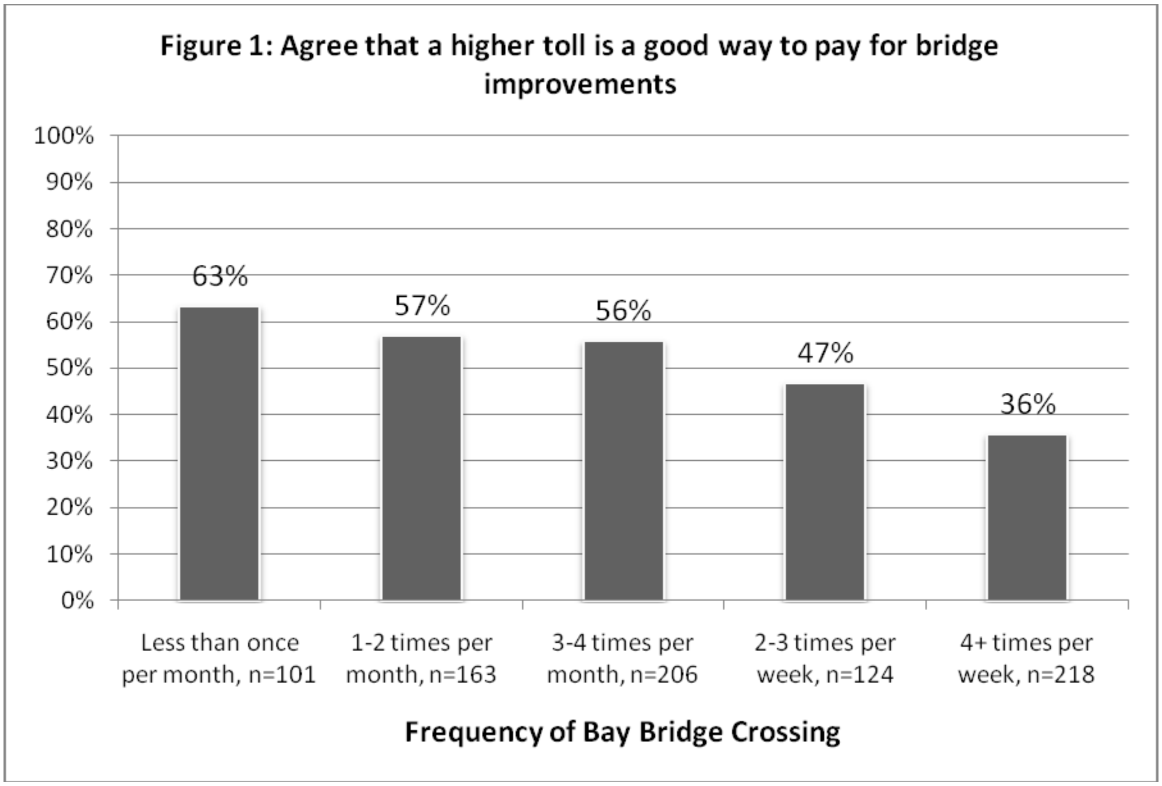
Figure 1: Agree that a higher toll is a good way to pay for bridge improvements
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
63%
57%
56%
47%
36%
Less than once per month, n=101
1-2 times per month, n=163
3-4 times per month, n=206
2-3 times per week, n=124
4+ times per week, n=218
Frequency of Bay Bridge Crossing

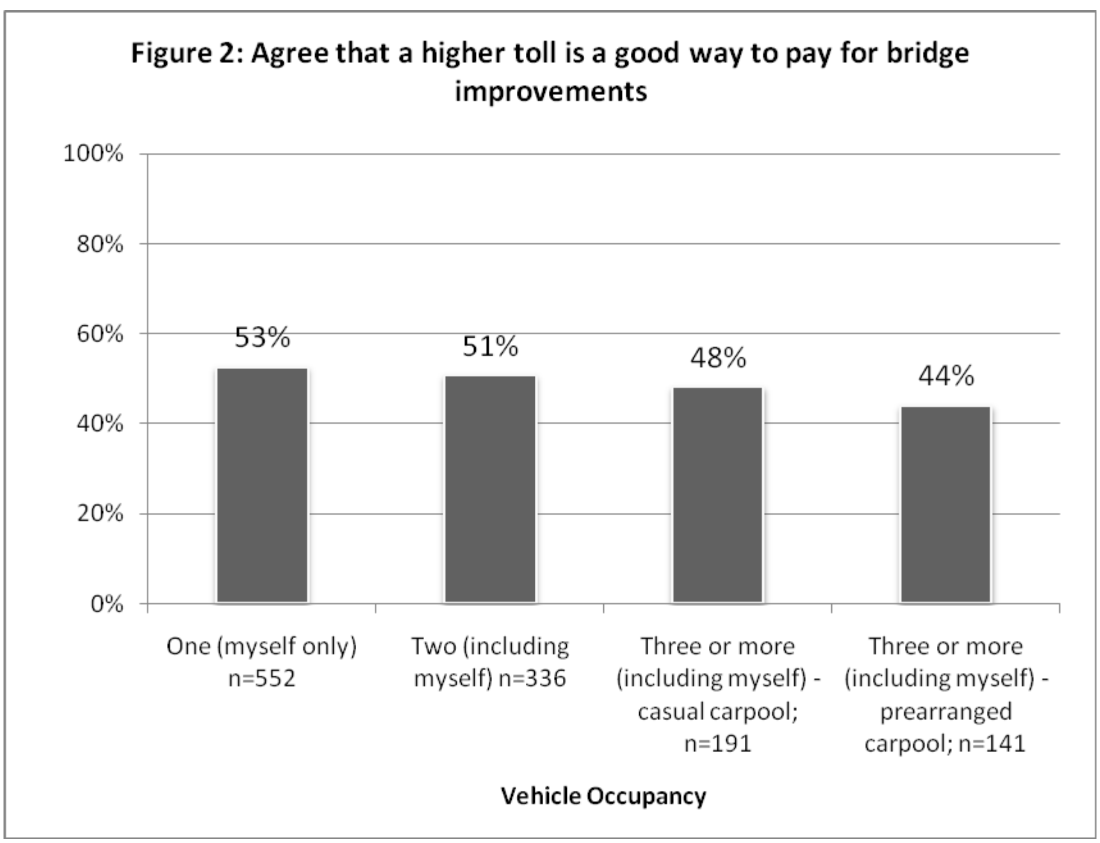
Figure 2: Agree that a higher toll is a good way to pay for bridge improvements
100%
80%
60%
40%
20%
0%
53%
51%
48%
44%
One (myself only) n=552
Two (including myself) n=336
Three or more (including myself) - casual carpool; n=191
Three or more (including myself) - prearranged carpool; n=141
Vehicle Occupancy

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Perceptions of changes to congestion levels on the bridge approaches after the toll increases

The UC survey asked a series of questions on whether the respondents had noticed a change in congestion levels. Respondents were asked whether they agreed or disagreed with the statement, "Traffic congestion is no different before and after the toll increase." Approximately 68% of people agreed, i.e., said they did not see much of a difference in congestion levels.

The UC survey also asked a series of attitudinal questions of the respondents that indicated they had been bridge-crossers since before the toll change. (The 120 survey respondents who first started crossing the Bay Bridge after the implementation of the new toll structure skipped these questions.) In particular, respondents were asked if they agree or disagree with the statement, "Peak period traffic congestion is lighter than before the toll increase." Of the 775 people that answered this question, 63% disagreed, which is generally consistent with responses from focus groups.

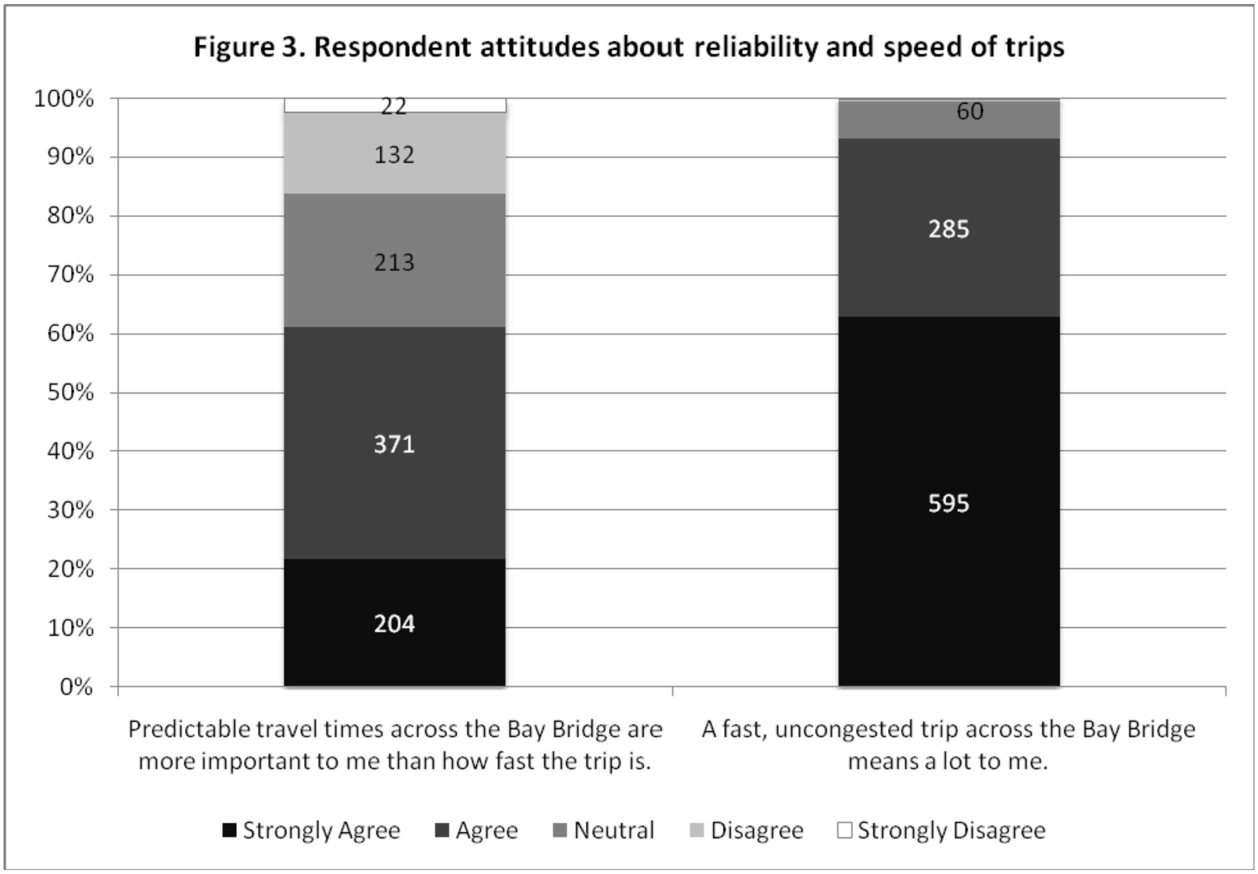
Looking at the respondents that answered the survey specifically thinking of their most recent westbound trip, we examined their responses by geographic origin and discovered that drivers in the I-80 corridor are the least likely group to perceive reductions in traffic after the toll increase, with under 20% agreeing that congestion was lower compared to over 30% who agreed on the 24 and I-880 corridors.

