Title

San Francisco Bay Area’s Spare the Air/Free Morning Commute Program: Program Effectiveness in Comparison to the Washington, D.C. and Los Angeles Area Strategy and Suggestions for Enhancing Ridership D.

Author
Joshua Widmann

Publication Date
2006-06-30

Ralph and Goldy Lewis Center for Regional Policy Studies
UCLA School of Public Affairs

San Francisco Bay Area's Spare the Air/Free Morning Commute Program:

Program Effectiveness in Comparison to the Washington, D.C. and Los Angeles Area Strategy and Suggestions for Enhancing Ridership Data Collection and Monitoring

Joshua Widmann

UNIVERSITY OF CALIFORNIA

Los Angeles

San Francisco Bay Area's Spare the Air/Free Morning Commute Program:

Program Effectiveness in Comparison to the Washington, D.C. and Los Angeles area strategy
and
Suggestions for Enhancing Ridership Data Collection and Monitoring

Submitted in partial satisfaction of the requirements for the degree
Masters in Urban Planning

Joshua Widmann
jwidmann@ucla.edu
March - April 2006

TABLE OF CONTENTS **Page**

TABLES AND APENDICES **Page**

EXECUTIVE SUMMARY

The Spare the Air/Free Morning Commute (Spare the Air) program in the San Francisco Bay Are funds up to five mornings of weekday transit when air quality is forecasted to exceed federal 8-hour ozone levels during the summer months. Spare the Air has existed for two years and data is limited to three fare free morning commute days. A similar program exists in the Washington, D.C. metropolitan area known as Code Red Air Quality Action Days, which funds free transit with the exception of rail and buses within the District of Columbia. These two programs are contrasted with one another along with the Los Angeles region transportation related air quality strategy in order to provide insight on which programs are most effective and appropriate for each region. In order to determine policy appropriateness, a literature review of transit fare elasticity and major air quality strategies in the three regions is undertaken. Lastly, the current Spare the Air program evaluation and the ridership collection, analysis, and reporting methodology are reviewed in order to make suggestions for more effective program administration.

Ridership collection and transportation related air quality strategy analysis indicates there is no one-sized-fits-all solution for all three regions, and in fact an appropriate strategy should be multi-faceted. Proper strategy should also consider whether its goals are long term or short term, whether or not costs are acceptable for a given program, and whether the public understands and is willing to participate in the program. Along with public support, agency support makes a difference as well. Effective leadership and vision can propel a program to many years of success, while lack of management can result in dismal consequences and a waste of public resources.

Passenger counting, analysis, and reporting in the literature and experience inform us that process, internal communication, and preparation is far more important than technology. While smart cards have been on the horizon for many years with their eventual implementation we shouldn't expect them to solve all of our problems, and we shouldn't expect initial implementation to be glitch-free as the Washington, D.C. case indicates.

Air quality program literature and experience demonstrates that while Spare the Air and Code Red data is limited there is much to learn from ridership data, emissions costs, onboard surveys, online surveys, and program evaluations. These programs should be continued with careful monitoring in order to collect more data. Overall, the costs are relatively low considering the programs fund a few days per year and the full number of days is rarely exceeded. Compared to ridesharing programs in the Bay Area the AQMD indicates Spare the Air is only 17 percent more costly for each ton of pollution reduced. Although Spare the Air is significantly more expensive than other air quality programs - 17 times more than Carl Moyer clean engine replacement, 3.4 times more than the smoking vehicle retrofit program, and 4.5 times more than the vehicle buyback program - with public experience and increased awareness, utilization fare-free programs provide a multi-pronged air quality approach, especially when other programs have “maxed out” on their ability to find additional older vehicles to scrap or engines to replace.

While the Los Angeles region does not fund free transit promotional programs, there are still lessons to be learned from the Los Angeles transportation based air quality strategy. Regulation 2202 has most likely had an effect on the higher carpool rates in Los Angeles compared with metropolitan San Francisco and Washington, D.C. Such a program in concert with carpool lanes provides a lower cost alternative to certain types of capital-intensive transit projects while tailoring to the variations in employment densities and transit accessibility. While half of required employers opt to pay for emissions credits instead of ridesharing, the 75 air quality exceedances in Los Angeles last year indicate that either ridesharing should not be optional, or emissions credits should be more costly. Such higher fees can perhaps fund additional engine related technology upgrade programs and perhaps a limited Spare the Air program in existing downtown areas in the region which have rapid transit access.

There are also lessons from the elasticity literature ranging from understanding the complexity of the relationship between fares, ridership and other external forces, to the understanding that utilizing premium markets may also perhaps have a great influence on transit ridership. Such premium markets could take the form of luxury coaches with feeder and distribution service as well as wireless internet technologies on transit vehicles. The Riverside Transit Authority has experimented with such programs, and implementation into areas with higher transit utilization rates may yield surprisingly beneficial results.

Taking such variations of customer markets, regional differences in mode splits, demographics, growth rates, and severity of air quality problems into account should prove to be the most effective strategy. This strategy should tailor its air quality and passenger counting approach as necessary.

1. INTRODUCTION

1.1 Background

This project comes out of an interest in the variation in transportation related air quality strategies between air districts in the Los Angeles metropolitan area, San Francisco Bay Area, and Washington, D.C. area. While the Bay Area Spare the Air/Free Morning Commute program funds free transit during days expected to exceed air quality levels, the Los Angeles region focuses on an overall automobile trip reduction strategy throughout the year. The Washington D.C. area also funds free transit on days predicted to exceed healthy air quality levels, known as the Code Red Air Quality Alert program. These two programs are the only known free transit related air quality programs nationwide.

The research herein will focus on three goals. The first is to lay out the goals of the Bay Area's free transit Spare the Air/Free Morning Commute program and examine the program evaluation in order to determine how these goals are evaluated by the Metropolitan Transportation Commission (MTC), the regional transportation planning agency. The second goal is to inform the current Spare the Air/Free Morning Commute program of its costs and benefits compared to Los Angeles and Washington, D.C. regional air quality strategies. The final goal is to determine how to better monitor the effectiveness of the Spare the Air program through determining appropriate ridership counting and analysis methodologies for each of the 21 participating operators. Additionally, a literature review of travel behavior in regards to fare changes will examine elasticity in all three regions in attempt to determine regional responsiveness to transit price reduction.

1.2. Air Quality Background

Ozone, found naturally in the stratosphere is a beneficial gas which blocks out ultraviolet light. At ground levels however, ozone acts as a harmful agent. Ground level ozone is formed primarily from nitrogen oxides (NOX) and volatile organic compounds (VOCs), while carbon monoxide also contributes to formation.[1] Unusually hot days and stagnant wind contribute to ozone by "cooking" the ingredients forming the ozone molecule O_3. California ozone standards are 0.09 parts per million (ppm) for 1-hour levels, while the 8-hour standard is 0.07 ppm.[2] The federal 1-hour standard has been revoked as of June 15, 2005 out of concern that it does not adequately offer health protection due to the fact that much risk is from multi-hour exposures. The federal 8-hour standard is 0.08 ppm. 1-hour standards are geared primarily towards peak exceedances in urban areas, while the 8-hour standard is more focused on downwind lower density foothill areas.[3] Just why the California 8-hour standard is more stringent is explained below.

[1] San Joaquin Valley Air Quality Management District. 2005. "Ozone Definition." Online Access: <http://www.valleyair.org/Air_Quality_Plans/AQ_plans_Ozone_definition.htm>
[2] SCAG. 2005. "SCAG Preliminary Draft Air Quality Chapter." Los Angeles, CA: SCAG.
[3] California Air Resources Board. 2000. "Final: Recommended Area Designations for the Federal 8-hour Ozone Standard." Sacramento, CA: CARB. Pg. 6.

Federal and State Clean Air Act

The Federal Clean Air Act was established in 1963, setting up regulations that enforced acceptable air quality levels. In 1969 the first State Ambient Air Quality Standards were established in California. In 1988 the California Clean Air Act was passed, setting a 20 year framework for air quality in the state. The Act requires attainment of the state ambient air quality standards by the "earliest practicable date." Those regions not in attainment were required to submit their attainment plans by July 1991.[4] Plans were supposed to reduce NOX and VOC 15% and 55% by 2001 respectively. Authority was given to ARB and the air districts to aid in meeting these goals. California standards are the only exemption allowed by the federal government where federal standards are superceded by state standards. Such is the result of extensive lobbying, which granted California the role as national testing ground for stringent emissions controls, despite concerns that uncoordinated state standards would result in confusion for automobile manufacturers and dealers as well as consumers. Amendments to the federal Air Quality Act in 1990 established a five category system for evaluating various attainment areas which corresponded to the severity of the ozone problem. Those areas with higher air quality problems were also given more time to fix the problem. The South Coast Basin in the Los Angeles area was the only "extreme" non-attainment area and was given until 2010 to be in attainment.[5]

California Air Resources Board

The California Air Resources Board (ARB) was formed in 1967 through an act that merged the Bureau of Air Sanitation and the Motor Vehicle Pollution Control Board. ARB has set the state standard for ambient air quality, for motor vehicle emissions, and gasoline pollution-forming chemicals levels. Notable automobile ARB regulations attempted to mandate a percentage of zero emission vehicles - 2% in 1998 and 10% in 2003. ARB also mandated the three-way catalyst in 1975 and its precursor, the two-way catalyst in 1973, along with exhaust gas recirculation in 1970, and crankcase storage in 1969.[6] Such standards attempted to lower emissions for each new generation of vehicles, while also testing vehicles regularly. The utilization of catalytic converters, the elimination of lead in gasoline, and the utilization of vapor recovery technologies at gas stations are noted by scholars as the three major ARB accomplishments.[7] ARB standards of reactive organic gasses (ROG) differs from federal standards for VOCs in that the ARB ROG definition includes ethane while the federal definition does not. In all other cases the terms can be used interchangeably.[8]

---

[4] CAEPA. 2006. "California Clean Air Act Streamlining AB 3048." Sacramento, CA: California EPA.
[5] Hall, Jane. 1995. *The Automobile, Air Pollution Regulation and the Economy of Southern California: 1965-1990*. Fullterton, CA: Institute for Economic and Environmental Studies at Cal State Fullerton. Pg. 28-32.
[6] Hall, Jane. *Ibid*, pg. 18-19.
[7] Hall, Jane. *Ibid.*, pg. 33.
[8] CARB. 2004. "Definitions of VOC and ROG." Online Access: <http://www.arb.ca.gov/ei/speciate/voc_rog_dfn_11_04.pdf>

Air Quality Management in Washington, D.C.
In the national capital region air quality is regulated by the Metropolitan Washington Air Quality Committee (MWAQC), which was created through the Clean Air Act 1990 Amendments. As with all air quality districts, they were required to submit their ozone attainment plan by 1994 to indicate how air quality was to be improved by 1999. The region however missed the deadline, but was given a six-year extension from the EPA.[9] In May of 2005 the EPA finally approved the 1-hour ozone plans for Virginia and the District of Columbia but disapproved the Maryland plan. While as of 2005 the 1-hour federal standard has been scrapped, the 8-hour ozone standard remains in effect. The new deadline for MWAQC is June 2010 in order to meet these 8-hour ozone standards.

