Searching for Induced Travel: Elimination of a Freeway Bottleneck and Subsequent Effects on Rail and Freeway Volumes

Joshua Seeherman*

Department of Civil and Environmental Engineering
University of California Berkeley
760 Davis Hall
Berkeley, CA 94720-1710
Phone: 510-642-3261/Fax: 510-643-5264
Email: jseeherman@berkeley.edu

Alexander Skabardonis

Department of Civil and Environmental Engineering
Institute of Transportation Studies
University of California Berkeley
109 McLaughlin Hall
Berkeley, CA 94720-1720
Phone: 510-642-9166/Fax: 510-642-1246
Email: skabardonis@ce.berkeley.edu

For Presentation and Publication

Case Studies on Transport policy

December 2015

*Corresponding Author

Abstract

The removal of a freeway bottleneck in California has allowed researchers to investigate short-term induced travel and potential mode switch from rail transit to the automobile as a result of reduced auto congestion. This particular bottleneck, a double lane drop due to reduced tunnel capacity, is a unique case as alternate routes are quite undesirable; the only other option is to consider riding nearby rail transit. Freeway volumes and rail ridership were examined in the years before (2012) and after (2014) the removal of the bottleneck to determine the extent of the induced travel. Freeway volumes during both commute periods increased between 10-13%, faster than other nearby locations, and ridership between stations close to either side of the pre-existing bottleneck showed declines of 3-5%, despite system wide increases in transit ridership. Differences of means testing confirmed that many of these changes were statistically significant. Findings concerning the magnitude of induced travel are relevant when making policy decisions on how to spend public monies when removing mature bottlenecks.

Keywords

Induced travel, bottleneck, modal switch, freeway congestion, California

1. Introduction

Within the San Francisco Bay Area, the Caldecott Tunnel bottleneck on State Route (SR) 24 had long been a flashpoint for frustrated drivers. At that location the eight lane freeway dropped to just six lanes passing through the three two lane tunnel bores. The reversal of the center bore back and forth to give the peak direction four lanes, once thought to be innovative, was increasingly failing to accommodate off-peak demand with only one bore and two lanes. Finally, in November 2013, a fourth tunnel bore was completed by the California Department of Transportation (Caltrans) allowing each direction to have four lanes throughout the day for the first time. Due to the topography of the area, the Caldecott Tunnel is the only reasonable crossing through the Berkeley Hills for a significant distance on either side. Prior to the fourth bore, drivers with the reverse commute were either faced with congestion from the four-to-two lane drop at the tunnel or, if their jobs were within reasonable walking distance from transit, ride the Bay Area Rapid Transit system (BART). BART also passes through the Berkeley Hills at a similar location and offered congestion free travel from Oakland to the expanding job centers in Eastern Contra Costa County. Although BART was originally designed to take commuters into San Francisco and Oakland, ridership had increased in the opposite direction, corresponding with the increased congestion at the Caldecott Tunnel reverse commute bottleneck on SR 24.

The completion of the fourth bore, removing a mature freeway bottleneck, offered researchers a unique opportunity to view the onset of short-term induced travel and study the changes in mode choice among reverse commuters who may have previously taken BART to avoid freeway congestion. Again, since the topography of the Berkeley Hills makes it quite hard for travelers on that particular commute to go any other way, it might be possible to observe a modal switch from rail transit (BART) to the automobile. Here, perhaps, we might see whether there is measurable short-term induced travel in a case where there exists a functional alternate mode; this case is not the situation of a typical freeway widening in a vacuum. In this case study, will commuters conduct a modal switch? Will more travelers use personal vehicles?

2. Background

2.1 Definitions

Induced travel due to freeway expansion has been a regular topic among researchers for nearly a century. A majority of the research has focused on what percentage of induced traffic, following freeway improvements, is from exogenous (i.e. from population growth or new housing units) or endogenous factors (i.e. increased supply lowers travel cost and latent demand appears). Over fifty years ago Downs (1962) was already documenting limited congestion relief from the construction of urban freeways and stating that freeway expansion would not improve travel time in the long term due to induced demand, a phenomenon he referred to as the "fundamental law of highway congestion." DeCorla-Souza and Cohen (1999) have proposed a simple definition, that induced travel is "an increase in daily vehicles miles traveled (VMT), with reference to a specific geographic context, resulting from expansion of a highway facility." Many other researchers have provided additional depth by breaking up induced travel into its constituent parts; Frohlich (2003) lists the five sources of new vehicles that constitute induced travel:

1) A time of day shift by existing traffic

2) A route shift from other roadways

3) Mode shift from transit to auto

4) Change in destination choice due to reduced travel time (longer trips)

5) Entirely new trips (latent new trips)

There is some commentary on whether all five of these contributions are truly *induced demand*. Cervero and Hansen (2002) stated that only the last three are induced demand while the others are merely induced travel. Noland (2001) also stated that all five constituted induced travel, although he noted that mode shift has been a subject of debate as no new trips are being made. Still others, such as Weis and Axhausen (2009), follow the DeCorla-Souza model and refer to all types of "additional demand generated by improvements in travel conditions" as induced travel demand.