Focus group respondents had mixed responses on whether they noticed a change in congestion levels. While many reported that they did not notice much of any change, some commuters said they have noticed a faster and easier trip since the toll increase. There was some time of day differential; those who noticed a difference traveled just after the toll increase at 5 a.m. or just before the decrease at 10 a.m. It is likely that peak shifting was a reason for the travel time improvements they noted. In addition, those who did not report much of a change often commented on choke points that were not related to the bridge. They pointed to the limitations of addressing congestion on one facility or link of many that must be used for a trip.

Travel Time Reliability

One reason that congestion changes might not be entirely noticeable to drivers is that travel time is variable day to day on most routes, a point that many participants in all of the focus groups brought up.

In both the UC survey of volunteers and the focus group surveys and meetings, we asked participants about the importance of a predictable trip time. We also asked them to comment on the importance of a fast, uncongested trip and to compare the two. While there was a very high desire for a fast, uncongested trip, a majority of respondents said that predictable travel times were more important (Figure 3).

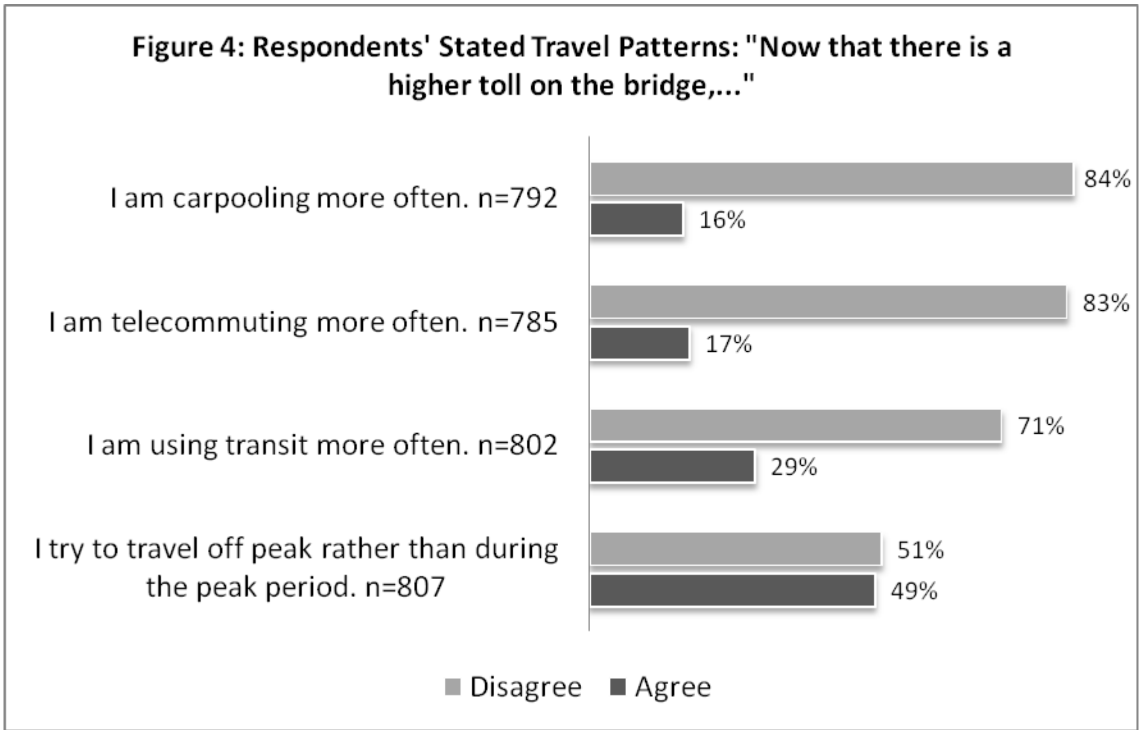


Predictable and reliable trips were clearly of interest to focus group participants as well, and they often compared the reliability of car travel to transit travel. For some respondents, auto travel was viewed as more predictable than transit travel, especially if the transit trip required more than one transfer between transit vehicles or systems. However, BART travel was seen as far more predictable by travelers that could easily get to and from the stations on foot or by car, with no transfers needed to other transit systems.

Relatively few travelers saw a significant difference in the predictability of travel times for their trips across the Bay Bridge or for the delays at the toll plaza. Thinking about their entire trip led many respondents to note that they hit congestion long before they arrived at the Bay Bridge toll plaza, and that some days it was much worse than others. Thinking just about the wait on the plaza up to the toll booths, a somewhat larger share of the drivers thought it was shorter since the toll increase, but still a minority. The focus group participants commented that even at the toll plaza, the delay was not very predictable day to day, varying by "5 or 10 minutes, at least," as one person put it.

Changes in travel behavior due to toll increases

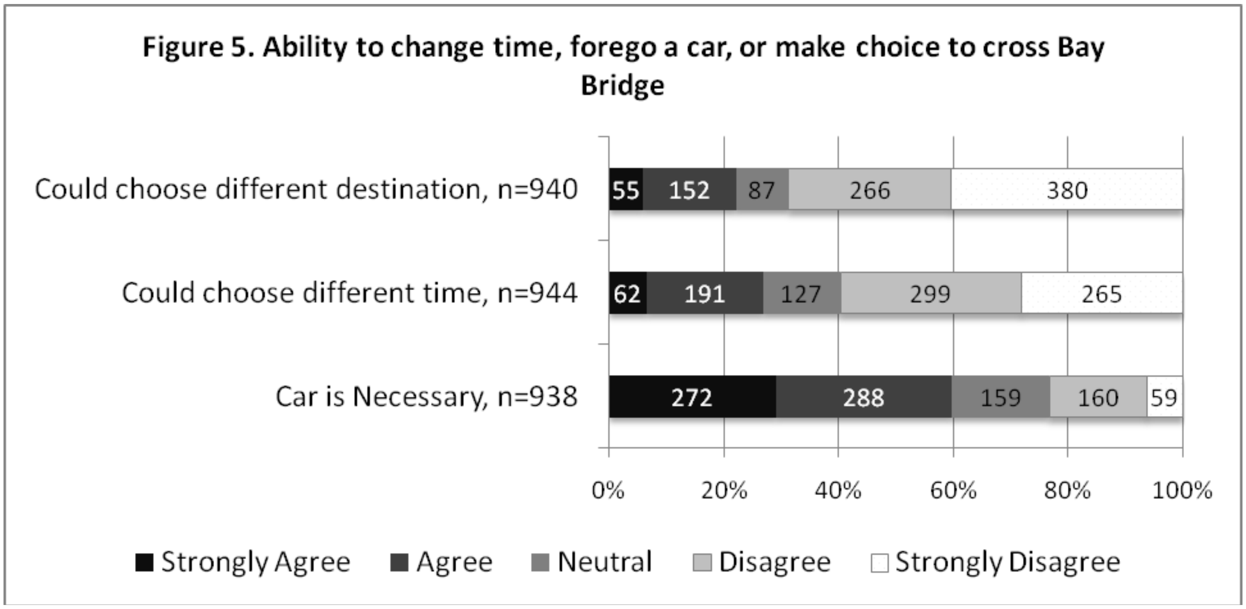
Survey respondents answered several questions regarding changes they have made in their travel behavior in terms of mode of travel or time of day since the peak toll increase. Figure 4 presents results from the UC survey. Focus group results largely mirrored these responses.



Almost half of the respondents said that they are making an effort to travel off-peak more frequently since the increase of the toll. About 29% said they were using transit more often. Seventeen percent are telecommuting more often, and 16% are carpooling more often.

Focus group respondents reported changes in many directions and for many reasons; some also made several changes at once. For example, some solo drivers are trying to telecommute more and to use transit more, though they still drive some of the time. Some carpoolers have moved to transit, some to driving alone, and some to travel off peak. Some have continued to carpool, but with just one other person, so they are not eligible for the HOV lanes at the toll plaza. Some transit riders are driving more because of greater crowding at transit parking facilities. But transportation costs and service levels were not the only reasons for change: loss or change of jobs, moving residences, and changes in household size are some of the reasons given for changing travel patterns. In addition, some focus group members reported that they have been trying to cut back on transportation expenditures because of the uncertain economy and so are reducing outings and combining trips. Others are offering rides to casual carpoolers because they are concerned about people who are short on cash in these hard economic times. Still others are casual carpooling to save money.

The UC survey also asked respondents whether they could travel at a different time of day or chose a different destination, and whether a car is a necessity for their trip (Figure 5).