1.3. The Regions

Three major regions from around the country were selected for this comparative exercise. They were selected based on the following criteria: (1) proximity to the San Francisco Bay Area, (2) severity of air quality exceedances, and (3) existence of Spare the Air and air quality related free commute programs. Two regions are in California while the third is the Washington, D.C. metropolitan area. These regions are governed by a variety of authorities responsible for planning and financing air quality conformance. Such differences are illustrated in Table 1: Governing Authorities and Extent of Jurisdictions.

San Francisco Bay Area air quality is monitored by the Bay Area Air Quality Management District (BAAQMD), which is in part funded by the Metropolitan Transportation Commission (MTC). The Association of Bay Area Governments is involved in so far as they provide population projections and regional census data. In Los Angeles the South Coast AQMD (SCAQMD) is the primary air quality control district for the region's six counties. The Southern California Association of Governments (SCAG) works in coordination with the SCAQMD on the "transportation strategy" and "transportation control measures" sections of the Air Quality Management Plan. In Washington, D.C. the primary air quality planning authority is the Metropolitan Washington Air Quality Committee Region and the National Capital Region Transportation Planning Board, both under the wing of the larger Metropolitan Washington Council of Governments planning authority. These areas do not include the Baltimore Metropolitan Council (BMC) area, which is included in the Census designated CMSA Washington, D.C. area but not the MSA area. Certain aspects of this paper however will discuss the CMSA region since the Los Angeles and San Francisco CMSA regions are discussed throughout.

While the air district and regional planning authority boundaries do not always exactly align, these differences will be for the most part ignored in this comparative exercise. The main differences however will be noted, which indicate much of the time that the air district boundaries are smaller than the regional planning boundaries. These main differences however will be noted as follows. The South Coast AQMD area is the entire

[9] Coalition for Smarter Growth. 2005. "D.C. Air Quality History." Washington, D.C.: Coalition for Smarter Growth. <http://www.smartergrowth.net/issues/air/history.html>

SCAG planning area with the exception of Ventura County which falls under the domain of the South Central Coast basin, and the three pieces of northern Los Angeles County, eastern Riverside and San Bernardino Counties, which collectively fall under the domain of the Mojave Desert basin (Appendix A). Central Riverside and all of Imperial County fall under the domain of the Salton Sea basin. In the Bay Area, the AQMD area contains all of the MTC nine county planning area with the exception of northern Sonoma County and northern Solano county, which are under the domain of the North Coast and the Sacramento Valley air basins (Appendix B). In Washington, D.C. the air district region contains the additional counties of Calvert as well as Stafford, while the National Capital Region Transportation Planning Board does not (Appendix C, Appendix D).

Table 1: Governing Authorities and Extent of Jurisdictions

Region	Governing Authorities	Counties / Cities
Los Angeles	-South Coast AQMD -Southern California Association of Governments	Counties: Los Angeles, Ventura, Orange, San Bernardino, Riverside, Imperial
San Francisco Bay Area	-Bay Area AQMD -Metropolitan Transportation Commission -Association of Bay Area Governments	Counties: San Francisco, Alameda, Contra Costa, San Mateo, Santa Clara, Marin, Solano, Sonoma
Washington, D.C.	-National Capital Region Transportation Planning Board -Metropolitan Washington Council of Governments - Metropolitan Washington Air Quality Committee Region	Counties: Frederick, Loudoun, Montgomery, Prince George, Prince William, Fairfax, Charles, Calvert, Stafford Cities: City of Fairfax, Manassas District: Washington, D.C.
Source: SCAQMD, SCAG, BAAQMD, MTC, NCRTPB, MWCOG		

1.4. Explanation of 2005 Spare the Air/Free Morning Commute Program: Results of July 26, 2005 Episode Document

GOALS AND STRATEGIES

Background

Spare the Air, while recently associated primarily with a free morning commute actually has been in existence since 1991. The program began as an educational program promoting voluntary changes in behavior during days predicted to exceed federal health standards. These changes included the encouragement of ridesharing, telecommuting, vanpooling, and transit use. Other suggestions to reduce air pollution included filling automobile gas tanks after sunset, abstaining from lawnmowers, and abstaining from barbeques. During the summer of 2004 the MTC began funding free morning transit the first five days expected to exceed federal 8-hour standard levels in any Bay Area location. The Spare the Air educational outreach activities continued as well. In total the AQMD has called 175 Spare the Air days, three of which funded free transit.

Goals

The MTC along with the BAAQMD and the 20 participating operators point out five goals of the Spare the Air/Free Morning Commute Program. These goals are the following:

1. Prevent federal and state ozone exceedances
2. Encourage commuters to drive less and use public transit more
3. Build transit ridership regionwide
4. Increase the public's knowledge of how to use public transit
5. Raise awareness of the Spare the Air campaign and the Spare the Air/Free Morning Commute Program.

The first goal aims to prevent both the 8-hour state level exceedance and the 1-hour federal exceedance levels. Compared to other regions the Bay Area has been quite successful having no 8-hour level exceedances in 2004 and one in 2005, and no 1-hour exceedances in 2004 and 2005. Whether these results are primarily due clean air programs or weather patterns is not clear, but Spare the Air has likely played a small role due to the fact that so few days have been issued.

By making transit free, the second goal, it is hoped that commuters will drive less and take public transit more frequently. This goal is targeted at commuters, which are assumed to be less transit dependent, and thus possibly influenced by free transit fares. Those agencies with the highest percent of commuters arriving at transit stations in single occupancy vehicles are the main focus – BART, Caltrain, ACE, Golden Gate Ferry, and Alameda Ferry.

Third, is the goal to build transit ridership not just in core areas where automobile trips are difficult to make, but in outer areas where the automobile is the dominant mode of transit. By converting the single occupancy driver category to transit significant air quality benefits can be reaped.

Fourth, fare free transit is also an attempt to show the public just which routes to take to get to their destinations so they may be able to repeat such transit trips in the future. This includes awareness of schedules, routes, transfers, fares, and payment methods.

Lastly, the goals of the program are to raise awareness of the existence of the Spare the Air program which not only aims to increase transit trips, but voluntary reductions in the use of polluting equipment on poor air quality days and general education on the relationship between air quality and pollution inducing behavior.

RESULTS

Air Quality and Ridership Results

The existing program evaluation document from 2005 examines the ridership from the single Spare the Air/Free Morning Commute occurrence for the 2005 season. The report discusses four main aspects. One deals with ridership and air quality based on ridership data obtained from the participating transit agencies. The second part of the report analyzes the results of the onboard survey, which looked at 1,174 surveys. The third part of the report looked at the results of the online survey. Forth, the report makes suggestions for future program analysis strategies.

Despite the limited data, the report attempts to provide insight on the change in ridership for each of the participating agencies, overall emissions reduced, and overall vehicle miles traveled (VMT) reduced. The total percent change in ridership was 6.7%, while total increase in ridership was 21,035 from the daily average 312,024 over the 4:00 a.m. to 9:00 a.m. period. Emissions reduced are estimated to be 0.049 tons of reactive organic gases (ROG) and 0.064 tons of nitrous oxides (NOX), both precursors to ozone. Total VMT reduced due to the increase in trips is estimated to be 64,270 miles.

The report also illustrates the conclusions from the onboard survey which discuss origins and destinations, Spare the Air day awareness, percent of new riders, and percent of riders expecting their use of transit to increase. Of all 1,174 completed surveys 85 percent were using transit for a work related trip. Of all respondents, 61 percent were aware that it was a Spare the Air day. About one third of riders learned of Spare the Air day through transit station advertising, nearly another third local television, and 30 percent local radio. The report also found that 77 percent of respondents typically take transit for their weekday work trips. Of all respondents, 25 percent indicated they expect their transit use to increase over the year. Lastly, the total number of new trips was 3.6 percent as reported.

The online survey also asked many of the same questions the onboard survey did, but unfortunately for the MTC only 80 surveys were completed. Although not statistically valid the results may still be of use since there is so little data on the Spare the Air days in general. The MTC reports that over half of online survey respondents reported taking transit over other modes. Respondents also had the opportunity to check of which changes would likely influence their use of transit. Cited most often was “more frequent service,” “lower transit fares,” and “free morning and evening Spare the Air commutes.” Bus advertisements were indicated as the primary source of Spare the Air awareness.

No conclusions were drawn about the effectiveness of the program due to the fact that only one occurrence was experienced. Future program evaluation suggestions were made as a way to propose additional performance objectives. All recommendations suggested a repeat of all techniques used in the 2005 evaluation with the exception that the online survey is uploaded immediately, instead of waiting a few days as was done in 2005. The recommendations also suggest the online survey only remain online for two to three weeks.

