Saving Money, Energy and Environment on BART

A comparative analysis of economic, environmental and energy impacts of commuting on the Bay Area Rapid Transit system instead of by automobile

Tom Lent

ILSR

Institute for Local Self Reliance

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Contact:

Institute for Local Self Reliance
2425 18th St. NW
Washington, DC 20009
202-232-4108
ilsr@igc.org
www.ilsr.org

The author can be reached at:

Tom Lent
Energy and Environmental Consulting
2464 West Street
Berkeley, CA 94702
510-845-5600
tlent@igc.org

Introduction

This report documents research quantifying the impacts of individual commuters choosing to ride the Bay Area Rapid Transit (BART) system in preference to driving an automobile.

Measures were developed to calculate:

- economic savings for the commuter
- reduced environmental impact, and
- reduced energy use

The study was commissioned by the BART Marketing and Research Department for purposes of providing scientific documentation to support efforts to encourage greater use of the BART system during the weekday commute.

This study is intended to support marketing campaigns to encourage commuters to take BART to work rather than as a policy analysis for selecting mass transit policy strategies. Therefore the emphasis is on the direct marginal impact of each commuter trip decision, rather than on the potential system and market transformation impacts that would be experienced by large numbers of commuters switching transport modes. The goal is to help BART answer the question for the potential rider of "what will happen if I ride BART today instead of driving?" This can result in different answers than if the question is framed as (for example) "what will happen if BART gets 2,000 more riders during peak commute hours."

Summary of results

The conclusions of this research make a compelling case for taking BART for the daily commute on economic, environmental and energy saving grounds.

Key findings are that a typical East Bay commuter who takes BART instead of driving a midsize car to a downtown San Francisco job:

- can realize direct economic savings exceeding $5,000 per year,
- avoids 5 tons of emissions, which reduces global warming, smog, asthma and other pollution related problems, and
- requires only approximately 1.6 kilowatt hours of electricity during the peak commute, and gets the equivalent of up to 250 mpg.

This report provides referenced documentation to substantiate these and a series of other indicators of the strong case for switching to transit. The intention of the report is to help enlarge the commuters' view of their commute costs from a simple gas pump calculation to include the larger set of real costs – both to society and to their own pocketbooks.

Base assumptions

Unless otherwise noted, the study is based upon a normal weekday commute during peak hours for a 9-5 job. Total commute distance round trip used is 40 miles (an average East Bay trip such as from Richmond, Lafayette, or Bayfair/Hayward stations to the Montgomery station) [1]. The car evaluated is a typical midsize car (Ford Taurus) medium vintage (2001), assumed to be driven single occupancy.

Economic savings

For calculation of the economic cost to the commuter, it is assumed that the commuter will continue to own the car regardless of the commute decision. This analysis, therefore, only includes marginal expenses (such as gas, oil, maintenance, tire wear and mileage based depreciation) related to the actual mileage driven, not fixed annual expenses such as insurance, financing, license fees and age based depreciation. This calculation also excludes less easily predictable sporadic expenses, such as accidents and health impacts. Obviously, if the commuter decides that the car is not needed the savings will be even higher than those shown here.

Mileage variable cost factors of the car modeled are as follows:

Mileage variable items*	**Cost/mile**	**Cost/trip**	**Cost/year**
Gasoline	$0.079	$ 3.16	$ 720.48
Maintenance	$0.043	$ 1.72	$ 392.16
Tire replacement	$0.008	$ 0.32	$ 72.96
Oil change	$0.006	$ 0.24	$ 54.72
Depreciation	$0.132	$ 5.28	$1,203.84
Total mileage variable costs	$0.268	$ 10.72	$2,444.16
*based on a 40 mile round trip in a mid size car			
Work days/year	228		
Fixed price per trip items			
Bridge toll		$2.00	$ 456.00
Parking		$18.42	$4,199.76
Total cost per round trip		**$ 31.14**	**$7,099.92**
Cost of same BART trip		$6.80	$1,550.40
Total savings		**$ 24.34**	**$5,549.52**

Derivation of cost factors is as follows:

Work days/yr = 5 days per week for 52 weeks - 2 weeks holidays, 3 weeks vacation, 1 week sick leave & 2 personal days

Gasoline = Fuel price ($1.808/gal) [2] ÷ EPA mileage (23 mpg) [3]

Maintenance = New car cost ($0.041/mile) + annual escalation factor ($0.008/year of car age) [4]

[1] This study assumes a commuter living relatively close to a BART station or getting there with little marginal impact. The impact of how the commuter gets to the BART station is beyond the scope of this report. Driving to BART, particularly if it involves a cold-start of a vehicle, may tend to reduce, but not eliminate, the energy, environmental, and cost savings of BART relative to the automobile. It should be noted that use of lower cost, lower energy use, and lower polluting vehicles such as hybrids or electric cars to access BART stations will enhance the personal and societal benefits of BART use.