Additionally, Frohlich notes that there is also a question of short-term versus long term induced travel. As discussed by Lee et al. (1999), the only change in the short term is on the supply side in terms of new lane-miles while demand remains constant. Lee defines changes in the short-term as induced traffic or travel. However, in the longer term one should see changes in the demand curve as people change their employment or housing. These types of permanent decisions are what Lee refers to as true induced demand.

2.2. Studies of Induced Travel

There have a number of studies using a variety of econometric methods to approximate the effect of induced travel. In the UK, Goodwin (1996) found an elasticity of 0.5 in the short term and close to 1.0 in the long term between reduced travel times and increased travel volume as part of a large change in the UK policy of motorway construction. In the US, demand elasticity comparing additional lane miles and VMT have been found to be between 0.5 and 0.9 by Hansen and Huang (1997) and Noland (2001) with long term elasticity nearly 0.9. Cervero and Hansen (2002), as a follow up to earlier works attempted to use a more refined model and still found short term values greater than 0.5. Lower values of 0.2 found by Hymel et al. (2010) appear to be from aggregation at the state level and more control variables. This accepted range (0.5 to 0.9) was upended by the Duranton and Turner study in 2011 which found a value of 1.03 on interstate freeways in the United States and virtually no benefits from increased bus transportation. This was followed up by a similar study in Japan by Hsu and Zhang (2014) that values could exceed 1.2, indicating the potential for a new equilibrium of travel speed that is worse after capacity expansion. In the reverse direction, Chung et al. (2012) analyzed the short and long term effects of the noteworthy removal of the freeway above the Cheonggyechoen River in Seoul replaced by an arterial. This study found that travel speeds returned to values pre-removal by virtue of a large drop in vehicle volume from deterred demand, changes in departure times, and mode shift. The researchers concluded that the "anxiety about additional traffic problems due to the associated decrease in road capacity was unfounded."

There has been a similar research analog in regards to induced travel from increases in fuel efficiency or reductions in fuel prices, known as the rebound effect. This form of induced travel compares vehicle-kilometers/liter of fuel to increases in VMT. Sorrell (2009) reviewed a number of empirical estimates and found that the average rebound effect ranged from 10% to 30%. Su (2011) found a value of 11% in the United States for the 2001-2008 period and found that the rebound effect became stronger at higher fuel prices. In Europe, when examining road freight transport Matos (2011) determined that during the 1987-2006 period the rebound effect was slightly higher at 24%.

It is noted that much of the research described above, with the exception of the Korean example, examines very large data sets at the county, state, or national level. This case study differs in that we get to directly examine the induced travel following the removal of a freeway bottleneck that has no alternate routes and has a viable alternate transit mode (BART). Indeed, lower estimates for induced travel found by Cervero (2003) as well as DeCorla-Souza and Cohen were during the examination of specific examples and a more detailed model of induced effects such as travel caused by induced investments and time-of-day switches by vehicles.

2.3 Study Area

This report focuses on travelers passing through two sets of tunnels through the Berkeley Hills in California, the Caldecott Tunnels of SR 24 and the parallel BART Berkeley Hills rail tunnel. These tunnels connect the highly dense and urban cities of Oakland and Berkeley on the west side to the suburban communities of Concord, Walnut Creek, Lafayette, and Orinda among others on the east side. Travelers going to San Francisco from the east must also use SR 24 to access the San Francisco Bay Bridge. Figure 1 shows a schematic of the area. To review, in the before case there was a lane drop from four lanes to two for the reverse commute, and after the fourth bore was opened this lane drop was eliminated. Figure 2 shows the changes. Note each bore has two lanes.