The 2004 summer saw two consecutive Spare the Air occurrences for the two participating operators – BART and LAVTA. Ridership for BART was estimated at a 16,000 and 24,000 increase – 5 percent the first day and 8 percent the second day - while LAVTA ridership was up 9 percent for the two day average. The fact that both days were in a row most likely contributed to the increase in ridership on the second day. The AQMD also reported that 24,000 signed up for email alerts, up by 50 percent from the prior year. AQMD survey results indicated a 12 percent reduction in driving and use of polluting equipment during the Spare the Air occurrences in 2004.[10]

The declaration of Spare the Air days is not void of a political milieu. In fact many have suggested that Spare the Air days are intentionally called on days when it is known that air quality levels will not be exceeded in order to show the effectiveness of the program. Calling two Spare the Air days in a row when the second day may not be forecasted to exceed standards is also another example of possible strategic forecasting.

Administrative Results

The MTC reported that all goals set out for the summer of 2005 were met. These goals included effective and timely coordination between MTC, the BAAQMD, and the transit agencies. Also, the MTC was satisfied with the level of coordination within agencies between the various departments including maintenance, operations, customer service, and dispatch. Media goals were met as illustrated by the cover page story and photo spread of Spare the Air in the region's most read newspaper, the *San Francisco Chronicle*. Additionally, the MTC learned that the best way for dissemination of Spare the Air alerts is "511," the region's transit and highway information system, which can be accessed through the Internet and over the phone. Complete reimbursement was also attained for all lost farebox revenue for the participating operators. Lastly, there were no exceedances of federal ozone standards on the Spare the Air day.

2. LITERATURE REVIEW: HISTORY AND GEOGRAPHIC COMPARISON

The following section highlights the history and reasoning behind each of the transportation related air quality efforts in the five regions, just whether or not such varying strategies are appropriate and most effective for each region. This section aims to

[10] AQMD. 2004."Bay Area's Summer Smog Season Closes on a Clean Note." San Francisco, CA: AQMD.

determine just why there are only two free transit related air quality improvement promotion programs in the country in order to later on determine if they are appropriate given their respective regional characteristics.

2.1 San Francisco Bay Area

Regional air plan responsibilities lie within three agencies – The MTC, the Bay Area AQMD, and the Association of Bay Area Governments. Two pertinent documents arise from AQMD planning efforts: (1) the Clean Air Plan, last updated in 2000 and (2) the Ozone Attainment Plan, last updated in 2001.[11] The main document produced by the MTC in order to gain federal funding is the long-range transportation plan, outlining approved projects for the next 25 years.

The MTC 2005 Transportation 2030 Plan, the long range transportation plan for the region, highlights four transportation related air quality "calls to action" pertinent to this paper. The first is Spare the Air, the second is the AQMD's Vehicle Buy-Back Program, which pays $650 for the purchase of vehicles older than 1985. The third is a bus/heavy duty vehicle emissions retrofit program. Last, is support of the California Air Resources Board's program to retrofit 1980-1994 automobiles by replacing the evaporative canister.

The San Francisco Bay Area Metropolitan Transportation Commission (MTC), the regional planning and financing planning organization, along with the Bay Area Air Quality Management District began the Spare the Air program 15 years ago in 1991 as an educational outreach program. Beginning in 2004 and continuing through 2005 the MTC began to fund up to five free morning transit commutes. At the time of the writing of this paper, two free morning commute summers have occurred. The first summer provided free transit for two operators - Bay Area Rapid Transit (BART) and the Livermore bus system, LAVTA. For 2005, the second summer of free commuting, the free morning commute was expanded to include BART along with 20 other rail, ferry, and bus operators.

Clean Air Plan
The Clean Air Plan is required to show a five percent reduction in ozone, yet no non-attainment area has done this so far.[12] The Ozone Attainment Plan, as demonstrated in the 2005 Ozone Strategy, explains how the Bay Area will be in conformity with the state 1-hour standard in containing stationary and mobile source emissions. Currently the region is not in attainment of this standard – 0.07 parts per million, which can happen when any station in the region crosses the threshold.[13] The California Clean Air Act (CCAA) requires the Clean Air Plan to address numerous goals, four of which are noteworthy:

- Implement feasibility measures as expeditiously as practicable

[11] Metropolitan Transportation Commission. 2005. Transportation 2030. Oakland, CA: MTC. pg 48.
[12] AQMD. 2005. Ozone Strategy Draft Volume 1. San Francisco, CA: AQMD. Pg. 10.
[13] Bay Area Air Quality Management District. 2005. "Bay Area 2005 Ozone Strategy Volume I: Draft September 2005." San Francisco, CA: BAAQMD. pg. 1.

- Adopt and implement best available retrofit control technology on all existing stationary sources as expeditiously as practicable
- Implement transportation control measures (TCM)
- Continue regional public education programs – Spare the Air, Bay Area clean Air Partnership, Clean Air Cities and Counties, Clean Air Consortium, youth campaigns, Smoking Vehicle Program

Most specifically are the TCMs, which detail transit related air quality improvement strategies. The strategies vary from focus on worksite, age, mode, innovation, and systems management. Nineteen are stated and explained in the Clean Air Plan.[14] They are as follows:

TCM 1: Support Voluntary Employer-Based Trip Reduction Programs
TCM 2: Improve Area Wide Transit Service
TCM 3: Improve Regional Rail Service
TCM 4: Improve Access to Rail and Ferries
TCM 5: Improve Intercity Rail Service
TCM 6: Improve Ferry Service
TCM 7: Construct Carpool/Express Bus Lanes on Freeways
TCM 8: Improve Bicycle Access and Facilities
TCM 9: Youth Transportation
TCM 10: Install Freeway/Arterial Metro Traffic Operations System
TCM 11: Improve Arterial Traffic Management
TCM 12: Transit Use Incentives
TCM 13: Improve Rideshare/Vanpool Service and Incentives
TCM 14: Local Clean Air Plans, Policies and Programs
TCM 15: Intermittent Control Measure/Public Education
TCM 16: Conduct Demonstration Projects
TCM 17: Transportation Pricing Reform
TCM 18: Pedestrian Travel
TCM 19: Promote Traffic Calming

These transportation control measures vary in their effectiveness, due to different costs, and different maximum achievable results. By far the lowest cost option for emissions reductions are Carl Moyer Program funded projects (Table 2), which focus on clean engine retrofitting in surface, on-road, off-road, agricultural pumping, airport ground support equipment, forklifts, and marine transit. One may ask why then are such less cost efficient programs even funded, such as the Vehicle Incentive Program (also Table 2), which funds purchasing and leasing of clean fuel vehicles at a cost of over 100 fold more per ton of pollution reduced than the Carl Moyer Program. Clearly, there are many objectives for each program, and while one may not perform so well on air quality, it may provide other benefits such as mobility, social equity, or congestion relief. Second most effective is the Vehicle Buy Back program which reduces pollution at a cost of $6,450 per ton. The Smoking Vehicle program is also relatively effective at $8,558 per ton. While not necessarily inherently bad programs, the Shuttle and Feeder Buses program,

[14] AQMD. 2005. Ozone Strategy Draft Volume 1. San Francisco, CA: AQMD. Pg. 38-42.

School Buses program, and Smart Growth programs all rank second, third, and fourth least effective in terms of air quality benefits of the total programs listed in Table 2. In terms of total tons removed, the Carl Moyer Program leads the way with 906 tons, followed by the vehicle buy back program with 582 tons, the trip reduction/ridesharing program with 239 tons, and arterial management with 167 tons. While these top four do not correspond to the top four least cost/ton programs, if the goal is total tons of pollution reduced and cost is not the main limiting factor, such programs are indeed effective.

Table 2: Funding and Emission Reductions from Incentive Programs for FY02/03[15]

	Cost	Tons	Cost/Ton
Smoking Vehicle	$522,008	61	$8,558
Vehicle Buy Back	$3,753,850	582	$6,450
Vehicle Incentive Program	$1,000,000	5	$200,000
Spare the Air	$667,690	23	$29,030
Lawnmower Buy Back	$158,800	6.7	$23,701
Trip Reduction/Ridesharing	$5,932,746	239	$24,823
Telecommuting (FY00/01)	$41,496	2	$20,748
Smart Growth	$995,186	34	$29,270
Arterial Management	$2,980,000	167	$17,844
Bicycle Facilities	$3,470,763	123	$28,218
Shuttle and Feeder Buses	$3,082,874	88	$35,033
Transit Buses	$1,463,370	58	$25,231
School Buses	$1,330,000	39	$34,103
Natural Gas Vehicles	$2,846,153	129	$22,063
Infrastructure for CNG	$375,615	NA	NA
Lower Emission School Bus	$3,172,852	127	$24,983
Carl Moyer Program (funds for clean engines)	$1,573,102	906	$1,736

*Emission reductions are total tons of ROG, NOX and PM combined over the life of the project.

2.2 Los Angeles

The South Coast Air Quality Management District (SCAQMD) oversees the air plan for most of Los Angeles County along with Orange County and western Riverside and San Bernardino Counties. The region does not fund free transit during expected air quality exceedance days and instead the SCAQMD has decided to focus on improving air quality not just on peak exceedance days, but as a whole with a long term strategy that emphasizes technological improvements in mobile source emissions, carpooling, and employee transit pass programs.

[15] Adapted from: Bay Area Air Quality Management District. 2005, *ibid*, pg. 37, Table 8.

Rule 2202 is one of the main regulations the SCAQMD administers over the Southern California region. This rule's purpose as stated is: "to provide employers with a menu of options to reduce mobile source emissions generated from employee commutes, to comply with federal and state Clean Air Act Requirements, Health and Safety Code Section 40458, and Section 182(d)(1)(B) of the federal Clean Air Act."[16] Rule 2202 applies to any employer with over 250 employees for a consecutive six month period. Employers must notify the SCAQMD within 30 days when they fall under the domain of Rule 2202.[17] As indicated by the SCAQMD only half of employers with over 250 employees actually participate in rideshare strategies. The other half of employers take advantage of a variety of other options allowing for the purchase of emission credits. One option that a significant number of employers participate in is the option to purchase credits at the cost of $60 per employee.[18]

More specifically the rule provides strategies for either emission reduction or trip reduction as illustrated in Table 3. Emissions reduction strategies can be achieved by a variety of on and off-road mobile sources, short term strategies, and credits gained through various activities. These activities can take the form of vehicle scrapping, clean on and off-road vehicles, and conversion to clean technologies for engines, heaters, and boilers.