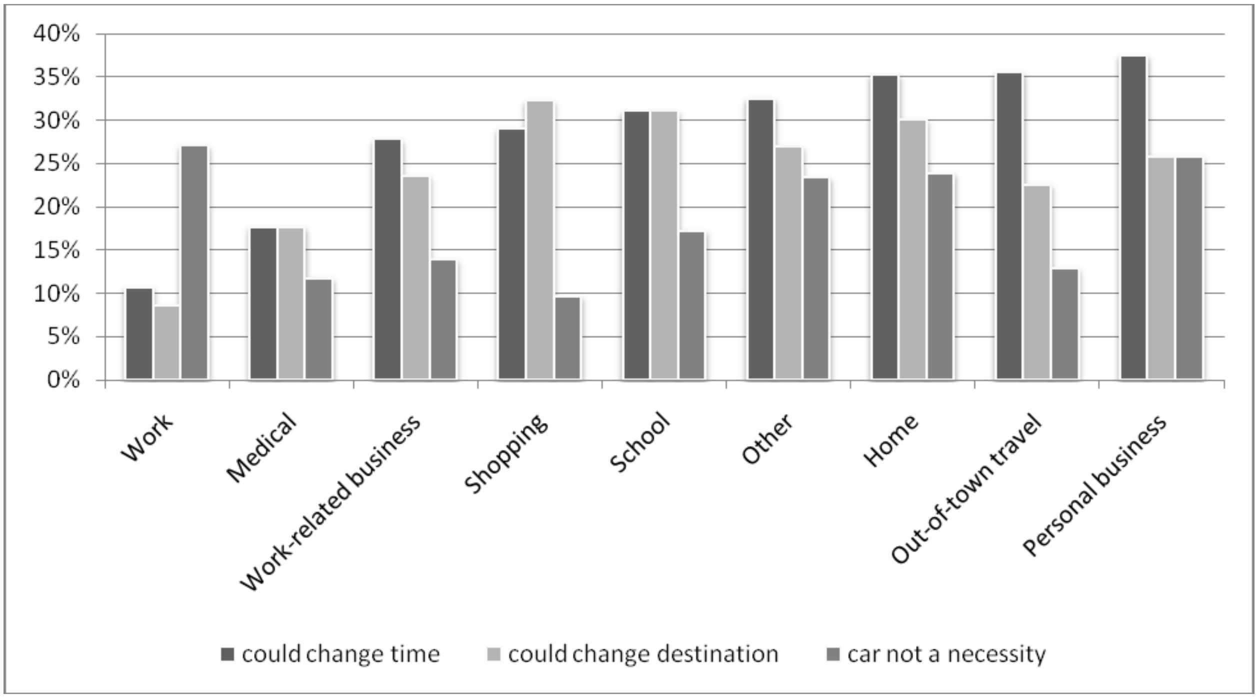


Approximately 22% say they could choose a different destination ("agree" and "strongly agree" responses), 27% could choose to travel at a different time ("agree" and "strongly agree" responses), and 23% indicate that a car is not necessary for their transbay trips ("disagree" and "strongly disagree.")

An important factor on whether a driver is flexible with their trip is the trip's purpose as to whether it is a discretionary such as for shopping or recreational purposes or non-discretionary trip such as going to work. Of the respondents that said they could change their destination so that they would not cross the Bay (207 of 954 total respondents), many were making trips that are typically discretionary. Just under half (101) were traveling for personal business, shopping; out-of-town travel; and other largely discretionary trip purposes (including recreation, visiting friends/family, pick-up/drop off). 53 respondents were crossing for non-discretionary reasons, including work, work-related business, medical purposes, and school. The final category of those who could change their trip were those heading home (53 respondents); this group could depart for home earlier or later most days. Their trip purposes (based on their activity where they started their trip home) were approximately 62% discretionary (33 of 53 respondents).

Figure 6 shows respondents' ability to change their trip timing, destination, or potentially mode by trip purpose.

Figure 6. Ability to change trip timing, destination or mode, by trip purpose.



Note: the percentages here represent the percent of travelers for a particular trip purpose that reported they could change their time of travel and/or destination and whether a car was a necessity.

Not surprisingly, work, medical appointments, and work-related business travel had the lowest level of flexibility – these are generally not discretionary trips. However, a high number of work-bound drivers said that a car was not a necessity for their transbay trips, indicating that their choice to drive may instead be based on time, money, or psycho-social factors (such as status or peer expectations, fear of crime on transit, etc.). In focus groups, many participants outlined a detailed cost-analysis that they used to decide on their trip mode and time, including the following factors:

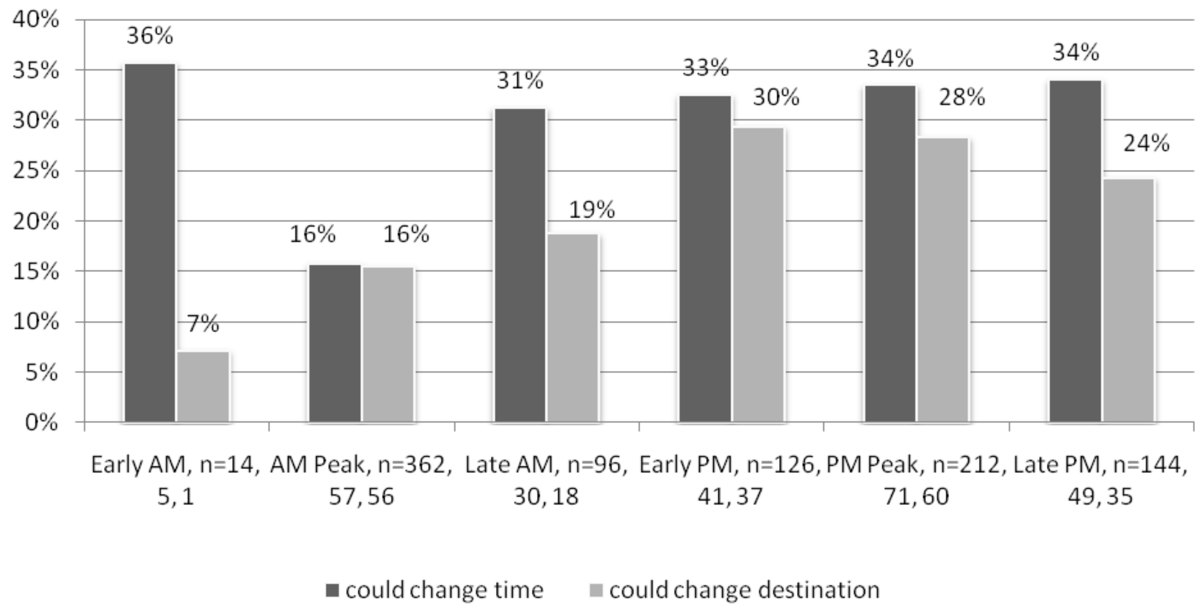
- Bridge toll – $2.50 (for carpools during peak), $4 or $6 for solo drivers and 2 person carpools.
- Payment for parking
- Cost of gas
- Time it takes to drive
- Transit availability based on time of day of desired travel
- Time it takes to get to transit
- Time to ride transit
- Time it takes to make transit connections, either in the East Bay, San Francisco, or both
- Walking distance to destination from transit

Focus group participants did not tend to take the fixed costs of owning a car, such as maintenance, depreciation, and insurance into account when evaluating the cost of driving across the Bay Bridge. However, they did indicate that slow access modes, infrequent service, and transfers were barriers to transit use, which is consistent with travel demand theory. They also indicated that parking charges were a key factor in deciding whether or not to drive; the availability of a free or very inexpensive parking space made driving a serious option, while having to pay market rates for parking was a deterrent. The vast majority of those who drove alone transbay had a free or inexpensive ($5 or less) parking space.

Several participants also noted that their choice to drive was based on the need to have a car for after-work activities, particularly if they were going to stay late in the city for entertainment or if they were traveling to areas not conveniently adjacent to frequent and reliable transit. (The latter areas also tended to have a higher abundance of curbside and off-street parking options.) In addition, a few noted that they had weekly toll budgets and would forego a discretionary trip to San Francisco on the weekend and instead find a substitute location or service on the East Bay, such as the local East Bay farmer's market or shopping area.

There were also notable findings in people's ability to change their destination or time of travel based on the time that they currently cross the Bay Bridge, shown in the chart below (Figure 7).

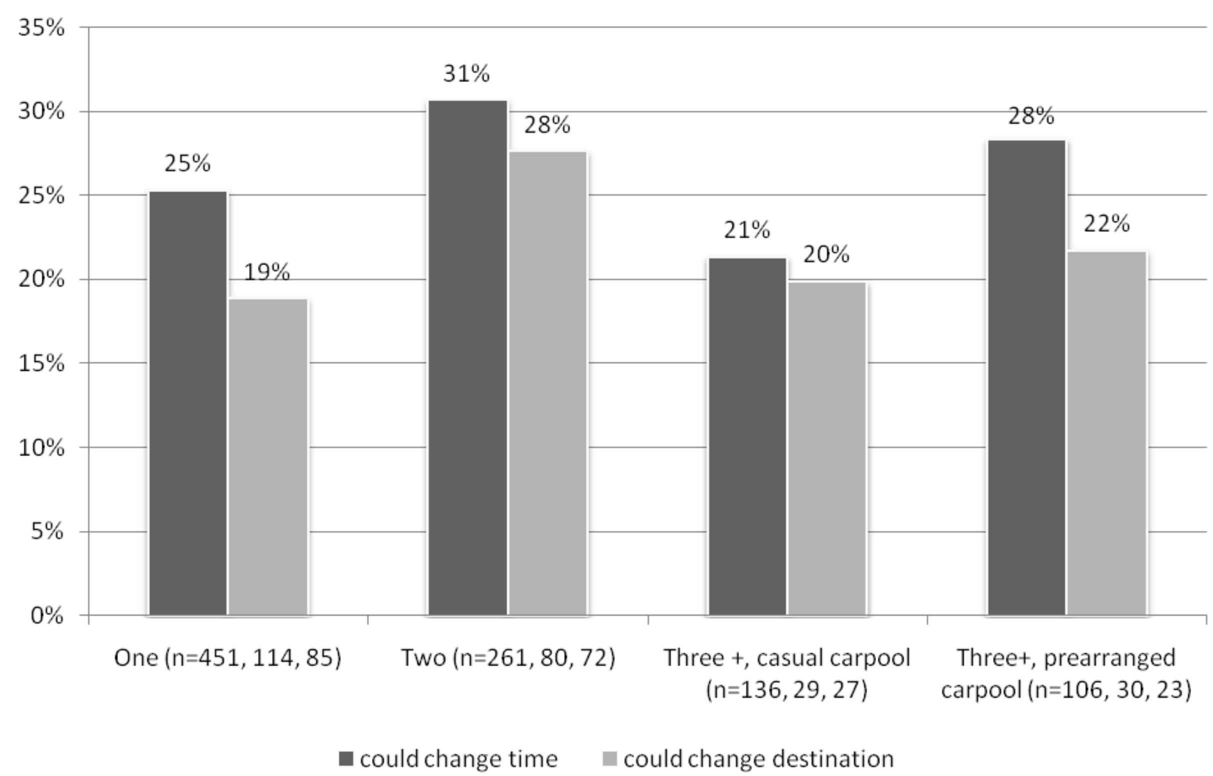
Figure 7. Ability to change time or destination by time of most recent trip



Only about 15% of those driving in the a.m. peak said they could change their time of travel, compared to 30-35% of those traveling at other times of day. Likewise only 15% of a.m. peak travelers (and 7% of very early morning travelers) could have changed their destination, compared to 18-28% of those who were traveling after 10 a.m.