Figure 1: Schematic of Regional Freeways

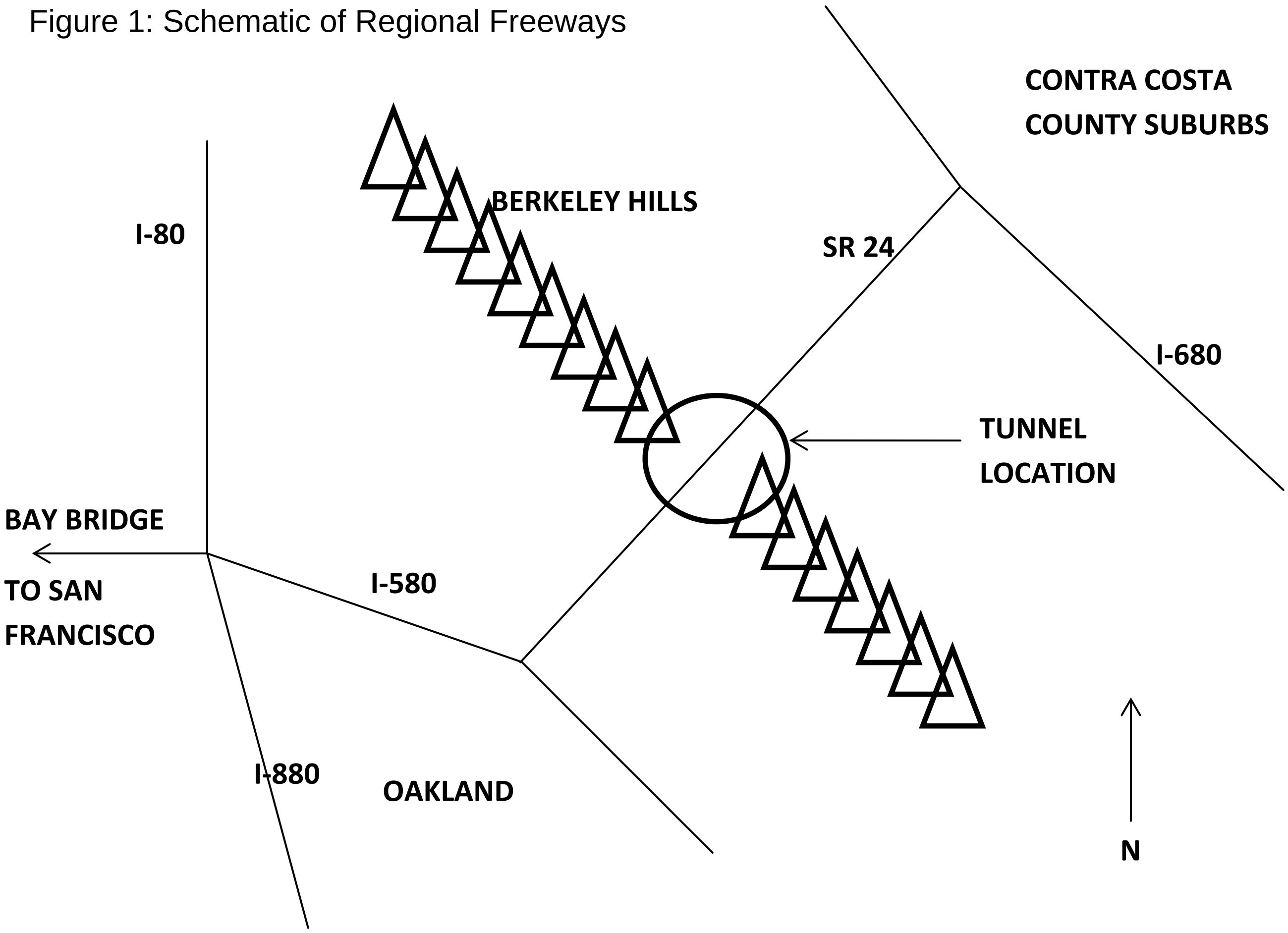
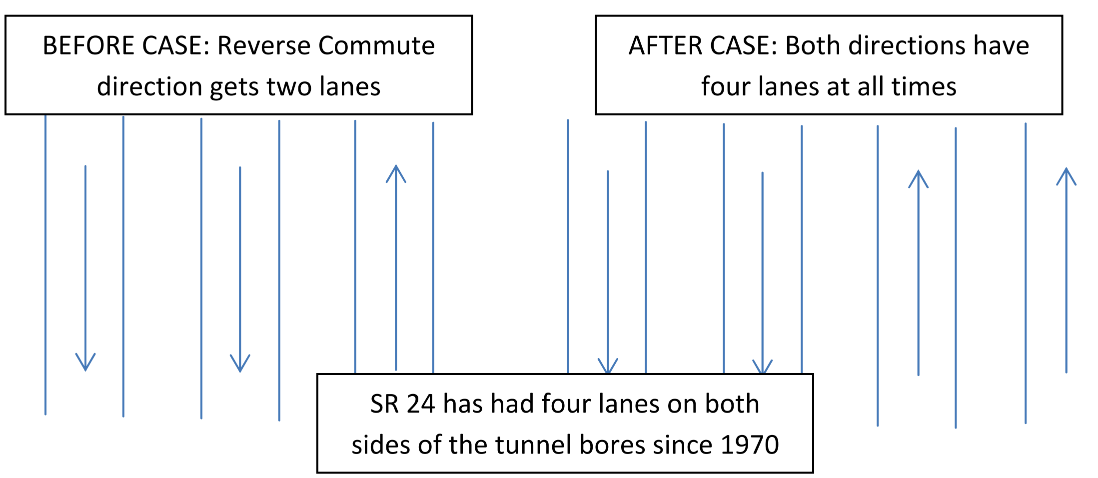


Figure 2: Before and after November 2013 opening of fourth two-lane Caldecott Tunnel bore on SR 24