[2] AAA Daily Fuel Gauge Report 8/6/03, CA Metro Averages, Oakland Regular average. *http://www.fuelgaugereport.com/CAmetro.asp*

[3] US Environmental Protection Agency, Fuel Guide, http://www.fueleconomy.gov/feg/findacar.htm.

[4] American Automobile Association, "Your Driving Costs 2003" *www.aaamissouri.com/new/library/drivingcost.* All AAA costs based upon rating of 2003 model year cars. Southern California AAA supplement indicated 0.4 cent increase for five year old car. $0.008 per year increase used here is a straight line extrapolation. *http://www.aaa-calif.com/members/corpinfo/costbrch.asp.*

Tire replace	= Cost per tire installed ($100)[5] X 4 ÷ replacement frequency (50,000 miles)
Oil change	= Cost per oil change ($30)[6] ÷ change frequency (5000 miles)
Depreciation	= First year cost of additional miles over 15,000 ($0.188/mile) – 10% per year [7] (mileage based depreciation only)
Bridge toll	= Bay Bridge as of October 2003
Parking	= Monthly unreserved rate ($350)[8] ÷ 19 working days/month (5 days per week for 52 wks – 2 wks holiday, 3 wks vacation, 1 wk sick leave & 2 personal days)
BART cost	= One way trip ($3.40)[9] X 2 trips per commute day

Savings would be greater for longer trips, newer or larger cars and if BART tickets are bought with pre-tax earnings, such as through Commuter Check or using high value discount tickets available via BART's Tickets-To-Go program. A range of cars and trips can be modeled using the Excel spreadsheet based BART Commute Savings Calculator that accompanies this report[10]. This model calculates savings for trips between any two BART stations and for a range of car types, from a compact (Chevrolet Cavalier) to a luxury SUV (Hummer). The age of the car can be varied and the user can select whether the BART tickets are bought with pre-tax dollars (in a program like Commuter Check) or not and whether parking is provided free or paid.

It is notable that the gasoline costs of the commute at 8 cents/mile for a mid size car getting 23 mpg are less than 30% of the total mileage related costs that are almost 27 cents per mile. Over the course of the year, the average car owner will spend another 6 cents per mile for maintenance – almost three quarters again as much as that paid at the pump. Mileage dependent depreciation will tend to exceed the total of both gas and maintenance costs, reaching over $2,000 per year for an SUV commuting from the vicinity of an outer station on the BART system such as Pittsburg/Bay Point to downtown San Francisco.

The chart below provides examples of the range of results for commutes to locations near the Montgomery BART station, ranging from $1.50 per day for an older compact car driven from North Berkeley with free downtown parking and no Commuter Check, to over $10,000 in annual savings for a Hummer driven from Pittsburgh/Bay Point and paying for downtown parking.

Sample results for comparison of commute by car versus BART

Assumptions:			
Car Class	Compact	Midsize	Luxury SUV
Year	1998	2001	2004
Start station	North Berkeley	Walnut Creek	Pittsburg/Bay Point
Pretax BART ticket	No	Yes	Yes
SF Parking cost	$0	$350	$350
Results:			
Driving cost	$ 7.23/dy / $1,649/yr	$32.73/dy / $7,463/yr	$51.98/dy / $11,852/yr
BART cost	$ 5.70/dy / $1,300/yr	$ 4.38/dy / $ 999/yr	$ 5.46/dy / $ 1,245/yr
Savings	**$ 1.53/dy / $ 350/yr**	**$28.35/dy / $6,460/yr**	**$46.52/dy /$10,610/yr**