In short, those who were driving in the peak period tended to be those who had relatively little flexibility in timing their trip, difficult transit access, and free or low cost parking. We also found that casual carpoolers have the least amount of flexibility in terms of timing. This is not surprising, given that their mode of travel depends on other casual carpoolers traveling at the roughly same time and is incentivized only during peak periods. Focus groups indicate that for many, it also has to do with occupation: casual carpoolers include large numbers of support staff and retail workers who must arrive by a specific time, students going to classes, etc. The most flexible group was two-person carpools, with 31% able to change their time of travel, and 27% able to change their destination; most of these two person carpools able to make travel changes were also making, discretionary trips for shopping or entertainment and are family members or friends traveling together (Figure 8.) Indeed, some of the prearranged carpools appear to also be familial.

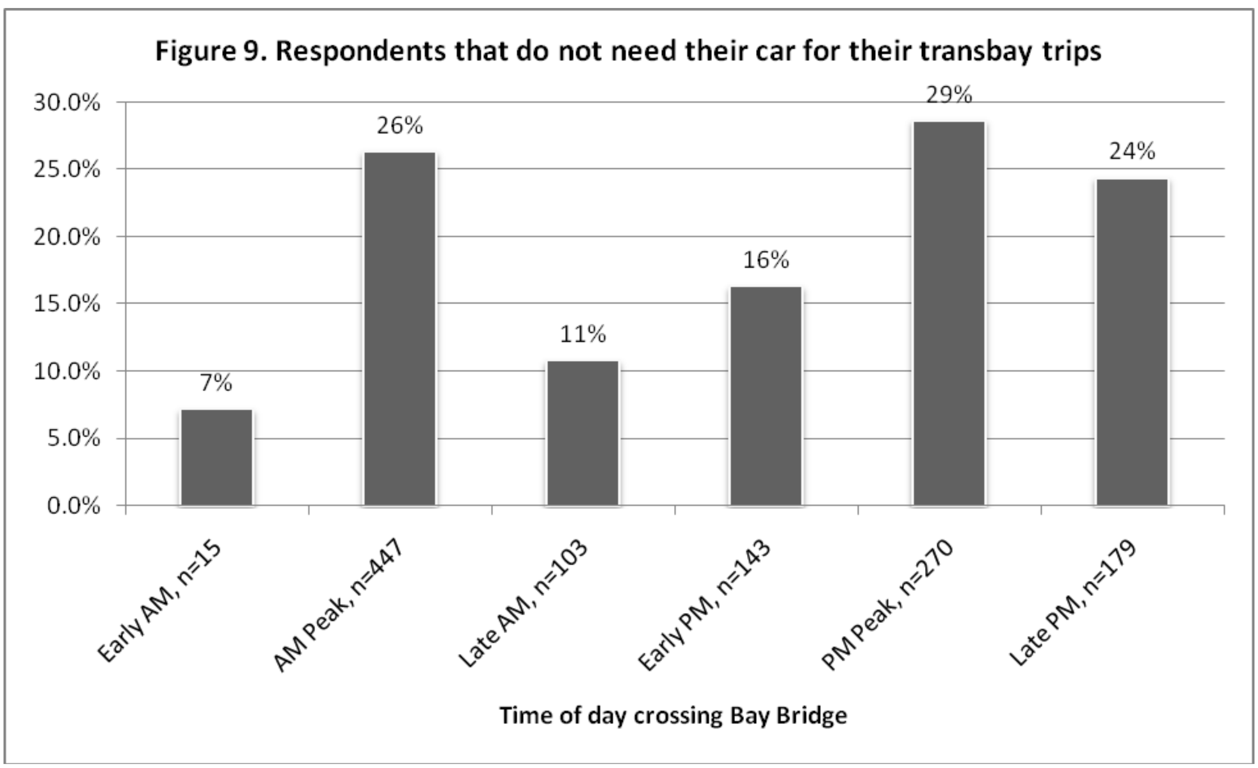
Figure 8. Ability to change time or destination by vehicle occupancy



Focus group participants revealed several changes in trip timing that they attributed to the increase in the peak bridge toll. Many mentioned increased congestion in the few minutes around the change of the toll, especially at the 10 a.m. hour. Carpoolers are highly motivated to reach the toll-gates before 10 a.m. so they can pay the lower toll, whereas non-carpoolers benefit from passing the toll-gates just after 10 a.m.

Reasons for Driving and Potential for Mode Shift to Transit

In the UC surveys, overall, 23% of drivers disagreed with the statement that a car is necessary for their transbay trips. Higher percentages of respondents in the a.m. peak (26%) and p.m. peak (29%) say that a car is not necessary for their transbay trips (Figure 9). Overall, though, the majority of drivers believe that they could not reasonably make their trip except by car. Reasons for this include the need for a car for work-related trips during the day; having a job with multiple, dispersed work locations; a need to provide a ride to another family member before or after the transbay trip; irregular work hours with unpredictable departure times; and a need to carry work tools or other supplies and materials on the trip.



Another question asked respondents to indicate their level of agreement with the statement: "I would like to use transit more often for my transbay trips." In total, almost half either agreed or strongly agreed that they would like to use transit more often.

Figures 10 and 11 show the variation in willingness to consider transit, based on whether people were parking for free, and also based on their vehicle occupancy. People that were not paying for parking at their destination were slightly less likely to indicate that they would like to use transit more often. Also, people in 3-person carpools were less likely to express interest in taking transit – prearranged carpools were in fact the least likely to do so. Prearranged carpools are more likely to be families, neighbors, or colleagues, and it is likely that their carpool provides an efficient and cost effective mode. Many also are going to destinations not well served by transit.

Finally, we looked at participants' desire to use transit more often, based on the time of day that they generally cross the Bay Bridge. We found the highest percentage of people who would like to take transit more often to be traveling during the p.m. hours – 55% of those during the p.m. peak would like more transit use, as would 52% of those traveling during the late p.m. hours (Figure 12). This was supported by the focus groups, where many respondents said that they would like to use BART for evening trips, but felt that they had to drive because BART service ended too early to allow them to complete their evening activities. This was particularly noted for weekend trips for participants attending a late concert or other event.

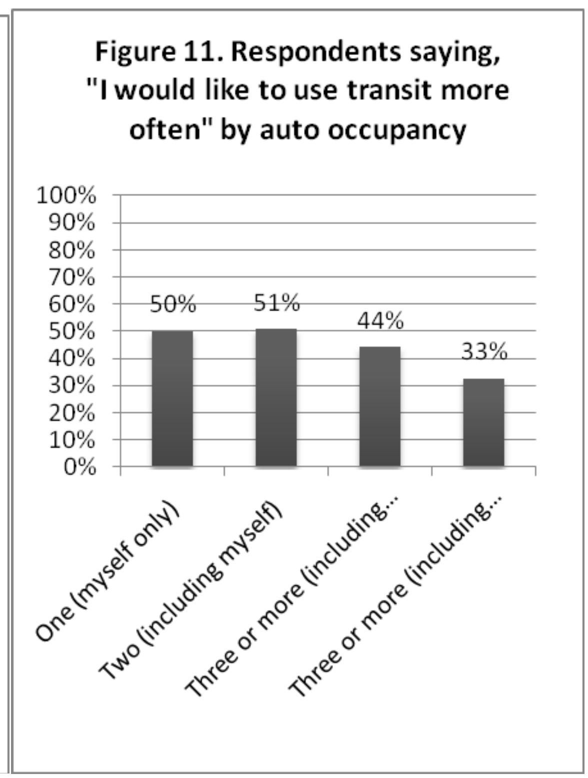


Figure 11: Respondents saying "I would like to use transit more often" by auto occupancy