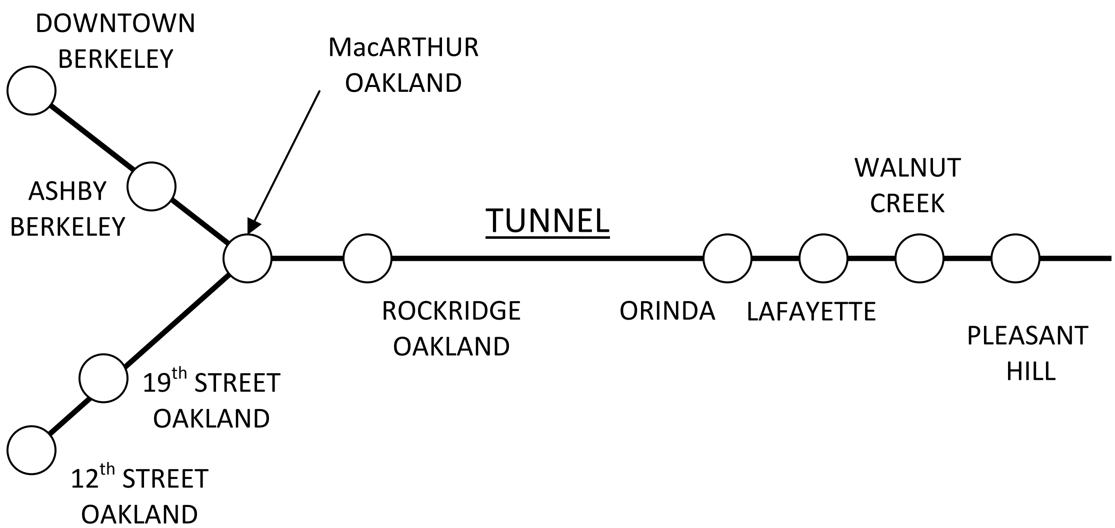
BART's Pittsburg / Bay Point line travels through the Berkeley Hills tunnel from Pittsburg first stopping in downtown Oakland before continuing on through the Transbay tube to San Francisco and further to San Francisco airport. Those with other destinations in the East Bay, such as toward Fremont or Berkeley can switch trains at the MacArthur and 19th Street Oakland stations with a timed transfer. Figure 3 shows the BART system map, with the Pittsburg / Bay Point line in yellow. The BART Berkeley Hills Tunnel is between the Rockridge and Orinda stations and directly adjacent to the Caldecott Tunnel on SR 24 shown previously in Figure 1. Rockridge and MacArthur are located within the City of Oakland.

Figure 3: BART System Map (*courtesy of BART*)

BART has had dramatic increases in ridership (from 4 million in Fiscal Year 1973 to 125 million in FY2015) and the Pittsburg / Bay Point line is no exception. However what makes this line unique is that many of the suburban stations to the east of Rockridge, particularly Walnut Creek and Pleasant Hill are job centers themselves and create an active reverse commute.

The analysis will also look at a smaller subset of ridership pairs between BART stations that are closer to the tunnel proper, with six stations in Oakland and Berkeley to the west of tunnel and the four closest stations to the east of it. These are shown below in Figure 4.

Figure 4: Subset of BART stations immediately adjacent to the Berkeley Hills Tunnel



2.4 Study Design

This report will examine both freeway volumes and the weekday BART trip pairs from both the entire network and the stations close to the tunnels shown in Figure 4. Exiting ridership counts for the trip pairs were compared between the sums of August-September-October in 2012 to August-September-October in 2014. For example, in August 2014 the average weekday trip count from Richmond to Orinda was 10 riders, meaning 210 trips were made between that pair in the month of August (there were 21 days). Freeway volumes will compare October 2012 and October 2014 during both the morning and afternoon peak. For this paper, freeway volumes were taken detectors using information from the Caltrans Performance Measurement System, known as PeMS.

3. Findings

3.1. Empirical

3.1.1 Freeway

Tables 1 and 2 show the changes between October 2012 and 2014 at the mainline freeway detector on SR 24 for the two reverse commutes.

Table 1: Changes in Freeway Volumes (vehicles/hour/lane), SR 24 Eastbound, morning commute

Time Period	2012 Volumes	2012 Average # Congested 5 min periods	2014 Volumes	2014 Average # Congested 5 min periods	2012 to 2014 volume changes
5:00-6:00	191	0	217	0	13.6%
6:00-7:00	487	0	523	0	7.4%
7:00-8:00	875	0	1006	0	14.9%
8:00-9:00	890	0	1016	0	14.0%
9:00-10:00	777	0	886	0	13.9%
PM Average	644	0	730	0	13.2%

Table 2: Changes in Freeway Volumes (vehicles/hour/lane), SR 24 Westbound, afternoon commute