Trip reduction strategies include reductions of trips during the peak period, and off-peak period, as well as ridesharing. The so called "Other Work-Related Trip Reductions" include reductions due to non-commute vehicle use, alterations of return trips home, using vehicles outside peak windows, utilization of non-regulated worksites, and utilization of contractors that participate in trip reduction programs. Vehicle Miles Traveled Programs include programs that reduce annual employee commute VMT such as from a relocation of the employment center, video-conferencing centers, and telecommuting centers. Employers may also utilize the parking cash-out program, which allows a cash allowance to employees, which equals the parking subsidy the employer normally pays to provide the parking space.

[16] South Coast AQMD. 2004. "Rule 2202 – On-Road Motor Vehicle Mitigation Options Implementation Guidelines" Diamond Bar, CA: SCAQMD.
[17] South Coast AQMD. 2004. "Rule 2202 – On-Road Motor Vehicle Mitigation Options." Diamond Bar, CA: SCAQMD.
[18] South Coast AQMD. 2005. *Personal Communication*. October 21st, 2005.

Table 3: SCAQMD Rule 2202 Emission and Trip Reduction Strategies

Emission Reduction Strategies	Trip Reduction Strategies
Clean On-Road Mobile Sources (Regulation XVI)	Peak Commute Trip Reductions
Clean Off-Road Mobile Sources (Regulation XVI)	Other Work-Related Trip Reductions
Pilot Credit Generation Programs	Vehicle Miles Traveled (VMT) Programs
Air Quality Investment Program	Off-Peak Commute Trip Reductions
Short Term Emission Reduction Credits (STERCs) From Stationary Sources (Regulation XIII)	
Area Source Credits (Regulation XXV)	
Source: South Coast AQMD. 2004. "Rule 2202 – On-Road Motor Vehicle Mitigation Options Implementation Guidelines" Diamond Bar, CA: SCAQMD.	

In addition to the SCAQMD, the Southern California Association of Governments (SCAG) is also involved in numerous air quality planning efforts, from determining whether or not the region is in conformity, to preparing both the Regional Transportation Plan (RTP) and Regional Transportation Improvement Plan (RTIP), to determining the appropriate transportation control measures, and preparing and approving parts of the SCAQMD's Air Quality Management Plan (AQMP). The Transportation Air Quality Conformity Determinations appear in the RTIP as well as in the RTP. These conformance determinations are necessary to ensure federal funding due to the Clean Air Act 176(c) (42 U.S.C. 7506(c)).[19] In March of 2005 SCAG determined the South Coast Basin to be an attainment area for the 8-hour Ozone Standard for the 2004 RTP and 2004 RTIP.

The Regional Comprehensive Plan Air Quality chapter also is another important duty of SCAG. It outlines SCAG's role in the region, identifies major sources of air pollution, and the effects of air pollution. The plan also outlines the roles of the SCAQMD and the California Air Resources Board (CARB), identifies outreach and educational efforts, and makes suggestions. The 1996 plan, the latest version, makes the following notable action pledges:

1. Jurisdictional Conflict: Minimize overlap of jurisdictions and air quality planning efforts (pg. 5-23)
2. Freight Movement: Utilize national and international standards (pg. 5-25)
3. Alternatives to Command and Control Regulation: Community-based shuttle services, VMT/emission fees, demand management programs (pg. 5-29)

[19] SCAG. 2006. "Air Quality Program." Los Angeles, CA: SCAG. Online Access: <http://www.scag.ca.gov/environment/airquality.htm>

4. Employer Rideshare Programs: Support current efforts, support alternatives to rideshare plans, evaluate cost-effectiveness of employer based air quality programs (pg. 5-33)

Such strategies although not exactly radical, represent the most progressive of all eleven calls to action. While critics may discredit the action pledges as vague, supportive of the status quo, lacking of large-scale alternatives, and ignorant of the possible mutual exclusivity of goals such as air quality and economy, proponents may argue that the vagueness allows for political innovation and that such innovation may circumvent previously thought conflicting goals. Much to the remaining action pledges support the broadly popular concepts perhaps lacking the necessary attention to the difficulties found in the particularities of each plan. Such broad concepts include supporting efficiency, pollution prevention, coordination, innovation, standards, monitoring, and cost-effectiveness.[20]

2.3 Washington, D.C.

In Washington, D.C. two agencies under the wing of the Metropolitan Washington Council of Governments are responsible for air quality planning. These are the Metropolitan Washington Air Quality Committee Region (MWAQC), the primary air quality planning agency, and the National Capital Region Transportation Planning Board (NCRTPB), the primary regional transportation planning agency that is required to maintain conformity for its projects. A Spare the Air type program funded through the Congestion Mitigation and Air Quality (CMAQ) program known as "Code Red Air Quality Action Days," is currently still funded for the Washington, D.C. metropolitan area. During Code Red days transit is free on most major bus lines with the exception of Metro bus, Metrorail, and commuter rail services.

MWAQC is responsible for preparing the State Implementation Plan, the air plan for the region. This plan highlights the various activities and their pollution reduction abilities. Policies range from vapor recovery nozzles, landfill regulations, and most importantly, transportation control measures. The MWAQC transportation control measures include alternative fuel vehicles, bicycle and pedestrian improvements, transit service improvement, and transit access improvement.[21]

The NCRTPB prepares plans and programs in order to obtain federal funds for projects. Members are comprised of local government representatives, state transportation agencies, and the MWATA ("Metro"). The agency is responsible for the Constrained Long-Range Transportation Plan (CLRP) and the Transportation Improvement Plan (TIP), listing projects funded for the future six years. Most pertinent from the CLRP is the section concerning transportation emission reduction measures (TERMs), which outline just how "excess emissions" for the region will be reduced. The list of TERMS is meticulously laid out over 50 pages for each of the states and the District of Columbia – from bridge enhancements, bus service expansion, CNG technology upgrades, taxi

[20] SCAG. 1996. "Regional Comprehensive Plan and Guide." Los Angeles, CA: SCAG.
[21] MWAQC. 2004. "Severe Area State Implementation Plan." Washington, D.C.: MWAQC. Pg. 7-66.

replacements, speed limit programs, Metrorail parking spaces, automatic vehicle locator systems, reverse commute programs, and bike racks.[22]

Similar to the Bay Area's Spare the Air program, air quality action days issue a color warning, successively getting worse from green (good), yellow (moderate), orange (unhealthy for sensitive groups), red (unhealthy), and purple (very unhealthy). On Code Red days (as well as Code Purple), transit is free for most of the region's buses with the exception of Washington, D.C. Neither the regional urban rail system, Metro, nor the commuter rail system are free on Code Red days. Ridership has thus far been inconclusive, as the most recent major program analysis in 2003 showed an actual decrease in 4.5% in ridership, which was attributed to lack of quality ridership data and external non-Code Red ridership pattern fluctuation.[23] Overall, data for 1999-2003 show a ridership reduction on average for all 29 code red days, thus an emissions gain. The remaining data used for the analysis was through a large phone survey of 300 households. Of these households 90 percent knew what Code Red meant and 17 percent indicated they took action.[24] During 2004 only one Code Red day was called, but due to the fact that it was on a weekend day, transit was not free. In 2005 data was scarce as well. One Code Red day occurred, but it was not forecasted and transit was not free on the unexpected occurrence.

2.4 Exceedance Days Compared

As indicated in Table 4, Los Angeles leads the three areas in both 8-hour and 1-hour exceedance days. In 2005 this lead is by 75 fold over the Bay Area, and over 4 fold over Washington, D.C. in terms of the 8-hour standard. Washington, D.C. and the Bay Area have reduced their exceedances to 0 in 2005 for the 1-hour standard, while Los Angeles remains at 27. While the Bay Area has recently trailed the District of Columbia in 8-hour exceedances, prior to 2001 it eclipsed Washington, D.C. 4 times out of 6 years. Washington D.C. and the Bay Area have also achieved the largest percent reductions in 8-hour violation days – an 85 percent reduction from highest to lowest annual exceedances in Washington, D.C. and a 100 percent reduction in the Bay Area. Los Angeles achieved a 43 percent reduction from its highest annual exceedance year to lowest exceedance year for the 8-hour standard. For 1-hour exceedance reductions both Washington, D.C. and the Bay area achieved 100 percent reductions, while Los Angeles achieved a 72 percent reduction from highest annual total exceedance days to lowest.

In terms of absolute reductions since 1995, Los Angeles leads the pack with a 52 day exceedance reduction for the 8-hour standard and a 71 day reduction for the 1-hour standard. Washington D.C. reduced its number of 8-hour exceedances by 10, and 8-hour exceedances by 6, while the Bay Area reduced its exceedance days by 17 and 11

[22] MWAQC. 2002. "Air Quality Conformity Analysis 2002 CLRP."
[23] Northern Virginia Transportation Commission. 2003. ""Effectiveness of Free Bus Fares on Forecast Air Quality Code Red Days." NVTC: Arlington, VA.
[24] MWAQC. 2004. "Severe Area State Implementation Plan." Washington, D.C.: MWAQC. Pg. 11-51, 11-52.

respectively. Across the 10 year period Washington, D.C. shows the most variation in 8-hour exceedance days, indicating that perhaps the trend line is not declining on the whole.