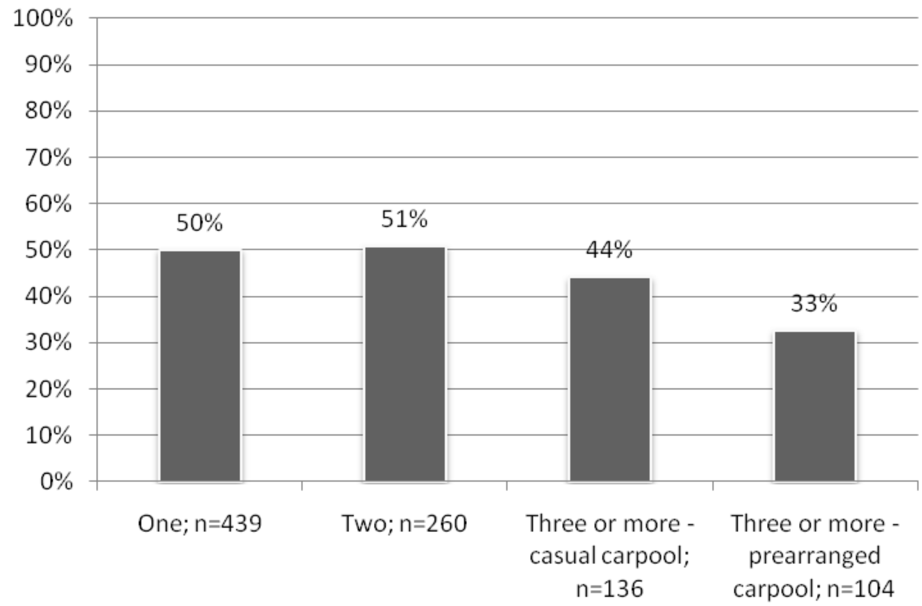
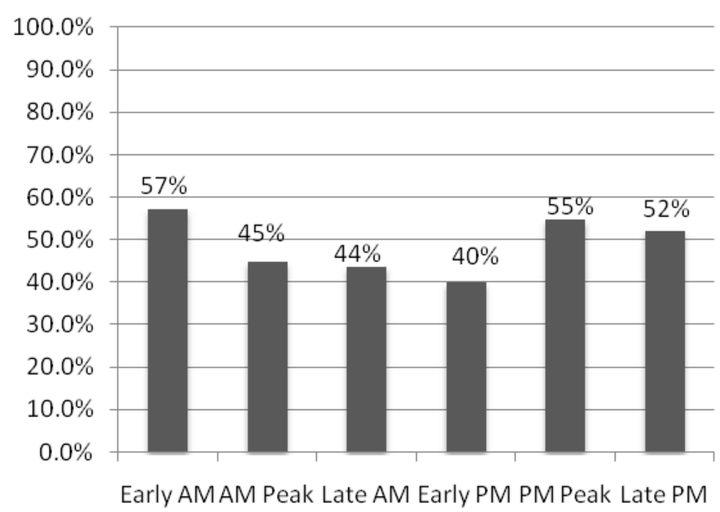


Figure 12. Respondents saying "I would like to use transit more often" by time of travel



The role of parking in travel decisions

The UC survey asked respondents whether they had paid for parking at their destination, with the following options:

- No, parking was free
- No, driver, employer or someone else paid for parking
- Yes, I paid for on-street, metered parking
- Yes, I paid to park in a garage/lot

They also were asked to provide the amount that they paid either at a curbside parking meter or in a garage/lot, if they indicated paying for parking. The following chart shows average payment for parking for respondents that pay at meters by the hour or in a garage by the hour, day, or month (Table 1).

Table 1. Reported Parking Prices

	Metered Parking (by hour)	Parking Garage (by day)	Parking Garage (by hour)	Parking Garage (by month)
N	60	93	52	18
Mean	$2.73	$15.86	$3.91	$91.33
Mode	$2.00	$15.00	$2.00	$175.00
Median	$2.00	$15.00	$3.25	$52.50

People that park in a garage reported paying, on average, $15.86 per day, which is a large portion of their total out-of -pocket trip cost. However, those that pay by the month, on average, pay a far lower rate than people paying by the day or hour. For a person that has a monthly spot in a garage, paying the average of $91.33 and driving into the city about 20 days per month, their parking cost per day would be just under $5.

However, the survey results showed that a majority (76%) of respondents did not pay for parking at their destination. 67% reported that they found free parking, and 9% said that an employer, driver, or someone else paid for parking, both in San Francisco and on the Peninsula south of San Francisco. Figure 13 shows the prevalence of free parking in San Francisco, compared to other destinations on the Peninsula by level of income. This chart excludes respondents that are casual carpool "riders" (49) and also respondents that are homebound (175). It includes drivers that answered "parking is free" or "driver, employer, or someone else paid for parking".

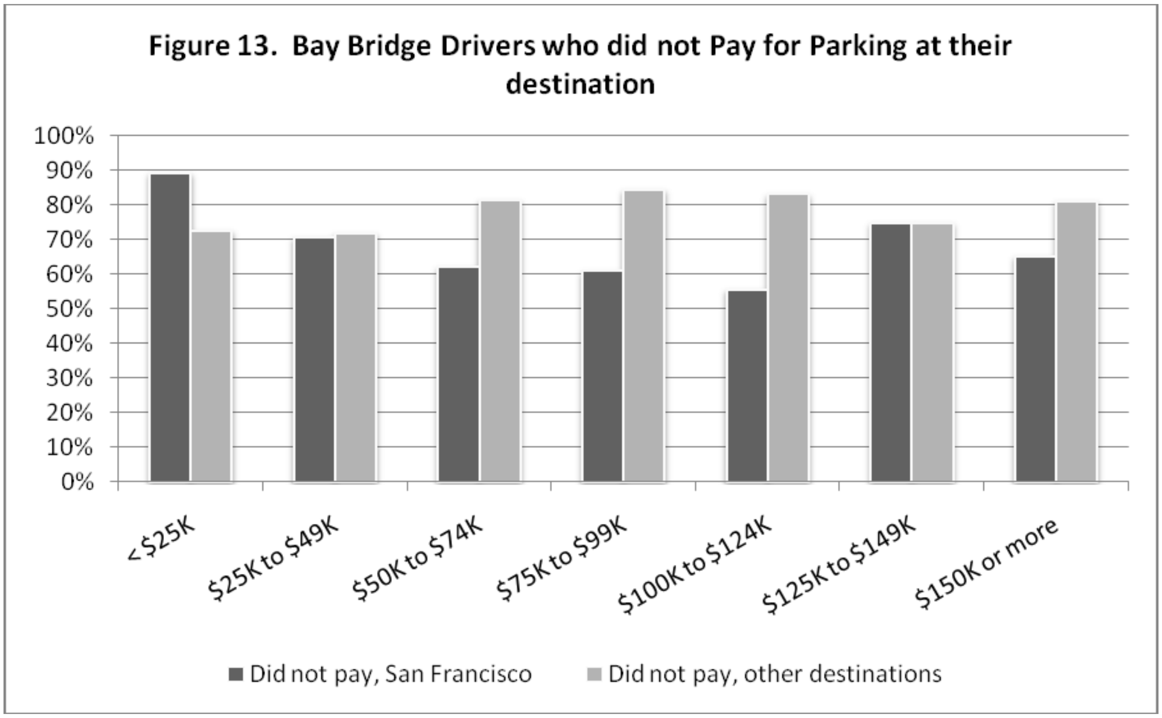
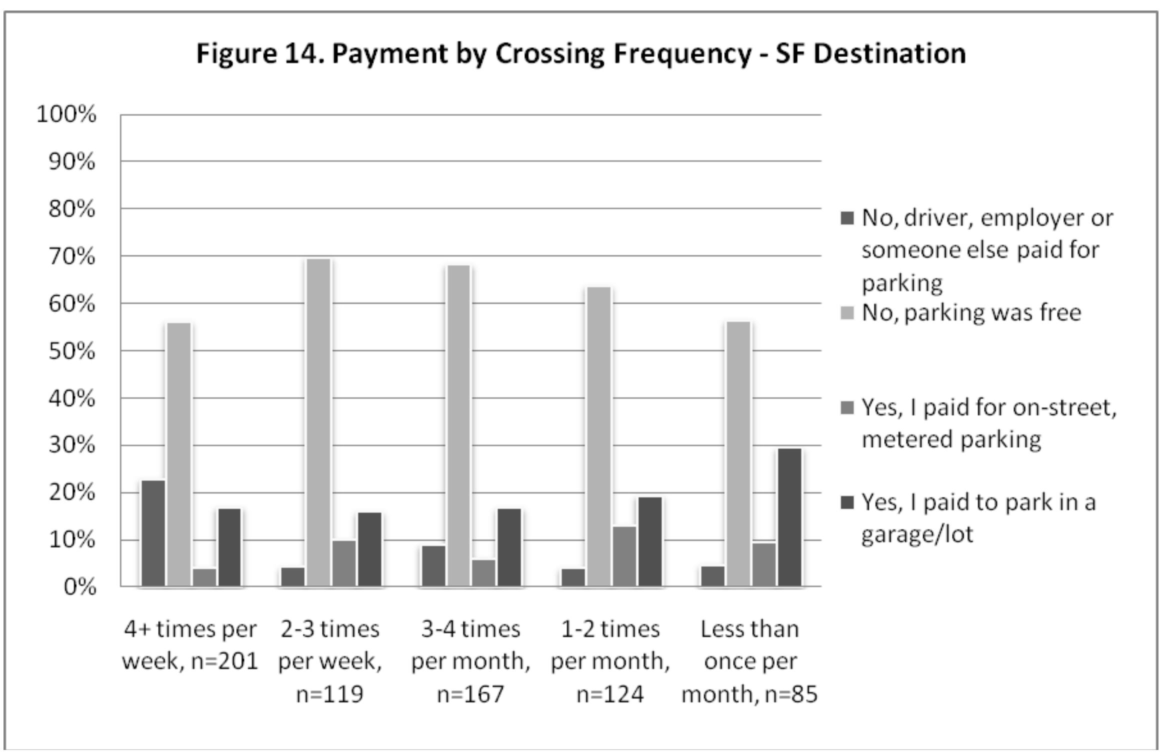


Figure 14 shows that drivers who travel across the Bay four or more times per week have a much higher rate of parking paid by an employer or someone else. The most infrequent crossers are most likely to pay for parking in a garage.



Focus group participants also emphasized the importance of parking in their decisions to drive across the Bay Bridge. Many reported finding free parking, and some even “bragged” about the good free spots that they knew about and did not want to reveal where those spots were to the group. Some that paid for parking acknowledged that it was a major cost that they did not like paying, but still felt that it was the best option when compared to transit for their particular trip. Others said that by paying on a monthly basis, they didn’t *feel* like they were paying for parking every day. Moreover, by paying on a monthly basis, several said, there is no incentive for them to reduce their driving trips, since the parking is already paid for (even if the monthly rate is a discount). Some focus group participants even commented that if they are paying for monthly parking, it makes sense to drive to get their “money’s worth” from their spot.