Time Period	2012 Volumes	2012 Average # Congested 5 min periods	2014 Volumes	2014 Average # Congested 5 min periods	2012 to 2014 volume changes
14:00-15:00	920	0	1048	0	13.9%
15:00-16:00	982	0	1104	0	12.4%
16:00-17:00	1016	2.3	1181	0	16.2%
17:00-18:00	1040	4.5	1257	0	20.9%
18:00-19:00	902	1.5	994	0	10.2%
19:00-20:00	659	0	750	0	13.8%
PM Average	920	1.4	1056	0	14.8%

Considering the recent economic improvements in the Bay Area, as well as decline in fuel prices, Table 3 and 4 are included to compare the SR 24 reverse commute increases with other local freeways between October 2012 to October 2014. Note there was no data available for SR 4 during the morning peak.

Table 3: Changes in Freeway Volumes (vehicles/hour/lane), Adjacent Freeways, morning reverse commute: All changes shown in percent change.

Time Period	SR 24 Eastbound Subject Direction	SR 24 Westbound Opposite Direction	SR 4 Eastbound Pass to the North	I-580 Eastbound Pass to the South	I-680 Northbound Local Suburban Freeway
5:00-6:00	13.6	21.4	No data	-16.5	4.7
6:00-7:00	7.4	1.2	No data	-11.5	-2.8
7:00-8:00	14.9	-3.8	No data	-3.4	4.5
8:00-9:00	14.0	-0.8	No data	-4.4	12.2
9:00-10:00	14.0	9.9	No data	-2.6	24.2
PM Average	13.2	3.7	No data	-6.0	9.2

Table 4: Changes in Freeway Volumes (vehicles/hour/lane), Adjacent Freeways, afternoon commute: All changes shown in percent change.

Time Period	SR 24 Westbound Subject Direction	SR 24 Eastbound Opposite Direction	SR 4 Westbound Pass to the North	I-580 Westbound Pass to the South	I-680 Southbound Local Suburban Freeway
14:00-15:00	13.9	1.1	12.4	-3.4	17.3
15:00-16:00	12.4	5.4	12.7	-5.0	1.4
16:00-17:00	16.2	5.4	10.8	-3.4	4.9
17:00-18:00	20.9	3.8	9.4	-5.8	-7.1
18:00-19:00	10.2	-0.2	8.6	-5.2	-8.8
19:00-20:00	13.8	0.3	10.7	1.6	-1.2
PM Average	14.8	1.8	10.7	-3.6	1.1%

3.1.2. BART Rail

There have been significant changes in trip-pair BART volumes from 2012 to 2014. Referring to the BART map, Table 3 reflects the changes within the system between all of the stations east of the tunnel complex (Orinda to Pittsburg) and all other stations with a 40,000 daily rider minimum. This table reports the average of August, September, and October.

Table 5: Changes in Station-Station Pair Daily Weekday October Volumes from Major BART Stations to stations east of the tunnel, 40,000 rider minimum.

Originating Station	2012 Volumes Through Tunnel	2014 Volumes Through Tunnel	Change
Embarcadero San Francisco	420,891	430,245	9,354 / 2.2%
Montgomery San Francisco	384,721	431,135	46,414 / 12.1%
Powell San Francisco	194,979	214,914	19,935 / 10.2%
Civic Center San Francisco	156,622	180,590	23,968 / 15.3%
12th St Oakland	111,201	111,810	609 / 0.5%
19th St Oakland	103,116	103,977	861 / 0.8%
MacArthur Oakland	56,125	53,414	-2,711 / -4.8%
Downtown Berkeley	52,398	54,044	1,646 / 3.1%
San Francisco Airport	44,939	50,991	6,052 / 13.5%
Rockridge Oakland	43,508	40,544	-2,954 / 6.8%
Coliseum Oakland Airport	42,067	36,358	-5,709 / -13.6%

Due to congestion on the San Francisco Bay Bridge and rising parking prices, station-pair volumes between stations east of the tunnel (Orinda to Pittsburg) and the four downtown San Francisco stops of Embarcadero, Montgomery, Powell and Civic Center have increased dramatically during the two year period between 2012 and 2014. The Coliseum - Oakland Airport station was separated as October ridership varies widely due to the performance of the professional baseball team that plays at the Coliseum, the Oakland Athletics. The 2012 team played six games in October and the 2014 team played zero.

Focusing on the local changes in more detail, Figure 5 shows the changes in volumes on pairs referenced in Figure 4; only stations close to the tunnel entrances. As a comparison, Figure 6 shows the volume changes to the four largest San Francisco stations instead.