Table 4: Ozone 8-Hour and 1-Hour Federal Exceedance Days

	8-Hour Federal Exceedance Days			1-Hour Federal Exceedance Days		
	Washington, D.C.	**South Coast AQMD**	**Bay Area AQMD**	**Washington, D.C.**	**South Coast AQMD**	**Bay Area AQMD**
1995	29	127	18	6	98	11
1996	18	132	14	1	90	8
1997	29	127	0	6	68	0
1998	47	111	16	6	62	8
1999	39	113	9	7	41	3
2000	10	111	4	2	40	3
2001	24	100	7	3	36	1
2002	38	99	7	9	49	2
2003	7	120	7	3	68	1
2004	7	90	0	2	28	0
2005	19	75	1	0	27	0
TOTAL	**267**	**1205**	**83**	**45**	**607**	**37**

SOURCE: SF Bay Area and Los Angeles: California Air Resources Board: http://www.arb.ca.gov
Washington DC: Metropolitan Washington Council of Governments: http://www.mwcog.org/environment/air/data/

2.5 Downtown Job Share Compared

Using the assumption that downtown jobs are the most transit accessible, and most likely to be utilized on free transit days, an attempt to determine just how many jobs are available in each of the three metropolitan areas is made in Table 5. On average the San Francisco CMSA contains the largest amount of total jobs in its downtown areas – 12.5 percent, while the Washington, D.C CMSA contains the second most – 11.3 percent, followed last by the Los Angeles CMSA at 6.4 percent. Both the San Francisco CMSA and Washington, D.C. CMSA contain nearly twice as many jobs in their downtown areas than the Los Angeles CMSA. The total San Francisco CMSA contains approximately 10 percent more jobs than the Washington, D.C. CMSA in its downtown.

Table 5 also indicates that in all three CMSAs, the primary downtown contains nearly all of the downtown jobs – 75 percent for downtown San Francisco, 91 percent for downtown Los Angeles, and 81 percent for downtown Washington, D.C. In total for all three CMSAs secondary employment centers account for 18.0 percent of all downtown jobs.

Although these percentage of employment statistics do not include other smaller secondary and tertiary employment centers, significant employment centers around other rail transit stations in the three respective systems, and automobile centric edge cities such as Tyson's Corners in Washington, D.C., Century City in Los Angeles, and Pleasant Hill in the San Francisco Bay Area, the estimate shows areas best targeted for free transit promotions are the primary downtowns in all three regions. If we are to decide between regions, more weight should be given for a Spare the Air program in San Francisco and Washington, D.C. than in Los Angeles. These suggestions align themselves well with the policy realities where free transit programs are in fact in existence in the San Francisco and Washington, D.C. CMSAs.

Table 5: Downtown Job Share

	Downtown Jobs	**Percent of Region**
San Francisco Bay CMSA	**3,416,100**[1]	**100%**
San Francisco	320,300 [1]	9.4%
Oakland	63,200 [1]	1.9%
San Jose	44,200 [1]	1.3%
Total Downtown Jobs	427,700	12.5%
Los Angeles CMSA	**6,792,619**	**100%**
Los Angeles	393,000[2]	5.8%
Pasadena	28,000 [3]	0.4%
Long Beach	14,000 [4]	0.2%
Total Downtown Jobs	435,000	6.4%
Washington, D.C-Baltimore CMSA	**4,147,419**	**100%**
Washington, D.C.	378,700 [5]	9.1%
Baltimore	90,000 [6]	2.2%
Total Downtown Jobs	468,700	11.3%

Notes
[1]MTC. Commuting to Downtown Highlights. Online Access: <http://www.mtc.ca.gov/maps_and_data/datamart/census/ctpp2000/>
[2] Guiliano, Genevieve. 2004. Impacts of Transportation Investments, from *The Geography of Urban Transportation.* pg. 248.
[3] City of Pasadena. 2006. "Demographic Statistics." http://www.ci.pasadena.ca.us/statistics.asp.
[4] Downtown Long Beach Associates. 2006. "Downtown Long Beach Business and Market Information."
[5] Downtown D.C. BID. "2004 State of Downtown Annual Report." Washington, D.C.: Downtown DC Business Improvement District.
[6] Downtown Partnership of Baltimore. 2006. "Downtown Economy at a Glance." Baltimore, MD: Downtown Partnership of Baltimore. Online Access: <http://www.godowntownbaltimore.com/economy.html>

2.6 Transit, Spare the Air/Code Red Occurrences, and Population Compared

Table 6 examines the details among the metropolitan area for population, transit use, 1-hour and 8-hour exceedance days, miles of rail transit, miles of freeways and arterials, vehicles, total vehicle trips, and average auto occupancy. Such differences in transit, transportation, and population can help to shed light on why certain areas chose different air quality strategies as well as which strategies we may wish to advise on.

Los Angeles leads the three regions in population, air quality exceedances, miles of commuter rail, urbanized area, freeway and arterial miles, vehicles, total vehicle trips, as well as average vehicle occupancy. In comparison to San Francisco, Los Angeles had almost 15 times more exceedances in total for the 8-hour standard and over 16 times more exceedances for the 1-hour standard. In comparison with Washington, D.C., Los Angeles experienced over 4 times the exceedances for the 8-hour standard and over 13 times for the 1-hour standard. Such exceedances are no doubt related to the significant higher number of daily vehicle trips, region size, mountainous geography, and relatively decentralized commute patterns. Comparing urbanized area, Los Angeles is over 2 times larger than San Francisco and 25 percent larger than Washington, D.C. Comparing rail transit miles may seem simple at first, however the extensive Los Angeles commuter rail system serves just 40,000 trips per week day. Comparing urban rail however is more insightful, showing Los Angeles falling behind both other urban areas in mile size and daily ridership. Los Angeles rail ridership is nearly 250,000 while San Francisco urban rail approaches 470,000 using a rough estimate (BART – 310,000; Muni rail– 150,000; VTA – 20,000) and Washington D.C. rail approaches 775,000 (Metro – 700,000; Baltimore MTA – 75,000). Despite somewhat similar miles in the primary heavy rail systems (LA Metro, BART, DC Metrorail) Los Angeles is still outdone in ridership significantly. Los Angeles leads all three regions in average automobile occupancy, primarily due to the AQMD's regulation 2202, mandating ridesharing programs for businesses over 250, but also likely due to an growing carpool lane network of 664 lane miles.[25]

Washington D.C. was well over San Francisco for total 8-hour exceedances – over 3 times the amount, while just slightly more for 1-hour exceedances – 20 percent. The capital region was almost double San Francisco for urbanized area, perhaps related to the lower densities at which east coast urban areas sprawl. While the Washington D.C. urban rail equivalent Metrorail more than doubled BART ridership, overall urban rail ridership was 60 percent higher when taking into account San Francisco Muni rail and VTA rail. When looking at arterials and freeways, the Washington D.C. and the Baltimore MSA total approximately 23,200 freeway and arterial miles, roughly the same number as the San Francisco CMSA (21,400 miles). The Los Angeles CMSA has approximately 75 percent more arterials and freeway miles than the capital region.

[25] SCAG. 2004. "Regional High Occupancy Lane Study." Los Angeles, CA: SCAG.

The San Francisco Bay Area CMSA is smallest in population, but not far behind the capital region. The Bay Area also has the fewest exceedances for both 1-hour and 8-hour standards, related to many factors including coastal geography and smaller population. The Bay Area while behind the national capital in transit ridership, is ahead of Los Angeles, largely as a result of geographical constraints limiting the spread of downtown San Francisco, while downtown Los Angeles' landlocked beginnings provided no constraints to increase employment and population density. Commuter rail use in the Bay Area (Caltrain – 28,000; ACE – 1,300) was close to Los Angeles (MetroLink – 40,000), yet the Bay Area comprises less than 50 percent of Los Angeles' population.[26]

[26] Although Caltrain operates in an urban setting and is utilized by many as an urban short distance rail service, for simplicity this analysis will define Caltrain as commuter rail due to its bi-level rolling stock, limit hours of operation, higher fares, generally upper income ridership, and most importantly operation under contract by Amtrak.

Table 6: Air Basin Characteristics: Population, Transit Use, Spare the Air/Code Red Occurrences

	San Francisco-Oakland-San Jose CMSA	**Los Angeles -Riverside – Orange County CMSA**	**Washington, D.C. – Baltimore CMSA**
Population	7,039,362	16,373,645	7,608,070
Weekday Work Trip Transit Use	10.9%	4.5%	14%
Total Federal One Hour Exceedances (1995 - 2005)	37	607	45
Total Federal Eight Hour Exceedances (1995- 2005)	83	1205	267
Miles of Rail Transit / Urbanized Square Miles	849 urbanized square miles (MTC) 1,435 urbanized square miles (2000 Census) 100 BART Miles 41 SF Muni Miles 31 VTA Miles 77 Caltrain Miles 86 ACE Miles	3,049 urbanized square miles (2000 Census) 512 Metrolink Commuter Rail miles 73.1 Metro Rail miles	2,434 urbanized square miles (2000 Census) 81 VRE commuter rail miles 106 MARC commuter rail miles 106 DC Metro miles 45 Baltimore MTA rail miles
Miles of Freeways	1,400	9,000	Freeways + Arterial Total: 12,500 D.C. MSA 10,700 Baltimore MSA
Miles of arterials	21,400	32,600	
Spare the Air Days 2005	1	NA	1 [1]
Spare the Air Days 2004	2	NA	1 [2]
Vehicles	4,330,000	8,500,000	3,800,000 D.C. MSA NA Baltimore MSA
Total Vehicle Trips	17,640,000	56,000,000	13,800,000 D.C. MSA NA Baltimore MSA
Average Auto Occupancy (Home based work trips)	1.10	1.19	1.13

Sources: MTC Transportation 2030 Plan; Washington, D.C. Metro Population from: LRP pg. 3-7, 5-5; TAMU
[1] Not forecasted but code red levels attained. No free transit.
[2] Weekend Day. No free transit.

3. FARE ELASTICITY AND TRAVEL BEHAVIOR

3.1 Background

In a recent TRB publication, McCollom and Pratt (2004) examine elasticity as it relates to mode, city size, and service area.[27] McCollom and Pratt show that on average fare elasticity is –0.4, that is, a 10% increase in fares results in a 4.0% decrease in ridership (8). For the Bay Area, data is available for BART from a 1988 study indicating elasticity of -0.31, which the authors point out is twice as large as other heavy rail systems. This is explained by McCollom and Pratt due to the fact that much of BART is paralleled by freeway and freeway flyer bus service (12-11). Also much of the literature reports that as city size increases, price sensitivity decreases. As city size increases from under 500,000 to over 5000,000, to over 1,000,000, fare sensitivity decreases from –0.35, to -0.30, to –0.24, respectively (12-13).