Impact of the toll increase on carpooling

Focus groups held with carpoolers tended to focus on how the $2.50 carpool toll has affected social interactions among casual carpoolers. Most focus group participants were casual carpoolers, though some were drivers and some of the drivers had a family member as a passenger and picked up casual carpooler rider so that they could use the carpool lanes. A few were members of prearranged carpools, mostly formed at the workplace.

Before the toll increase, the casual carpoolers traveled free. After the imposition of the toll, media coverage suggested that the toll portion of the cost should be shared, and many riders began offering $1 (1.25 in Vallejo) to the driver. Some drivers accepted it, a few asked for it, and some declined.

There was much initially much uncertainty on whether passengers should pay part of the toll and whether drivers should accept such payment when offered. Some participants reported conflicts between drivers and passengers over this issue and noted that it had introduced tension into an otherwise established set of practices wherein there was previously little interaction between drivers and passengers. However, by mid-2011 things had settled down, but a number of transbay travelers in the focus groups reported that they had quit casual carpooling because of conflicts over tolls and cost sharing. Some continued to drive solo or in two person carpools (not eligible for the toll lane) and some had switched to transit.

Current and former pre-arranged carpool members provided some insights into reasons for carpooling's decline among this group. Pre-arranged carpool members mostly were staff support workers or other service workers with fixed work schedules and limited travel budgets. Some were tech workers who were paid to ride a company van because their skills were in short supply. Both groups had been matched with other workers to form a carpool, or in some cases a vanpool, by services offered through the workplace. Difficult economic times had led to layoffs and hiring freezes, which made it hard to fill vans or even find three people from the same area who could ride together. Difficult economic times also made employers less willing and/or able to provide ridesharing assistance, according to the focus group members. Many reported that their employers had cut back or ended commute alternatives programs, or terminated financial incentives for commute alternatives. When the toll increase was announced, some focus group members said, their employers decided they could not cover this added cost; furthermore, some used it as an opportunity to discontinue their subsidies and supports for carpooling, instead going to a flat commute allowance. This policy was implemented at several focus group members' workplaces effective July 1, the first day of their fiscal year - which also coincided with the start of the toll increase. With incentives removed, assistance terminated, and a new toll, many drivers and riders decided it was time to change travel choices. While the number of current or former pre-arranged carpool members in the focus groups was too small to make statistical inferences, their explanations for reductions in carpooling suggest avenues for future research.

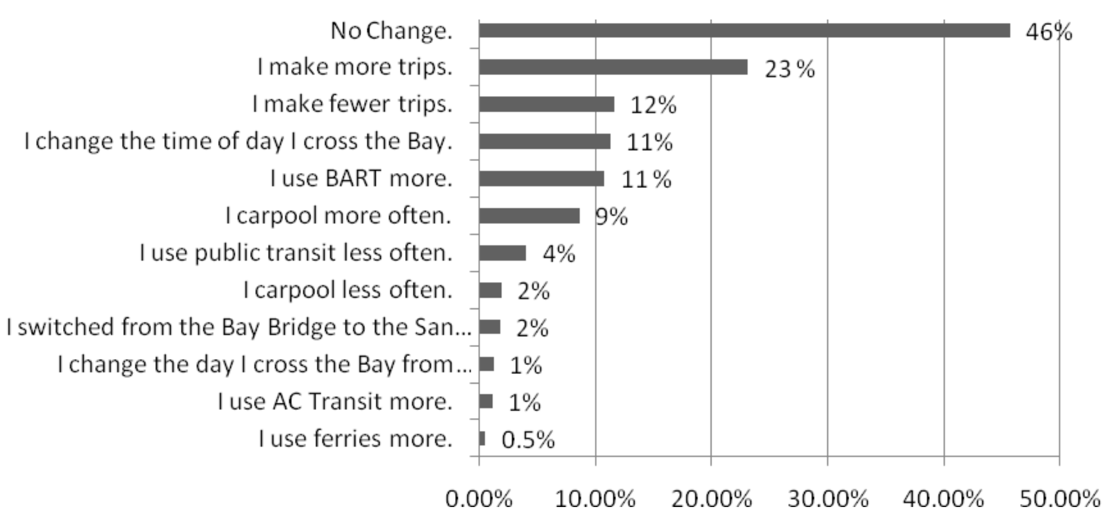
Supplemental Findings from BATA 2011 Survey

The BATA 2011 "After" survey was generally consistent with the above findings, but did also reveal additional information to further understand traveler's perceptions and responses to congestion pricing on the Bay Bridge

Changes in Travel Behavior

Figure 15 displays the percentage of respondents, which indicated given travel behavior shifts over the previous year (2010-2011). As can be seen, no change and making more trips are the dominant behaviors. The increase in travel may be a function of an improving economy.

Figure 15: Travel behavior changes from 2010-2011 by percentage



(n=4749, percentages do not sum to 1 as multiple responses permitted)

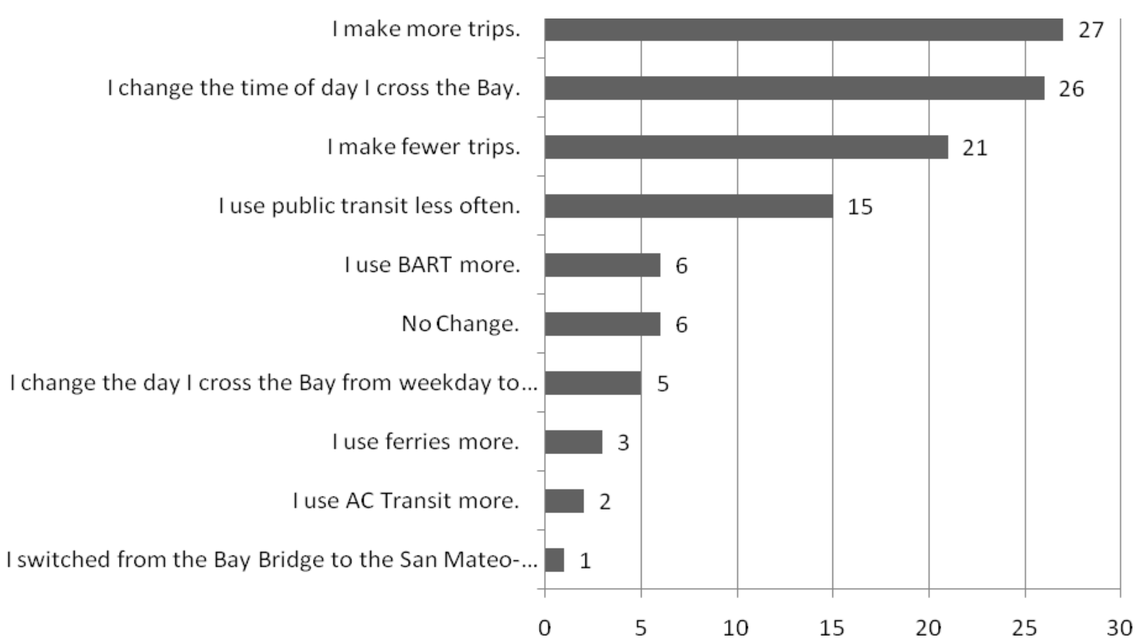
Carpooling

Respondents were asked whether they have changed their travel behavior in the last year. Out of the 2576 who indicated changing their travel behavior, 409 indicated that they carpool more (8.61% of total) and 91 indicated that they carpool less (1.92% of total). Respondents also were asked to provide the reasons for their change in travel in open-ended questions. The question format allows for a broad range of responses and allows us to get specific justification for behavioral changes. Many cited that the increase in the peak toll to $6 and gas prices have influenced their decision to carpool more. Traffic congestion combined with travel time savings in the carpool lanes also were frequently cited.

Others noted that changes in the work and home location have led them to carpool more because new locations now require them to cross the bay or because transit is perceived to be less convenient than in the past due to schedule changes. Others indicated that a new co-worker joined the office and became a carpool partner, or that a household member's job or family situation changed thereby allowing the household members to carpool together. In addition, some viewed the FasTrak lanes specifically as highly congested and saw carpooling as a way to bypass use of these lanes. Some indicated that they were concerned about the environment and were carpooling to reduce carbon emissions/environmental impacts.

The three most common changes in travel behaviors for those who reported carpooling less were that they changed the time of day they cross the bridge (26 of 91 or 29%). Others said they were making more trips (27 or 30%), apparently something that makes other modes (and perhaps having a regular parking space or a monthly transit pass) more appealing. Others still are making fewer trips in total (21 or 23%). Figure 16 shows the responses for those who carpooled less.

Figure 16: Frequency of other reported travel changes for those who report carpooling less



The survey also allowed an open-ended answer about why carpooling had decreased, which garnered 82 responses. Many respondents viewed carpooling as no longer as an option because of personal circumstances. The reasons often included moving to another city, new job or change in work hours, work-related travel and more personal activities, new relationships, children in the household, and personal injury. Others noted that their carpool partner was no longer available as one of them had changed jobs. Some also noted that the new of the carpool toll combined with perceived increase wait times at the casual carpool sites had canceled out the benefits of carpooling. Only a few responses cited the cost of carpooling.