[5] Tires replacement costs are based on sale prices for 50,000 mile tire at Sears in August 2003 and include tax & installation. AAA estimates of tire costs were significantly higher at 1.8 cents/mile.
[6] Oil change costs based upon an informal survey of East Bay auto shops in August 2003.
[7] Depreciation is based upon AAA's analysis of incremental mileage based depreciation per 1000 miles driven above and beyond a base of 15,000 miles per year. AAA's figures actually suggest higher rates for the 1st 15,000 (from $0.20/m to $0.30) but the lower rate that AAA suggests for miles over 15,000 is used to allow for uncertainties over how much of the first 15,000 mile depreciation is simply due to aging not miles. Southern California supplement indicated that at 5 years the depreciation rate for the excess miles is half the rate for new car. Depreciation is therefore reduced by straight line extrapolation at 10% per year. Others have asserted much higher depreciation rates than AAA (see *http://www.oasisdesign.net/transport/cars/depreciation.htm*).
[8] Parking rates based on 2002 Colliers International CBD Parking Survey, Unreserved average rate *http://www.colliersmn.com/prod/ccgrd.nsf/Region/CA0D746DD80773B285256BF0006884E4/$File/NA+Parking+Rate+Survey+2002.pdf*.
[9] October 2003 rate from Lafayette to Montgomery stations.
[10] Available for download from http://tlent.home.igc.org/download/BARTCalculator.xls.

This analysis makes clear that there are a plethora of hidden costs of putting extra mileage on a car driven to work. Savings from giving the car a rest and taking BART to work instead can range from $1.50 to almost $50/day, totaling from $350 to over $10,000 per year. Many of these costs are not obvious on a daily basis to the driver but add up to real costs over the course of the year.

The only way to match BART economically is with a 10 year old car (hence with no remaining depreciation value) getting 28 mpg or better, driving from North Berkeley or closer with free parking in downtown San Francisco and no Commuter Check – a pretty unusual set of circumstances. With social costs included (such as pollution) BART can never be beat.

Reduced environmental and health impact

There are a range of air pollution impacts with serious health impacts to which cars contribute significantly. Air pollution claims 70,000 lives a year in the United States and emissions from driving are a major contributor[11]. The pollution caused by driving to work causes global warming, asthma, cancer and other health impacts[12]. Powered primarily by electricity from hydroelectric power, riding BART virtually completely avoids contributing to air pollution impacts.

Ozone & Asthma: Ozone is formed when nitrogen oxides (NOx), volatile organic compounds (VOCs) and heat from sunlight mix. The Bay Area is a high ozone area. Combustion engine vehicles are the major contributor of the gases responsible for ozone formation in the Bay Area.[13]

The Children's Health Study, an ongoing research project conducted by the University of Southern California, recently linked ozone with asthma in children. Researchers followed 3,500 children in southern California for over five years in twelve southern California cities. Six of these cities had higher than average ozone levels and six had lower than average ozone levels. Children who lived in the higher ozone level communities developed asthma at a rate three times higher than children who lived in the lower ozone cities. This is particularly significant because it is the first time that high smog levels have been directly linked to asthma development in children who did not previously have respiratory ailments[14].

Like children, senior citizens are also particularly vulnerable to harm from vehicular air pollution. For example, a study published in Health Affairs found a strong relationship between particulate matter (another significant vehicular emission) and inpatient and outpatient care required by people of ages 65-84 across 183 metropolitan statistical areas (MSAs)[15].

Global warming: Combustion engine vehicles are significant contributors to global warming. Transportation contributes about 25% of all U.S. global warming emissions[16]. EPA estimates that cars emit 25.3 lbs of carbon dioxide (CO^2) and other global warming gases per gallon consumed. The typical midsize car modeled here is therefore calculated by the EPA to emit 1.1 pounds of global warming gas per mile[17]. This translates into 44 pounds per day for the typical 40 mile round trip commute modeled here – more than 5 tons per year.

[11] Bernie Fischlowitz-Roberts, Air Pollution Fatalities Now Exceed Traffic Fatalities By 3 To 1, September 17, 2002, Earth Policy institute, *http://earth-policy.org/Updates/Update17.htm.*

[12] Transportation Cost and Benefit Analysis, Cost Summary and Analysis, June 2003, Victoria Transport Policy Institute, Victoria, BC, *http://www.vtpi.org/tca/.*

[13] Bay Area Air Quality Management District, Emissions Inventory, Table IV "Percent Distribution of Projected Bay Area Summer Emissions 2003", *http://www.baaqmd.gov/pln/emissioninv.asp?Grp=1.*

[14] California Air Resources Board, Children's Health Study, Sacramento, CA October 7, 2002, *http://www.arb.ca.gov/research/chs/chs.htm.*

[15] Victor Fuchs and Sarah Frank, "Air Pollution and Medical Care Use by Older Americans: A Cross Area Analysis," Health Affairs, Vol. 21 No. 6, November/December, 2002, *www.healthaffairs.org.*

[16] US Environmental Protection Agency, Global Warming Emissions, Washington, DC, 2003 http://yosemite.epa.gov/oar/globalwarming.nsf/content/Emissions.html.