Figure 5: Combined change in ridership (%) from six local stations in Oakland and Berkeley (Figure 4) through the tunnel complex, 2012 to 2014

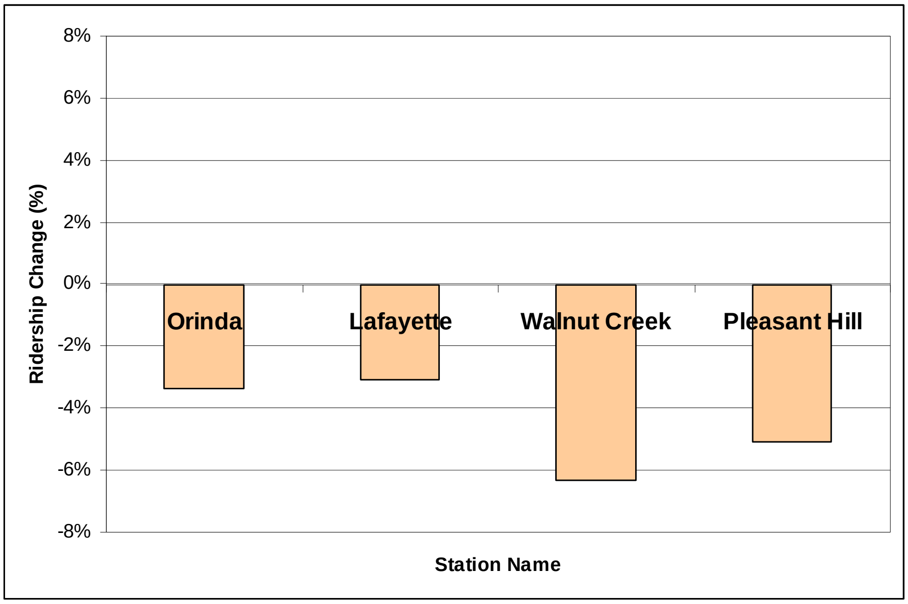
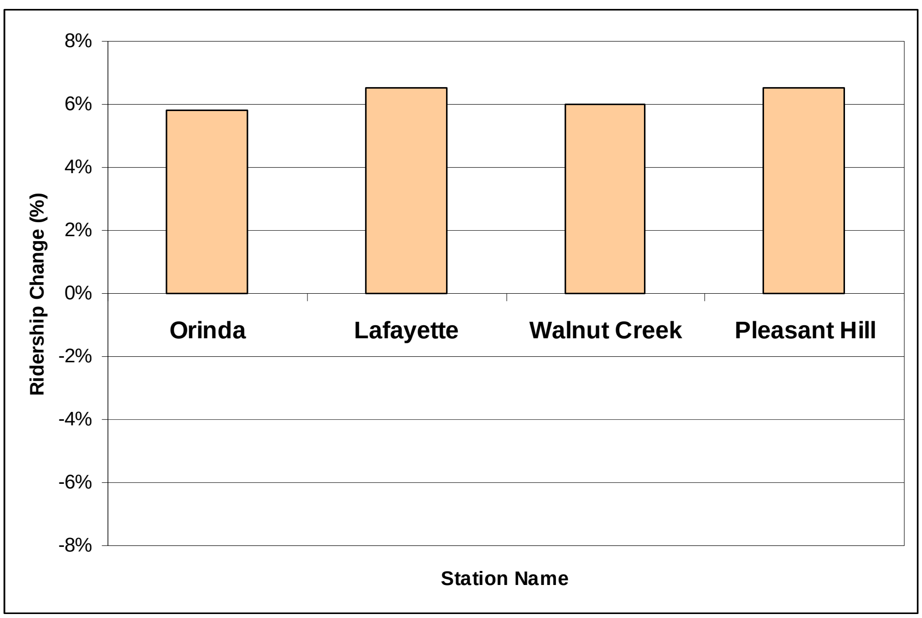


Figure 6: Combined change in ridership (%) from the four San Francisco stations through the tunnel complex, October 2012 to October 2014



3.2. Basic Statistics

A comparison of means analysis (ANOVA) was performed to see whether these changes, empirically observed, were statistically significant. The ANOVA will focus on issues raised in Figure 5; namely to verify statistical significance of the decline in travel between stations in close proximity to the tunnels, potentially due to the expansion of the adjacent freeway tunnel. Note that these averages are for the entire year, not just October.

Table 6: Summary of Analysis

Station	2012 Daily Average	2014 Daily Average	Difference	T-Statistic
Orinda	438.3	415.2	-22.8	2.09
Lafayette	594.1	564.6	-29.5	2.78
Walnut Creek	1116.5	1050.9	-65.1	4.47
Pleasant Hill	1089.4	1068.2	-21.2	1.11
SR 24 westbound Afternoon Peak	306.5 per 5 min	351.8 per 5 min	45.2	15.74

4. Discussion

The freeway data show clear and distinct changes due to the opening of the fourth tunnel bore. Comparing the 2012 volume with 2014, for the reverse commute there were significant increases at every hour during both the morning and afternoon peak periods, as high as 20 percent during the 17:00-18:00 hour. High growth at 17:00 could indicate an increase in reliability of the trip due to the opening of the fourth bore, which allows commuters to travel closer to their optimum time. Comparing these increases with other local freeways in Tables 3 and 4, SR 4 gained the highest ridership, particularly in comparison to the opposite direction (the traditional commute) and the similar direction at the nearest pass to the south (I-580). This could imply not only a mode switch but a population of drivers who have started to drive on SR 24 instead of I-580 once the fourth bore was opened. The reverse commute on SR 24 increased on average 13.2% and 14.8% respectively for the morning and afternoon peaks, as opposed to 3.7% and 1.8% is the conventional direction to and from the Bay Bridge.