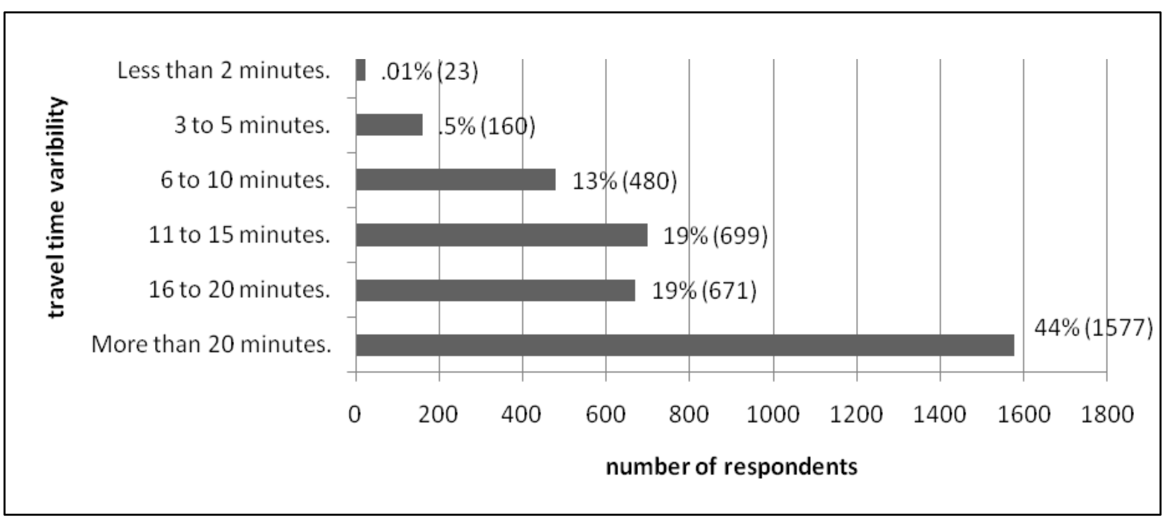
These survey responses reveal that travel behavior and choices on whether to carpool are complex, and not simply related to the new carpool toll and FasTrak requirements. Some travelers are carpooling more, not less because of the higher $6 peak toll and recent higher gas prices. Others have been deterred from carpooling because of the carpool toll. Some are carpooling to avoid traffic congestion in the corridor. On the other hand, many others are carpooling less because of personal circumstances unrelated to the carpool toll requirements.

Variability of Commute Length

A variety of questions were asked regarding the variability of travel time, departure time, and the respondents' reactions to trip variability characteristics. To begin, 3207 respondents (89% of the 3610 respondents who answered this question) said that they make this trip at the same time of the day—indicating some degree of inflexibility in scheduling among this set of travelers.

Respondents were also asked to describe how much their travel time varied on their typical transbay trip. 3610 respondents answered this question. Figure 17 shows that large share of the respondents experience high variability, with 44% reporting variability longer than 20 minutes and another 19% reporting travel times that could differ by 16-20 min. day to day.

Figure 17: variability in day-day travel time for transbay trips



The third question in this grouping inquired as to the respondents preference for faster travel times or more consistency in their travel time, asking: “Regardless of the mode you use to travel to work, if you had a choice between a commute that was always 30 minutes, or a commute that varied unpredictably from 20 to 40 minutes, which would you prefer?” A significant majority (81%) of responses desired consistency (749 of the 919 responses).

Summary of Survey and Focus Groups

The general responses and perceptions about congestion pricing reported here were not surprising given that a $2 peak toll increase is just a small portion of the average round trip costs, which can range from $15 to $30. On the other hand, it was surprising that many drivers had access to free parking in San Francisco. Free or highly subsidized parking turned out once again to be a prime determinant of driving versus taking transit.

Survey and focus group respondents reported high levels of variability in traffic volumes and delay for their transbay trips, not only on the bridge approaches but at other locations along the way. Thus, the respondents experience varying levels of congestion during their trip whereby minutes “saved” in one part of the trip may be minutes “lost” along other portions, particularly at bottlenecks, such along I-80, I-580 and at the Caldecott Tunnel on Highway 24.

Finally, travel behavior and perceptions of congestion pricing appeared to have changed as travelers settle in and adjust to the new toll schedule.

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Appendix E

Effects of Congestion Pricing on Business Practices:

A Preliminary Assessment of the Impact of Bay Bridge Congestion Pricing

Effects of Congestion Pricing on Business Practices:

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Introduction and Overview

Congestion pricing can lead to a variety of responses, including changes in business practices. Some businesses will take steps to take advantage of improved travel conditions, adjusting hours of operation or expanding activity because of better access to labor, other inputs, and markets. Other businesses will make adjustments that are intended to compensate for higher costs, such as offering commute subsidies to employees or, in the longer run, moving to places that are less congested and therefore do not require congestion pricing . This paper examines business responses to congestion pricing in the context of a July 2010 toll increase on the Bay Bridge, which imposed charges on peak period carpools for the first time, increased weekday peak period tolls for other motor vehicles from $4 to $6, retained the previous toll of $4 for off-peak weekday travel, and raised weekend tolls from $4 to $5.

Three types of business practices were considered in this study. First, inquiries were made about changes in travel assistance programs for employees and the extent to which congestion pricing was a factor. Second, changes in business hours of operation and customer incentives such as subsidized parking were explored. Finally, changes in scheduling of freight operations and deliveries were investigated. These changes are ones that might be expected to occur in the short run to medium run in response to congestion pricing, or even in anticipation of it. A companion paper (Murakami et al., 2011) considers longer term economic development and location impacts that are likely to appear only after several years.

Research Approach

This paper is based on previous studies of the business impacts of congestion pricing, published in scholarly journals and in professional reports, on websites, and in the press; previous focus groups and interviews with San Francisco business leaders, business owners or managers, and trucking and delivery companies, carried out by the author and others for an earlier study of congestion pricing on the Bay Bridge; information obtained through surveys and focus groups of individual Bay Bridge travelers carried out by the author and colleagues for the current study and dealing primarily with changes in employee travel assistance programs; and interviews with major business groups and a sample of individual businesses in the retail, office, and freight industries, also carried out by the author for the current study. A full survey of potentially affected businesses was beyond the resources available for the project. Focus groups and interviews with business association leaders and an assortment of other business owners and managers are not designed to produce statistically reliable results, but nevertheless can uncover issues and expose strategic thinking in response to congestion pricing.

Findings

Evidence from previous studies

Previous work on congestion pricing has noted that both individuals and businesses may take a variety of actions in response to congestion pricing, from changing the way the transport system is used, to changing work schedules and hours of operation, to moving to less congested and hence less costly locations. Since a congestion charge is intended to create time savings in return for an increase in out-of-pocket costs (Arnott and Small, 1994, Santos, 1994), its effects will depend on the business' (or individual's) value of time. (National Research Council, 1994.) A business that produces time-sensitive products or has labor with high values of time may welcome transport pricing strategies that reduce congestion, cutting travel times and improving travel time predictability. Time savings alone could outweigh monetary costs. In particular, the costs of receiving and shipping materials and products could decline. Shorter travel times also imply that a larger labor pool can be tapped and a larger number of potential suppliers and customers can be reached readily, factors that can help hold down costs and increase profits. Additional benefits of reducing congestion include lower pollutant emissions and lower fuel use and other vehicle operating costs, as well as savings from reduced accidents (all of which increase in inefficient stop-and-go travel). Some of these lower social and environmental costs should accrue to businesses.(Santos, 1994, National Research Council, 1994.)

Theoretically, then, congestion pricing should deliver benefits to businesses by reducing time costs of travel. This does not mean that all businesses will see a net benefit, however. For those who are heavily dependent on deliveries or other travel during congested times of day, and who may not have good alternatives for themselves or their customers, congestion pricing may increase costs and shrink markets.

In practice, the evidence is blurry. Congestion pricing programs are real-world projects, and none so far has been designed and implemented in a way that would satisfy research design standards. Even when before-after studies of business activity and practices are carried out, with-without comparisons are rarely done and important data elements are not always collected. This makes it hard to sort out congestion pricing effects from other changes that could affect business performance .In addition, studies of congestion pricing impacts have tended to focus on changes in traffic volumes, travel times and speeds, rather than on longer term impacts on transportation and travel, business performance, and the economy.

Evidence from congestion pricing implementations in Singapore, London and Stockholm (all cordon pricing schemes) suggests that overall economic benefits to businesses outweigh costs, but some businesses benefit more than others and also are more likely to be supportive of congestion pricing than others. In London, the issue of business impacts became controversial, with contradictory news reports and contested government studies). One news report claimed that businesses were broadly supportive six months after implementation(Clark, 2003), but another reported sharp business opposition, with claims that retail sales had declined precipitously and delivery costs had increased sharply (Muspratt, 2004). The controversy continued for years, with a BBC (2007) report stated that there was an average drop in business in the congestion pricing zone of 25%, while Transport for London studies that found that in comparison with other districts of the region, the area inside the charging zone had higher productivity and profits (Transport for London, 2006). Eliasson (2007) reports that in Stockholm, there had been fears that retail inside the cordon would be adversely affected, but studies were not able to show any adverse effects.

Cordon pricing affects all entrants into a district, whereas congestion pricing applied to a single facility only affects the vehicles that use that facility. One such facility is the high occupancy vehicle toll (HOT) lanes on I-15 in San Diego. The HOT lanes allow solo drivers to use travel at uncongested speeds for a fee that varies with congestion levels. (The lanes are maintained at LOS C or better.) Researchers at San Diego State (Steffey, Supernak and Kaschade, 2003) conducted a business impact study to assess whether businesses valued the HOT lane option. They found that delivery-based businesses and businesses directly adjacent to I-15 were more likely view themselves as highly dependent on travel services in the corridor than other businesses, and were also more likely to regard the HOT lane program as having a positive impact. However, businesses in general saw the HOT lane as "substantially lower in importance as a factor affecting business performance than such primary factors as supply of goods and labor, price of certain commodities, and tax levels and policies".

The same point should be made about businesses in San Francisco and points south. While many commuters and customers travel across the Bay Bridge to reach San Francisco, many other trips are internal to San Francisco or are coming to San Francisco from the North Bay, the South Bay, or the Peninsula, and so are unaffected by toll policies on the Bay Bridge. This fact means that the effect of Bay Bridge congestion pricing is necessarily dilute. (Trips to cities south of San Francisco in San Mateo County are even more likely to be local, and few transbay trips to San Mateo County use the Bay Bridge, especially during peak periods.)

Findings from earlier Bay Bridge studies

In a study of congestion pricing on the Bay Bridge conducted in the 1990s, focus groups and interviews with area business leaders were conducted by consultants to MTC (including the author). The focus groups and interviews discussed the potential impacts of a $3 peak period toll increase that was being considered, and businesses' anticipated short-term and longer-term responses to it. Note that the proposal was for a substantially higher toll than the any of the ones implemented in 2010 on the Bay Bridge. The toll was estimated to reduce delay at the toll plaza by about 25 minutes.