[17] Global warming gas (GWG) emissions estimate is from US Environmental Protection Agency FuelEconomy.gov Guide, Washington, DC, *http://www.fueleconomy.gov/feg/findacar.htm.* GWG emissions are based on EPA fuel economy estimates driving at 55% city / 45% highway miles and based on full

Mainstream smoke of a typical United States commercial non-filter cigarette contains about 60 mg of CO^2.[18] This translates to 8,366 cigarettes worth of CO^2 per mile driven for the modeled mid size car.[19] Therefore for each day's trip this global warming gas generation translates into as much CO^2 as would be produced if everyone in a capacity crowd in San Francisco's PacBell Park smoked 8 cigarettes[20].

Time and Stress: Commuting by personal car is a significant stressor as well. The average Bay Area commuter wastes 42 hours a year sitting in traffic. Bay area residents waste an estimated average of 42 hours per year (over one work week) sitting in traffic congestion[21]. On BART, commuters sleep, read, or just relax. A full exploration of the stress reduction values of leaving the commute car at home is beyond the scope of this study but there is a substantial literature on stress and commuting showing the personal costs of car commutes[22].

Combining personal cost and social environmental impact costs

A study by the Victoria Transport Policy Institute that combined the costs of owning as well as operating a car with the social costs such as air pollution, accidents, and congestion and calculated the true cost of car driving at over $1.00 per mile[23]

Reduced energy use

The typical mid sized car modeled in this paper consumes 397 gallons of gas every year just for this 40 mile round trip commute[24]. A BART trip uses no gasoline, but an energy comparison can be made.

Determining the energy savings from taking a trip by BART instead of by car required an analysis of BART energy usage patterns. BART's energy use per person-mile (one person carried one mile) varies considerably by time of day. BART can move people for a lower watt hour (wh) per person mile during the rush hour than during the lower volume midday hours[25]. We sampled BART records of hourly system kilowatt hours (kWh) usage and passenger trips for two weeks (weekdays only) in July of 2003. Passenger trips were converted into passenger miles and divided into the hourly kWh usage to obtain watt hours per passenger mile. The results were quite consistent. During the lowest day time ridership hour in the midday lull (noon – 1PM) BART averaged 360 watt hours per person-mile (wh/p-m). From 4-5PM the average was 251 wh/p-m and from 5-6PM it was only 171 wh/p-m.

But these numbers, low as they are, are really only of interest to the policy maker, deciding whether to build a BART system or a rail extension. To determine the impact of the individual commuter deciding to travel one trip by BART instead of by car the calculation should be based not on the average usage per person-mile, but the *marginal* usage. That is, the question should

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gasoline fuel life cycle but do not include any auto manufacturing emissions. EPA factor is 25.3 lbs of GWG per gallon consumed. EPA listings are annual figures for 15,000 miles of driving at 55/45.

[18] Gori & Ellis, Reduction of Carbon Monoxide in Cigarette Smoke, National Institute of Health - Preventive Medicine, http://tobaccodocuments.org/lor/81211252-1262.html.

[19] Conversion factor of 453,592 mg/pound – 60 mg/cigarette yields 7560 cigarette/# CO^2. 7560 cigarettes/# CO^2 X 1.1 # CO^2/mile = 8366 cigarettes/mile.

[20] 8366 cigarettes/mile X 40 mile round trip = 334,650 cigarettes worth of CO^2 per commute trip ÷ capacity of PacBell Park (41,059) *http://www.ballparks.com/baseball/national/pacbel.htm.*

[21] [May 2001 Urban Mobility Study by Texas Transportation Institute *http://www.transportationca.org/research/5-7-01/fact_sheet.shtml.*

[22] For example: Gatersleben & Uzzell, The journey to work: exploring commuter mood among drivers, cyclists, walkers and users of public transport, EPUK 2003, *http://www.envpsy.org.uk/abstracts.php.*

[23] Transportation Cost and Benefit Analysis, Cost Summary and Analysis, June 2003, Victoria Transport Policy Institute, Victoria, BC, *http://www.vtpi.org/tca/.*

[24] 40 miles ÷ 23 mpg X 19 workdays /month X 12 months

[25] Some factors include: that the higher passenger load means that the energy cost of lighting and other station loads is spread over more passengers, cars are run closer to capacity and there is more efficient use of regenerative braking,