The authors then go on to discuss the federally funded programs that tested free transit during the 1970s. Due to fiscal constraints, many of these programs were eliminated. The American Public Transit Association however has records of over 50 cases where fare free transit programs are in effect from central business district promotions, local service promotions, university fare free programs, and free feeder systems. As of 1999 nearly all of the catalogued services are bus transit, with the exception of four that are light rail (31). For these cases - off-peak and peak times, CBD and non-CBD services, student and senior citizen based programs – the average elasticity was determined to be –0.32. Programs outside the CBD not surprisingly were found to have lower elasticities, where alternatives such as walking are not as viable. By length, the literature shows that (32).

Cervero (1990) has also contributed to the elasticity literature, pointing out that transit ridership is largely a function of fares, service and automobile characteristics (117).[28] While fares have risen slightly faster than the consumer price index it is also difficult to isolate effects of fare change on ridership (118, 121). Using the often cited Simpson-Curtin Rule from 1968 elasticity is accepted by many to be -0.33. This was based on study of 77 cases over a 20 year period (122). Simpson-Curtin has its limits, where at higher points on the demand curve there are cut off points. More and more are priced off the system up until a sort of breaking point at $2.00 ($3.04 in adjusted 2006 dollars).

Cervero moves on to discusses submarkets – those with cars, those without cars, and the various populations within these groups who respond to fare changes and service changes differently. Perhaps obvious to many, but still important in order to lay out elasticity principle, the paper points out that those with cars are less sensitive to fare changes (124). Such a lesson is applicable to Spare the Air with its goals marketing to automobile commuters from the suburbs in order to influence long term travel behavior. Peak period

[27] McCollom, Brian E. and Richard Pratt. 2004. “Transit Pricing and Fares.” *TCRP Report 95.* Washington, D.C.: Transportation Review Board.
[28] Cervero, Robert. 1990. “Transit Pricing Research.” *Transportation* 17, 2: 117-140.

elasticities are less sensitive: -0.268 compared to –0.667 for off-peak, which is intuitive since automobile trips are more difficult during peak periods and peak period trips are generally work related, thus more essential (129).

Also of significance for Spare the Air are the lessons learned from free fare promotions in Trenton, NJ and Denver, CO, which eliminated midday fares in the 1970s. Overall the literature Cervero cites concludes that the benefits did not outweigh the negatives. Scheduling was more difficult due to uncertainty with passenger loads, there were more confrontations with drivers, more “incidences of rowdyism,” and little congestion relief (130). Although midday fare elimination is not exactly the same as the Spare the Air morning commuter demographic, the elements of uncertainty in operations certainly is relevant.

Cervero concludes that service improvements correlate with higher ridership more so than fare reductions. By tailoring to submarkets, ridership gains can be achieved, since some want premium services and are willing to pay. We should focus on what the market literature refers to as the “3 P’s” – product, price, promotion: appropriately tailored products, adequate prices to maintain service, and promotion through marketing (135-136).

Many of the UMTA demonstration programs in the 1970s were presented in a report of 41 case studies in fare free and fare reduction programs while they were still in operation.[29] As part of the Service and Methods Demonstration Programs, the report aims unfortunately not to attempt to draw conclusions but to highlight the details of each case study. The report still however contains useful overall findings. In these findings, operators viewed the fare free and fare reduction programs as success mainly because most were still in operation, which is a result of either agency or public support. Operators also viewed these programs successful because they met their goals of mobility enhancement, increased public image of transit, air pollution reduction, congestion relief, social equity, CBD retail stimulation, and increased ridership. Fare reductions overall lead to increased ridership, but revenue however was not increased. Perhaps most interestingly, in the methodology guidelines, UMTA chose to omit programs that were temporary fare cuts, which would have eliminated Spare the Air, had it been around at the time. These temporary programs were viewed as of “marginal interest.” Perhaps also because of the unreliability of data, something current Spare the Air and Code Red programs are restrained by, temporary fare reduction programs were omitted.

Cervero and Wachs, et al (1980) discuss the efficiency and equity implications of various fare policies in order to determine whether or not variations in fares pay for the variations in vehicle revenue service hours.[30] While such research mainly focuses on flat fares, it does yield insight into the theoretical issues of transit pricing theory and alternative pricing concepts, along with providing elasticities for the Southern California Rapid Transit District (now, Los Angeles MTA) and AC Transit. Defining elasticity as “the

[29] UMTA. 1977. Low-Fare and Fare-Free Transit. Washington, D.C.: DOT.
[30] Cervero, Robert and Wachs, Martin, et al. 1980. Efficiency and Equity Implications of Alternative Transit Fare Policies. Los Angeles, CA: UCLA School of Architecture and Urban Planning.

proportional change in transit demand resulting from and expressed as a proportion of change in price," Cervero and Wachs, et al illustrate the fare elasticities for the SCRTD and AC Transit as:

- SCRTD: -0.07 to - 0.15
- AC Transit: -0.15 to -0.25[31]

These estimates will be utilized later, while although possibly dated, they remain the most comprehensive available to date for the two systems.

As part of the wave of UMTA funded demonstration programs and studies in the 1970s Wachs (1973) examines fare free transit for the Los Angeles region.[32] By first providing a history of transit and urban form in the region leading up to the formation of the Southern California Rapid Transit District (SCRTD), Wachs lays out a mode choice model in order to provide a ridership estimate. Lastly Wachs offers up conclusions pertinent to short and long-range transportation policy as well as insight on the social, political and environmental impact of free transit. The environmental benefits of fare free transit are as follows:

- Significant environmental benefits should not be expected due to the fact that only 2.2% of trips in the Los Angeles region are by bus. (pg. 94)
- Even doubling ridership will not produce significant benefits (pg. 94)
- Environmental benefits can be reaped in cities where a significant proportion (31%) of trips are taken on public transit such as Chicago and Philadelphia (pg.94)

Wachs then concludes by stating fare free transit conflicts with the concept of improving transit for the region of Los Angeles (108). This is due to the fact that higher emphasis is placed on improving service than eliminating fare. Eliminating fares merely contributes to "aggravating …an already troubled political situation surrounding regional transit" due to the increasing fiscal constraints. Wachs further goes on to state that "[e]nvironmentally, the no fare issue has been shown to be essentially unattached to the clean air issue" (108). However, Wachs goes on to offer hope perhaps that if automobile trips can be reduced, that clean air benefits can be achieved by stating "the battle over clean air will remain squarely centered on the problem of reducing automobile emissions" (108). Although Spare the Air is a fare free program, its temporary nature may disqualify many criticisms of Wachs.

Another significant study in the Los Angeles region was undertaken by Wu (1984) concerning fare changes on ridership for the SCRTD.[33] Wu builds a model in order to examine variables such as sex, income and age on fare elasticity while also evaluating the average absolute percentage error (AAPE) comparing the modeling efforts to actual ridership data. Wu insightfully warns of the dangers of elasticity models because they do not take change into account, particularly change in socioeconomics. These external changes can highly influence transit use and ridership cannot be forecasted unless

---

[31] Cervero and Wachs et al, *ibid*, 1980. Pg. 118, 123.

[32] Wachs, Martin. 1973. "Feasibility of Fare-Free Transit for Los Angeles." Los Angeles, CA: UCLA School of Architecture and Urban Planning.

[33] Wu, Jenn-Chang. 1984. "Impact of Fare Change on Modeling and Forecasting Transit Patronage." Master's Thesis. Los Angeles, CA: UCLA Department of Architecture and Urban Planning.

elasticity data is appropriately updated (pg. 82). Wu also provides insight into the four different ways of calculating elasticity: (1) point elasticity – the measure of change at a point on the elasticity curve, (2) line elasticity – the measure of elasticity assuming change occurs along a straight line, (3) mid-point elasticity – a more refined version of the line elasticity used for prices falling significantly on a curve, and (4) arc elasticity – a measure of a constant point elasticity using a logarithmic formula which performs better for rising prices but worse than the mid-point formula for falling prices (pg. 40-41). If more technical analysis were to be done, the mid-point elasticity would be used, due to the fact that the focus of this paper is the ridership increase due to falling prices.

3.2 Los Angeles Fare Sensitivity

While ridership continued to decline in many areas around the country since the end of World War II (although prior to war rationing efforts nearly all sources indicate an already declining trend) in the 1980s Los Angeles experienced something much different, due to a drop in fares funded from the Proposition A half-cent sales tax. Due almost entirely to the fare drop from $0.85 to $0.50 over this period from fiscal year 1983 up until fiscal year 1986 ridership increased a total of 40 percent.[34] This experiment, one of the only major fare reduction attempts in the country, provides hard evidence that fares do play an important role in transit ridership.

In terms of elasticities, Cervero estimates that the SCRTD elasticity is somewhere between -0.07 and - 0.15.[35] Wu, however estimates overall elasticity to be -0.031, while perhaps more equivalent to rail: freeway fliers at -12.47 and express multi-stop at –1.24.[36] The 1983 fare drop of 41 percent represented a ridership increase of 40 percent, thus in this case, elasticity was –1.02.

The UCLA Lewis Center also yields insight on fare sensitivity showing that major reasons individuals in Southern California do not use transit are as follows:

- High Fares: 2.0 percent
- Lack of frequent service: 11.2 percent
- Takes too long: 15.6 percent
- Established routes do not meet travel destinations: 27 percent
- Safety: 3.9 percent[37]

Perhaps not surprisingly for Southern California, fares are low in the list because transit in the mind of many commuters is just not a practical option in terms of time (15.6 percent), poor service (11.2 percent), and poor routing (27 percent). Although transit service may be an absolute last option, the fact that a transfer is probably necessary, along with a wait time, and the uncertainty of the route also no doubt play a significant

[34] Rubin, Thomas and James E. Moore II. 1997. “Better Transportation Alternatives for Los Angeles.” *Reason Policy Study No. 232.* Los Angeles, CA: Reason.
[35] Cervero and Wachs et al, *ibid*,, pg. 123.
[36] Wu, *ibid*, pg. 47
[37] Haselhoff, Kim and Paul Ong. 2005. Southern California Survey 2005. Los Angeles, CA: UCLA Ralph and Goldy Lewis Center for Regional Policy Studies.

role in the low use of transit where nearly all trips are in the car (77.1 percent solo drivers and 12.9 percent carpool trips).