Business leaders representing corporate headquarters and other large offices believed that the toll would be well worth the predicted time savings, commenting that most who were driving worked long and often irregular hours and that a more predictable, less congested trip would reduce stress and boost productivity. The business leaders also favored investing the tolls in transit as a mitigation strategy, assisting those who would be priced out of cars by the toll. Retailers were less sanguine because they believed that early morning customers (e.g. those wishing to arrive before 10 or 10:30 a.m.) would be deterred from coming to the city by such a high toll and would not find the time savings to be sufficiently important to pay an additional $3 for them. Restaurant owners worried about being charged a surcharge for deliveries, especially those restaurants too small to be able to schedule the dates and times that deliveries occur. However, many business leaders noted that only a portion of workers, customers, and delivery services would be affected by a Bay Bridge toll, and felt that this meant the impact could not be too severe.

Trucking companies and delivery services were initially strongly opposed to the congestion pricing proposal, but as discussions in focus groups ensued, they allowed that they would probably be able to save labor costs (then$ 14-16/hr, so a 20 min savings would be worth ~$5, more than the toll). Delivery services also related that they maintained small terminals in several parts of the region because congestion made it necessary to have "delivery districts", and commented that if congestion pricing really worked, they might be able to gain additional savings by consolidating these terminals.

The proposed bridge toll increase received support from the MTC and from several legislators, and had endorsements from prominent business leaders. However, at that time, approval from the Legislature would have been needed to implement the toll, and opposition from the then-leader of the State Senate killed the proposal.

Findings from 2011 Bay Bridge focus groups and surveys

Business managers could take action to compensate for or partially offset the effects of a toll if they were concerned that higher costs would reduce their attractiveness as a workplace or business enterprise. This sometimes occurs when the economy is booming, especially for workers with skill sets that are in high demand; it is less likely in shaky economic times as at present, or for organizations whose jobs are easily filled. Survey respondents and participants in focus groups carried were asked about employer commute programs and subsidies, as part of a broader examination of transbay travel patterns and the impacts of Bay Bridge congestion pricing on travel choices. Most of the respondents were employees, though about 15% were senior managers of large organizations or owners or managers of small businesses. Many of the respondents and participants reported they did not have commuter benefits at work, and others had only pre-tax treatment of parking and transit costs. A few had a variety of commuter allowances and subsidies.

Focus group participants elaborated on these programs, and a number of them noted that changes had been made to the programs recently because of the economic downturn. In some cases, employers had sharply cut back or discontinued transportation assistance programs such as rideshare matching and transit pass discounts. Some had gone to a simpler commuter check or flat amount of transportation assistance instead. Shuttle services also had been cut back or discontinued. Focus group participants attributed the changes to need for cost-cutting measures.

The focus group participants had not received, nor did they expect to receive, any additional commute assistance or other compensation because the Bay Bridge toll went up. As one put it, "It only affects East Bay commuters, and besides, only the executive office is going to get tolls paid for them." In general, the participants believed that the toll would affect business activities indirectly if at all, especially since the increase was only a dollar or two for most travelers and therefore would be absorbed by most employees without comment.

Findings from Interviews with San Francisco business interests and freight operators

To further examine employer perspectives, the author conducted interviews in person and by telephone with San Francisco business interests in mid-2011. (Several of the business leaders also were engaged with San Mateo County businesses.) Representatives of business organizations and individual business owners and managers were asked to discuss their general impressions of how the new toll structure on the Bay Bridge was working, and to discuss changes that businesses or employees had made or were considering because of the new tolls. The interviews were held after the toll increase had been in place for at least nine months so that the responses could be based on a period of experience with the new tolls. Each interview lasted 20-30 minutes. A total of 12 interviews were completed.

The business association representatives were supportive of congestion pricing, acknowledging that the time saved by commuters due to reduced congestion was generally worth more to them than the toll cost, and that there were good alternatives from the East Bay to San Francisco and the Peninsula - BART, buses, ferries, and carpool incentives. Most also noted that the congestion price toll structure only applied to the Bay Bridge and that many employees, clients and customers came from San Francisco itself, or from the Peninsula, the South Bay, or Marin and points north and so were unaffected by the Bay Bridge charges. Also, while most employees must commute in the peak periods, customers and clients are more likely to arrive at 10 a.m. or later - many retail establishments do not even open before then - and so most of them would be unaffected by the toll increase. On the way out of the city, no toll is collected on any of the bridges, so outbound travelers are not affected even if they choose to travel in the evening peak.

Asked about measures taken to offset the toll, the interviewees responded that none of their organizations had done anything. Two of the interviewees reported that some privately owned parking facilities had reduced rates or offered new "early bird specials", and speculated that this was done in part to offset the toll, though they also thought the economic downturn might be a bigger reason for parking demand to decline. Several of the interviewees commented that most East Bay car commuters must use at least a gallon of fuel to commute to San Francisco and back - some use considerably more than one gallon - and they pointed out that the increase in fuel costs may be a bigger expense for commuters than the peak period toll increase on the Bay Bridge.

The interviewees had heard complaints about charging for carpools, but they had mixed opinions about it. All felt a carpool charge was fair, since carpools do add to the vehicles on the bridge s and therefore should help pay for the bridge costs. All also felt that the time advantage of HOV lanes and the discount from regular tolls were significant benefits to carpoolers, rewarding their willingness to share rides. However, several of the interviewees stated that they did not think the public education on the toll increase, and especially carpool charges, had been adequate; they felt there was a great deal of misunderstanding about why carpool tolls had been added and that this had caused problems. Finally, two of the interviewees were skeptical about carpooling in general, arguing that many carpoolers would be on even more efficient transit systems were carpooling incentives not offered.

The biggest concern about transportation to and in San Francisco that the business group voiced was not about the Bay Bridge congestion charge, but about cuts in transit service and increasingly unreliable service. This, they said, was affecting employees "coming from every direction" and was leading to more late arrivals and stress than any of the bridge toll changes.

Concerns were voiced about potentially higher delivery costs for small retail establishments with insufficient market presence to dictate hours of delivery outside the peak periods. The business leaders noted, however, that it was too early to see such impacts because the toll increases for truckers would not go into effect until July 2011, with another increase in 2012. No hard evidence of increased delivery costs was available at the time of the interviews.

The interviewees were asked about potential or actual business responses to the congestion charge, ranging from changing hours of operation to compensating for higher costs by offering bigger commute allowances, shopper parking discounts, etc. None of the small group interviewed was aware of any such changes at office or retail establishments or major institutions such as hospitals and universities. The general reaction was that the toll increase (zero for some, $1-2.50 for others) was not large enough or ubiquitous enough to trigger changes in business practices, especially at a time when businesses were experiencing the economic downturn themselves. They also noted that many employers were trying to simplify their commute programs and that commuter checks that provided a dollar amount of assistance but did not get involved in employee mode choice were viewed as a sensible strategy. Some noted, in addition, that for statewide, national and international organizations, company policy on commuter assistance was not necessarily set in the Bay Area.

Representatives from three freight companies - a trucking company and two delivery services - were among the business interests interviewed. These companies are heavily impacted by congestion on freeways and on city streets in many parts of the region and consider congestion a major cost. They already use routing, scheduling, and terminal strategies to avoid congestion, however, and try not to tie up their deliveries in the worst of the congestion.

The freight company representatives were well aware that toll increases were on the way, and that a delay in their implementation had been approved to allow trucking firms to incorporate the higher tolls into service contracts. (As of July 1, 2011, the toll for three-axle vehicles or combinations increased from $6 to $10.50; for four-axle vehicles the toll went from $8.25 to $14; for five-axle vehicles, from 11.25 to $18; for six-axles, from $12 to $21; and for seven or more axles, from $13.50 to $24.25; a second increase is scheduled for 2012 and will be set at $5 times the number of axles.) The freight companies interviewed were expecting to pass the higher tolls on to customers in the form of higher rates when contracts are renewed, or had added already added surcharges to cover them, if current contracts allowed. They noted that there were ways of avoiding the tolls, e.g., going around the Bay instead of across it, or using a more circuitous route and a lower-toll bridge; but they scoffed at the idea that very many truckers would do this, because of the significantly longer distances for most trips and the multiple locations where trucks could get caught in congestion. However, they also commented that single vehicle owner-operators, not interviewed for this study, would have different experiences and concerns, because most have less ability to use technology to overcome traffic problems or to dictate terms and conditions to customers. They might not be able to pass costs forward to customers in the current tough economic times and might have to absorb the costs, leading to a variety of problems with both personal and social consequences.

Discussion

The findings from this study indicate that business impacts of congestion pricing are likely to be diverse; while previous studies have found net positive impacts, some types of business are likely to benefit more than others. Businesses that are time-sensitive or employ workers with a high value of time or much-sought-after skills will benefit from faster and more reliable transportation and the resulting increase in access to labor pools and markets. Businesses that require deliveries during times of heavy congestion charges, or whose customers are not as time sensitive but may be cost-sensitive, could be adversely impacted.

Because Bay Bridge congestion pricing is only applicable to one corridor into San Francisco, is applied only to inbound, weekday, peak-period traffic, and is a modest, flat surcharge, the design of the program has a modest and dilute impact on businesses even if many of their employees and customers or clients use the bridge to visit them. Because the impact is seen as partial and odes, few steps are likely to be taken to offset the passenger vehicle toll increases or otherwise compensate for them.

Employers believe that gas prices are a bigger issue than toll increases for auto commuters, and that transit level of service is a much bigger issue than auto commuting, in terms of San Francisco / Peninsula accessibility and business well-being.

Turning to freight impacts, businesses are aware of recent and planned increases in truck tolls and the large freight companies have been making changes in contracts and prices to pass costs forward to customers. They already have in place logistics and operations strategies to reduce congestion costs. Owner-operators are likely to be more heavily impacted because they have fewer options for managing their costs.

Because freight tolls are just now being implemented, however, it is too early to tell what the overall impacts will be on freight or freight customers. Sizeable freight tolls could lead to a reorganization of freight logistics. Impacts on businesses are uncertain and are likely to take several years to fully materialize. Future study will be needed as the new tolls are implemented and absorbed.

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