Additionally, in terms of congestion, on average in the afternoon there were a total of 8.3 congested 5 minute periods per day in 2012, for a total of 41 minutes, while in 2014 there were no congested periods due to the elimination of the bottleneck. For a commuter, this is a very significant change, and lends further evidence to the theory that drivers could consolidate their start times due to increased reliability of commute duration, shown previously by the highest increase at 17:00-18:00.

The examination of the BART ridership does not produce as clear a result as the freeway ridership but does indicate some changes. Clearly, BART ridership from the stations west of the tunnel (e.g. west of Orinda) to the San Francisco stations has increased dramatically, with some stations (e.g. Montgomery) indicating over a 10 percent increase in just two years, shown in Table 5. This can be attributed to a number of factors including improvements in the overall economy and increased congestion on the San Francisco Bay Bridge, which may have caused a small mode shift to BART for those trips. The regional metropolitan planning organization has reported that congested conditions on Bay Bridge approaches exiting San Francisco exist for over 7 hours (1:25-8:30) during the afternoon peak (MTC, 2013.

Continuing to look at Table 5, which could reveal short term induced freeway travel with a switch from BART to the improved freeway, the evidence does support some movement away from BART. The two stations closest to the tunnel, Rockridge and MacArthur, both in Oakland, did report drops in westbound ridership of -6.8% and -4.8% respectively with an aggregate absolute loss of 5500 riders per day. Ridership was flat to the Oakland downtown stations (12th and 19th street), with Downtown Berkeley the only local station Bay to report gains greater than 1000 riders per month through the tunnel. Figure 5 provides perhaps the strongest evidence of a potential modal switch, as it appears that ridership is down at stations closest to the tunnel. Indeed BART itself has begun to adjust from reduced demand at the stations in and around the Berkeley Hills tunnels, specifically the stations highlighted within this research. In September 2015, citing demand from stations at the far eastern end of the line (e.g. beyond Walnut Creek) to downtown San Francisco and a drop in the reverse commute, BART announced that in the morning some reverse commute trains would skip Rockridge, Orinda, and Lafayette stations and turn around mid-line at Pleasant Hill. By skipping Rockridge and Orinda, BART was abandoning the reverse commute trip between the two stations on either side of the rail tunnel, conceding this traffic to the newly expanded road tunnels. Riders traveling in the primary direction from these stations had complained that the trains were full by the time they left Concord en-route to San Francisco (Cabanatuan, 2015).

A closer examination of comparisons of means looked at the trip pairs from stations in Figure 6, comparing one year before the new freeway tunnel (2012) to the year after its opening (2014). Reviewing the results of the ANOVA tests from Table 5, there was weak significance in the declining ridership from the stations east of the tunnel to one station (Orinda), strong significance to two (Lafayette and Walnut Creek), and no significance to the fourth (Pleasant Hill). This would seem to indicate that the decline in ridership from stations in Oakland and Berkeley to at least Lafayette and Walnut Creek is not simply from natural fluctuations. Although not directly comparable, the comparison of means test found the increase in afternoon freeway volume to be highly significant.

Even though there is some evidence of switching and short term induced demand, there are many different unknown factors that could be having a strong effect on changes in ridership such as parking changes and land development. It may be that parking rates or the number of parking spaces has changed for employers located near the stations to the east of the tunnel. Most importantly, while the economy has improved regionally in terms of job growth, increases in residences vary greatly from station to station, which could significantly affect the number of BART riders. It may simply be that growth is flat at stations that are seeing smaller ridership increases (or losses). Orinda and Lafayette, for example, are relatively wealthy communities with very little population growth. These unknowns are too significant to ignore when making a strong conclusion about changes from BART to the freeway, although they would not be able to explain the *decline* in ridership seen in Figure 5.

In summary, there have been changes to volumes on both the freeway and the BART system since the removal of the Caldecott Tunnel bottleneck with the construction of the fourth tunnel bore. With the off-peak freeway congestion completely removed, volumes during both commuter periods have increased greater than many of the surrounding freeways. The highest increase was during the 17:00-18:00 hour, indicating that congestion relief has changed the volume time-of-day profile with travelers switching their afternoon start times to a narrower range. In terms of BART volumes, there is some evidence that volumes have dropped on station pairs when both stations are in close proximity to either side of the tunnel, and this may indicate a switch to driving for these local trips. This only applies to trips to stations immediately to the east and west of the tunnel, as BART has continued to see growth to stations further afield where new residential construction is more active.