3.3 D.C. Area Fare Sensitivity

Surprisingly little research into elasticity exists in the capital region. Over the various operators and modes in the national capital region elasticity no doubt varies. Recent estimates from the Washington Metropolitan Area Transportation Authority (WMATA) indicate that fare elasticity was "apparently close to zero," as indicated in 2002 by a 4 percent increase in ridership despite a fare hike. Also related to this ridership increase however was the economic growth the region experienced, the opening of new rail stations, and new customer service initiatives.[38] If this zero elasticity is the case, the capital area would be least sensitive to fare change of all three areas. Some estimates indicate elasticity in a more theoretical vacuum where responsiveness to fares alone is measured is –0.22 for Metrorail.[39] In Baltimore the literature indicates bus work trip elasticity is –0.09, however the study is from 1978.[40]

3.4 Bay Area Fare Sensitivity

Compared to Los Angeles, elasticity in the Bay Area is more sensitive to fare change, likely due to lower poverty and to more transit-friendly urban form concentrations of employment and residences. According to Cervero (1980) AC Transit elasticity is -0.15 to -0.25 (123) while Cervero (1990) indicates BART elasticity is –0.31. The higher BART elasticity is again attributed to the existence of parallel highways for many of the trips suitable for either automobile or freeway flier bus use. According to the San Francisco Muni Planning Department elasticity may very well be zero, as ridership results from the September 2005 fare hike (20%) indicate no reduction in trips.[41]

Spare the Air ridership indicated a –0.067 elasticity, which should be taken with a grain of salt due to the lack of comprehensive ridership data beyond one instance. If the Spare the Air promotion is defined as a 50% fare reduction as a result of morning only free transit, elasticity doubles to –0.134. A more detailed analysis may even identify the proportion of daily trips that were actually free to determine a more approximate fare reduction – as low as 25 to 30 percent – thus quadrupling or tripling elasticity estimates to –0.268 and –0.223 respectively.

If we are to only use Spare the Air ridership, fare elasticity estimates per operator is outlined in Table 7. Utilizing the various assumptions of the morning commuter ridership as 50 percent, 30 percent, and 25 percent of daily trips, we see the variations in elasticity estimates for a point elasticity as defined by Wu. Assuming a 50% share of daily ridership elasticities range from as low as –0.02 (VTA Bus) to as high as –0.78 (Benicia

---

[38] WMATA. 2005. "Monthly Financial Report Fiscal 2005." Washington, D.C: WMATA.
[39] Franklin, Robert and Kurtis Swope. 2002. "Demand for the Washington, D.C. Metrorail." *Work in Progress.* Annapolis, MD: United States Naval Academy.
[40] McCollom and Pratt, *ibid¸pg. 35*
[41] San Francisco Muni. 2006. *Personal Communication.* January 2006.

Transit). Assuming 30% ridership occurred in the morning hours, elasticity ranges from –0.033 (VTA Bus) to –1.1847 (Benicia Transit). Assuming morning ridership is 25% of daily ridership elasticity ranges from -0.04 (VTA Bus) to –1.436 (Benicia Transit). These assumptions do not include operators who experienced an actual decrease or flat-line in ridership on the Spare the Air occurrence.

Table 7: Fare Elasticity Among Bay Area Operators

	4 – 9 AM Baseline Ridership	Percent Increase	Elasticity (Point) – Assuming 50% Ridership	Elasticity (Point) – Assuming 30% Ridership	Elasticity (Point) Assuming 25% Ridership
ACE	1,345	1.3%	-0.026	-0.0429	-0.052
AC Transit	22,031	14.2%	-0.284	-0.4686	-0.568
Alameda Ferry	565	7.0%	-0.14	-0.231	-0.28
BART	103,216	0.0%	0	0	0
Benicia Transit	116	35.9%	-0.78	-1.1847	-1.436
Caltrain	2,992	5.2%	-0.14	-0.1716	-0.208
County Connection	3,720	0.4%	-0.08	-0.0132	-0.016
Dumbarton Express	386	-4.7%	0.094	0.1551	0.188
Golden Gate Bus	8,550	-6.0%	0.12	0.198	0.24
Golden Gate Ferry	1,885	15.5%	-0.31	-0.5115	-0.62
Muni	121,023	14.5%	-0.29	-0.4785	-0.58
Petaluma Transit	118	-20.0%	0.4	0.66	0.8
SamTrans	10,845	-3.8%	0.076	0.1254	0.152
Santa Rosa CityBus	1,666	9.4%	0.188	0.3102	0.376
Sonoma County Transit	1,390	-1.7%	0.034	0.0561	0.068
Tri Delta Transi[t]	2,857	5.5%	-0.11	-0.1815	-0.22
Union City Transit	1,268	9.2%	-0.184	-0.3036	-0.368
VTA Bus	25,183	1.0%	-0.02	-0.033	-0.04
VINE	306	3.6%	-0.072	-0.1188	-0.144
WestCat	862	4.1%	-0.082	-0.1353	-0.164
Wheels/LAVTA	1,704	2.9%	-0.058	-0.0957	-0.116

Source: MTC. 2005. “2005 Spare the Air/Free Morning Commute Program: Results of July 26, 2005 Episode.”

4. SAN FRANCISCO BAY AREA CURRENT RIDERSHIP COLLECTION, ANALYSIS, AND REPORTING METHODOLOGY

4.1 Existing Ridership Collection Methodology

Existing techniques of ridership collection range from onboard mechanical counts, hand counts, faregates, automated passenger counting (APC) technologies utilizing infrared and weight sensing counting techniques, and electronic registering farebox (ERF) technologies (Table 8). These techniques used varied by agency due to mainly agency size. The smallest agency, Benicia Transit utilized manual counts but so did the largest agency, San Francisco Muni.[42] APC technologies were only employed with Caltrain and some VTA vehicles, although some agencies are considering upgrading (Tri Delta Transit). A variety of agencies use ERF technologies ranging from very small agencies – VINE, medium small agencies – Alameda Ferry and Dumbarton Express, medium agencies - Santa Rosa, Sonoma County Transit, and Wheels/LAVTA, to the larger operators - AC Transit, County Connection, Golden Gate Bus, San Francisco Muni, SamTrans, and VTA Bus.

[42] Muni remains the exception however due to the fact that manual ridership counts were part of the Spare the Air plan in order to gain more precise data.

Table 8: Ridership Collection, Analysis, and Reporting Methodology for July 26, 2005 Spare the Air Occurrence

	Collection Methodology	Analysis Methodology	Reporting Methodology	FUTURE CHANGES
ACE	Manual	Average of Two Previous Tuesdays	Slower	ERF
AC Transit	Electronic Registering Farebox (ERF)	Cash receipts for month of July 2005.	Slower	
Alameda Ferry	Manual	Average of Two Previous Tuesdays	Slower	None
BART	Faregates	July 26, 2005 PM ridership; Comparable day is average of similar June A's home game days on June 14 and June 28, 2005.	Quicker	
Benicia Transit	Manual Count (clipboard)	Average of Two Previous Tuesdays	Quicker	None
Caltrain	APC	February 2005	Medium	
County Connection	ERF	Average of Two Previous Tuesdays	Medium	
Dumbarton Express	ERF	Average of Two Previous Tuesdays	Slower	
Golden Gate Bus	ERF	Average of Two Previous Tuesdays	Medium	
Golden Gate Ferry	ERF	Average of Two Previous Tuesdays	Medium	
Muni	Manual Count - 6 surveyed transit routes; ERF	August 16, 2005; 6 routes expanded to systemwide ridership	Medium	
Petaluma Transit	NA	Average of Two Previous Tuesdays	Medium	
SamTrans	ERF	Average of Two Previous Tuesdays	Medium	
SantaRosa CityBus	ERF	Average of Two Previous Tuesdays	Quicker	
Sonoma County Transit	ERF	Average of Two Previous Tuesdays	Medium	
Tri Delta Transi[t]	Manual	AM peak 2004-05 counts.	Medium	APC
Union City Transit	Manual handheld counter	Average of Two Previous Tuesdays	Medium	
VTA Bus	ERF, Some APC	Same Day of Week on Prior Week; 27.9% of daily ridership	Medium	
VINE	ERF	Average of Two Previous Tuesdays	Slower	
WestCat	NA	Average of Tuesdays in July 2005; 23% of daily ridership	Medium	
Wheels/LAVTA	ERF	Average of Two Previous Tuesdays; 23% of average daily ridership.	Medium	

Source: MTC. 2005. “2005 Spare the Air/Free Morning Commute Program: Results of July 26, 2005 Episode.”

4.2 Existing Ridership Analysis Methodology

Comparison Day Selection
Most operators – 14 of 21 - compared the Spare the Air occurrence to the average of the previous two Tuesdays ridership (Table 8). The remaining analysis methodologies were a mixed bag, comparing the July 26th ridership to: monthly averages of July (AC Transit), the two Tuesdays in June 2005 with A's games (BART), an average of February 2005 ridership (Caltrain), expanding passenger counts from 6 routes on Tuesday August 16th, 2005 to systemwide ridership (Muni), an average of a.m. 2004-2005 counts (Tri Delta Transit), the prior Tuesday ridership (VTA Bus), and all Tuesdays in July 2005 (WestCat).

Estimating AM Ridership
A variety of techniques were used to estimate the actual a.m. ridership as a result of the inability to actually measure it. Because BART had open faregates during the a.m. free period it decided to estimate the morning ridership using p.m. faregate data. Many other agencies – AC Transit, Caltrain, VTA, and WestCat estimated a.m. ridership by taking a percentage of a daily average. These percentages varied by agency due to differences in daily distribution of trips.