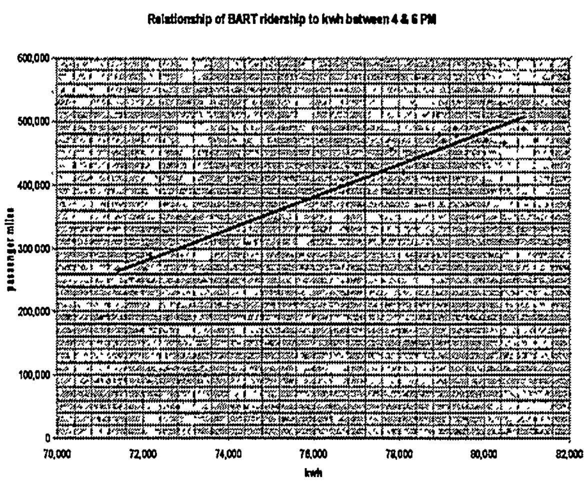
be "how much more energy does it take to carry one more passenger one mile during the peak commute hour?" As the declining average rate calculated above indicates, the marginal energy cost is even lower than these numbers indicate.

During the commute hours, BART consumes an extremely low average of only 41 watt hours per additional passenger mile traveled. BART travels at an average speed station to station of about 35-40 miles per hour. That works out to approximately 1.6 kilowatts per additional commute trip at a 1500 watt added instantaneous load[26] – about the same as a small toaster oven or a hair dryer.

As the chart below indicates, this 41 wh/p-m number is quite reliable. Despite the relatively small sample size (ten days of two hours of data or 20 data points) the data points are clustered very closely around the trend line.

If the system is running cars below capacity at rush hour (as is currently the case), adding more commuters won't immediately require adding more cars. In this case, the 41 wh/p-m number is a very reasonable number to use for commuters. A more conservative factor that is relevant to midday rides as well as commutes and that factors in the cost of more riders requiring more cars would be the marginal difference between midday lull passenger miles and the rush. The all day average marginal energy usage per additional passenger mile is approximately 100 wh/p-m. At the 100 wh/p-m factor, a midsize car uses 23 times more energy to transport a single passenger than BART uses to transport one additional passenger. At the 41 wh/p-m rush hour factor, that number climbs to 52 times the energy.

Comparing to MPG fuel efficiency: Given that BART gets virtually all of its electricity from hydropower rather than from burning fossil fuels, savings of gasoline are virtually 100% of the amount used by a car. Assuming, however, that energy is transferable between modes, we can use energy equivalents to create a mile per gallon equivalent comparison. BART's comparative fuel efficiency depends upon the context. At most conservative – taking total passenger miles and kilowatt usage at the least efficient midday lull time – effective fuel efficiency is 136 person miles per gallon equivalent. During commute hours BART gets up to 250 people miles per gallon equivalent[27] more than ten times that of a typical car.



[26] 41 watt hours X 40 miles = 1640 watt hours, Lafayette to Montgomery station is 20 miles and takes 31 minutes = 38.7 mph, Richmond to Montgomery takes 35 minutes = 34.3 mph. 36 passenger miles per hour X 41 watt hours per passenger mile=1476 watts.

[27] 1,516,639 kWh used from 4-6 pm in the test period ÷ 7,533,387 passenger miles = 0.201 kilowatt hours per passenger mile. 0.201 kilowatt hours per passenger mile X 3413 BTU/kwh X 1.15 (15% line losses) = 789 BTU/passenger mile on BART.
The net energy of a gallon of gasoline is 167,276 BTU (124,000 btu/gal energy content X 1.349 BTU of energy required to refine and transport 1 BTU of gasoline - R.A. Hinrichs, 1996, Energy: Its Use and The Environment http://www-personal.umich.edu/~rcnh/gs102/EnergyEquiv.html. Energy cost of refining & transport, USDA Economic Research Service Report #721, http://www.ers.usda.gov/publications/aer721/aer721.pdf)
167,276 BTU/gal ÷ 789 BTU/passenger mile = **212** MPG (passenger miles per gallon equivalent) on BART. Narrowing the view to only the 5-6PM commute hour 0.171 kWh/p-m yields 249 mpg equivalent.

Conclusion

A compelling case can be made to the individual commuter to leave his or her car home and take BART for the daily commute on economic, environmental and energy saving grounds. For example, a typical East Bay commuter switching from driving a midsize car can realize direct economic savings exceeding $5,000 per year, avoids 5 tons of emissions, which reduces global warming, smog, asthma and other pollution related problems, and requires only about 1.6 kilowatt hours of electricity during the peak commute, and gets the equivalent of up to 250 mpg.

This report provides referenced documentation to substantiate these and a series of other indicators of the strong case for switching to transit. Together a collage of these facts supported by strong imagery can help enlarge the commuters' view of their commute costs from a simple gas pump calculus to include the larger set of real costs to society and to their own pocketbooks.