This case study has shown that the removal of a mature freeway bottleneck can potentially have an effect on nearby rail transit volumes through the process of short term induced travel, although these effects appear to be somewhat limited in scope. These changes should be considered when making financial decisions on bottleneck relief. Certainly future work could include looking a greater time interval, investigating the effects on downstream bottlenecks, or environmental implications.

5. Acknowledgements

The authors thank Yi Liu for her helpful comments.

REFERENCES

Cabanatuan, Michael. "BART, packed with record crowds, to expand service." *San Francisco Chronicle / SFGate.com*, September 13, 2015. http://www.sfgate.com/bayarea/article/BART-packed-with-record-crowds-to-expand-service-6499611.php (Accessed November 2015)

Cervero, Robert. 2003. "Road Expansion, Urban Growth, and Induced Travel: *A Path Analysis*." *Journal of the American Planning Association* 69 (2): 145–63. doi:10.1080/01944360308976303.

Cervero, Robert, and Mark Hansen. 2002. "Induced Travel Demand and Induced Road Investment: A Simultaneous Equation Analysis." *Journal of Transport Economics and Policy* 36 (3): 469–90. doi:10.2307/20053915.

Chung, Jin-Hyuk, Kee Yeon Hwang, and Yun Kyung Bae. 2012. "The Loss of Road Capacity and Self-Compliance: Lessons from the Cheonggyecheon Stream Restoration." *Transport Policy* 21 (May): 165–78. doi:10.1016/j.tranpol.2012.01.009.

DeCorla-Souza, Patrick, and Harry Cohen. 1999. "Estimating Induced Travel for Evaluation of Metropolitan Highway Expansion." *Transportation* 26 (3): 249–62. doi:10.1023/A:1005161903828.

Downs, Anthony. 1962. "The Law of Peak-Hour Expressway Congestion." *Traffic Quarterly* 16 (3).

Fröhlich, Philipp. 2003. "Induced Traffic: Review of the Explanatory Models." In *3rd Swiss Transport Research Conference, Ascona*.

Goodwin, PhilB. 1996. "Empirical Evidence on Induced Traffic." *Transportation* 23 (1): 35–54. doi:10.1007/BF00166218.

Hansen, Mark, and Yuanlin Huang. 1997. "Road Supply and Traffic in California Urban Areas." *Transportation Research Part A: Policy and Practice* 31 (3): 205–18. doi:10.1016/S0965-8564(96)00019-5.

Hsu, Wen-Tai, and Hongliang Zhang. 2014. "The Fundamental Law of Highway Congestion Revisited: Evidence from National Expressways in Japan." *Journal of Urban Economics* 81 (May): 65–76. doi:10.1016/j.jue.2014.02.002.

Hymel, Kent M., Kenneth A. Small, and Kurt Van Dender. 2010. "Induced Demand and Rebound Effects in Road Transport." *Transportation Research Part B: Methodological* 44 (10): 1220–41. doi:10.1016/j.trb.2010.02.007.

Lee, Douglass, Lisa Klein, and Gregorio Camus. 1999. "Induced Traffic and Induced Demand." *Transportation Research Record: Journal of the Transportation Research Board* 1659 (January): 68–75. doi:10.3141/1659-09.

Matos, Fernando J.F., and Francisco J.F. Silva. 2011. “The Rebound Effect on Road Freight Transport: Empirical Evidence from Portugal.” *Energy Policy* 39 (5): 2833–41. doi:10.1016/j.enpol.2011.02.056.

Metropolitan Transportation Commission, 2014. “Top 50 Congested Locations – 2013: Ordered by Rank. Accessed at https://cbssanfran.files.wordpress.com/2015/01/top_50_congested_2013.pdf

Noland, Robert B. 2001. “Relationships between Highway Capacity and Induced Vehicle Travel.” *Transportation Research Part A: Policy and Practice* 35 (1): 47–72. doi:10.1016/S0965-8564(99)00047-6.

Sorrell, Steve, John Dimitropoulos, and Matt Sommerville. 2009. “Empirical Estimates of the Direct Rebound Effect: A Review.” *Energy Policy* 37 (4): 1356–71. doi:10.1016/j.enpol.2008.11.026.

Su, Qing. 2011. “Induced Motor Vehicle Travel from Improved Fuel Efficiency and Road Expansion.” *Energy Policy* 39 (11): 7257–64. doi:10.1016/j.enpol.2011.08.047.

Weis, Claude, and Kay W. Axhausen. 2009. “Induced Travel Demand: Evidence from a Pseudo Panel Data Based Structural Equations Model.” *Research in Transportation Economics* 25 (1): 8–18. doi:10.1016/j.retrec.2009.08.007.