Expansion of Sample Counts
Other agencies used sample onboard surveys to attempt to get an estimate of average daily ridership. San Francisco Muni, the region's largest operator by ridership employed this method by surveying six routes nearly a month later on a Tuesday a.m. period. This ridership number was expanded to system wide ridership through application of a correction factor.

4.3 Existing Ridership Reporting and Quality Control Methodology

Existing ridership reporting largely depends on agency size and resources, method of passenger counting, and method of passenger counting analysis. Agencies smaller in size, but also smaller in resources are able to transmit ridership data relatively quickly (Benicia Transit, Petaluma Transit). Agencies with medium size budgets but exhibiting more advanced technologies were also able to provide ridership data relatively quickly (Santa Rosa CityBus). Large agencies were unable to provide quick turnaround due to a variety of factors from the highly politicized landscape around ridership (AC Transit), inability to have ridership counted and analyzed due to large amounts of data (VTA), the need for special onboard passenger counting day to approximate average ridership (Muni), and the need to examine past catalogues of ridership to find an appropriate comparison day (BART).

Various factors came into play with other agencies of medium size, which were unable to transmit ridership as fast as some of the other agencies. Alameda Ferries, a medium sized operator was plagued by staffing difficulties. County Connection, also a medium sized operator was hampered by data analysis difficulties and a lack of human resources to analyze the data. Dumbarton Express, another medium sized agency, was hindered by its lack of established internal structure due to its recent separation off from AC Transit and formation as a independent agency. Golden Gate bus was faced with difficulties of understaffing for its many roles as a bus and ferry service provider and bridge authority.

Both VINE and ACE, smaller sized agencies were hampered by staffing shortages. Both agencies had no prior experience with Spare the Air and were also likely unaccustomed to the new tasks of determining appropriate ridership comparison days by mining previous ridership data files.

5. PROPOSED SAN FRANCISCO BAY AREA RIDERSHIP COLLECTION, ANALYSIS, AND REPORTING METHODOLOGY

5.1 Background

Stern (1997) highlights fare collection policies, equipment, disputes, fare evasion, and fare change policies obtained by interviewing 18 U.S. transit agencies.[43] Of most importance for this project is the section on equipment. Stern makes a note that of all 67,000 buses in the national fleet, 55,000 are equipped with some type of GFI farebox (15). Clearly, nearly all systems seem to be headed toward the higher technology end of the passenger counting spectrum.

In "Passenger Counting Technologies and Procedures" Boyle (1998) provides significant insight on costs and organization of ridership data, frequency of ridership counts, and technologies.[44] Today a wide variety of counting techniques are in use – from paper and pencil, to handheld units, electronic fareboxes, automatic passenger counters, and smart cards. Boyle makes a number of conclusions of use for this paper. One is that procedures for counting ridership are usually more important than technology. Second is that technology upgrades are necessary, and it should be expected for more time and effort during initial implementation phases. Third, is that agencies can learn from one another though site visits. Fourth, is that customization of equipment usually results in failure. Fifth, senior management commitment is necessary. Sixth, the passenger counting system must be under constant supervision. Seventh and finally, due to new necessary relationships between departments at an agency, new responsibilities should be clarified among all concerned and interacting bodies (2-3).

Boyle also finds that 50 percent of agencies report daily counts, 33 percent report monthly counts, 48 percent of agencies calculate ridership from revenue totals (9), and 42 percent conduct complete counts (9). A variety of factoring and sampling techniques are used. Most agencies use multiple methods for sample counting – over two thirds use paper and pencil and two thirds also use fareboxes (10). Boyle then goes on to explain

---

[43] Stern, Richard. 1997. "Bus Transit Fare Collection Practices." *TCRP Synthesis 26.* Washington, D.C.: Transportation Research Board.
[44] Boyle, Daniel K. 1998. "Passenger Counting Technologies and Procedures." *TCRP Synthesis of Transit Practice 29.* Washington, D.C.: Transportation Research Board

benefits and drawbacks related to each of the four counting techniques which are first defined here:

(1) Manual Technologies – Pencil and paper or handheld units used vehicle operator or survey administrator counting boardings and alighting per stop.

(2) Electronic Registering Fareboxes – Farebox keeps track of total number of fares and at which stop they are inserted.

(3) Automatic Passenger Counting – Infrared beams and or weight sensitive treadle mats which count passengers as they board and alight a bus, record times at each stop, and providing disaggregate data.

(4) Smart Cards – Electronic fare cards that are usually swiped in front of a reader in order to register payment, which recalibrates fare balances using a radio frequency built in computer chip.

Table 9 details the benefits and drawbacks of the various passenger counting technologies Boyle examines. Manual technologies are cost effective in terms of technology costs, require little training, and are useful at measuring disaggregate levels of trips. Drawbacks are accuracy due to the either initial errors on the collection level or the reporting level. Manual technologies are highly labor intensive and thus costly due to the need for additional staff to ride the buses to track ridership.

Electronic Registering Fareboxes (ERFs) are able to provide data on the aggregate level, by route, trip and block, offer improved accuracy and reliability over manual technologies, and allow for the tracking of boardings by fare category. Their drawbacks are hardware and software problems, especially during the first few months of implementation, data accuracy during these times, and compliance on the part of the operator to use the equipment correctly.

Smart cards offer benefits in that they provide data down to the stop level and also allow for easier transit system integration and faster boarding. Their drawbacks are like other new technologies, difficulties at first especially with farebox and onboard equipment integration, along with data retrieval and software bugs.

Lastly, Automated Passenger Counting (APC) technologies offers benefits of detailed data collection, additional types of data such as boarding times, and cost savings. Drawbacks are again software and hardware problems, as well as data processing time.

Table 9: Passenger Counting Technologies: Benefits and Drawbacks

	Benefits	Drawbacks
Manual Technologies	1.Low capital expenditures 2.Useful at disaggregate levels 3.Does not require special technical knowledge	1. Accuracy and consistency of the data 2. Labor intensiveness of manual techniques 3. Reliability of the traffic checkers 4. Cost and consequent limitations on data collection resources.
Electronic Registering Fareboxes (ERFs)	1.Aggregate levels of data 2.Ability to count ridership by route, trip, block 3.Improved accuracy and reliability 4. Tracking of boardings by fare category	1. Mechanical/equipment problems 2. Operator compliance 3. Software problems 4. Accuracy of ridership data.
Smart Cards	1.Stop level data for passengers 2.System integration	1.Difficulties of integration with farebox and onboard equipment 2.Data retrieval difficulties 3.Software bugs
Automatic Passenger Counting (APC)	1.Detailed data collection 2.More types of data collection 3.Cost savings	1.Software bugs 2.Data processing can be time consuming 3.Hardware problems – equipment failure and durability of APC units
Source: Table created from Boyle (pg. 11-14)		

Boyle also discusses costs of the various passenger counting systems. As demonstrated in Table 10, APC systems use over three times less staff than the highest staff-intensive systems. ERF on average is second least costly using 15.7 staff on average, but not very far behind hand-held units and manual units which use 17.8 and 17.2 staff respectively. These also costs vary per agency size. In smaller sized agencies, APC is extremely less labor intensive than the most intensive– hand-held units – 23 times less in the cases Boyle researches. Staffing needs for APC jumps dramatically for medium and large agencies – an over fifteen and twenty fold increase respectively. Hand held units increase in labor needs the most on an absolute scale when transitioning from small to large sized agencies – over 32 more employees needed. This is contrasted with an absolute difference of 20, 21, and 6 for the remaining three types of passenger counting technologies. Clearly, hand-held units are not appropriate for large agencies, while APC is most appropriate for medium and smaller agencies, if costs are our only concern.

Table 10: Average and Median Number of Employees Assigned to Passenger Counting by Passenger Counting Technology

	Total		**Large Agencies**		**Medium Agencies**		**Small Agencies**	
Technology	Average	Median	Average	Median	Average	Median	Average	Median
Manual	17.2	10.5	23.2	23.9	16.4	8	2.8	2.8
Hand-held units	17.8	9	38.5	38.5	8.5	8.5	6.3	6.3
ERF	15.7	12	23.2	23.9	14.6	8	1.6	1.6
APC	5.1	4	6.5	6.5	5.5	4	0.3	0.3
All Systems	13.9	7	22.8	22	13	7	3.2	2.8
Source: Boyle, pg. 18.								

Many recent studies have examined regional system integration of standardized automated fare collection systems (Lobron 2003).[45] Lobron notes the difficulties of the transfer of "legacy systems," the necessity for cooperation in the region over fare levels, media formats, and cost-recovery methods, and the need to resolve regional financial issues (3). By modestly adjusting current technologies, agencies can transition their way from paper flash passes to more high technology approaches such as the smart card. Standardization can the eventually be achieved through the continued utilization of proven platforms (4).

Moving to the forefront of today's technologies, Chira-Chavala and Coifman (1996) investigate the impact of the smart card along the I-110 busway corridor in the Los Angeles area, the first smart card program of its kind in California.[46] They found that the smart card was well received by both operators and riders due to the convenience, speed, cost effectiveness of data collection, and reductions in driver stress. Across three transit agencies using the busway, 600 smart cards were distributed to assess their worth. Operating costs were found to be 34 percent lower for fare collection, on the high end, while somewhat similar to ordinary fare collection costs on the lower end. Boarding times were improved up to 150 percent compared to cash fares. Vehicle dwell times were roughly the same for both fare collection methods. Capital cost outlays for first-generation smart card technologies however are higher than the fare box, but with time the authors conclude costs should drop as technology prices drop and agencies become more familiar with the systems.

[45] Lobron, Richard. 2003. "Developing a Recommended Standard for Automated Fare Collection." *TCRP Research Results Digest 57*. Washington, D.C: TRB.
[46] Chira-Chavala, T. and B Coifman. 1996. "Impacts of Smart Cards on Transit Operators." Berkeley, CA: UC Berkeley Institute of Transportation Studies.

5.2 Proposed Ridership Collection Methodology

Clearly the literature indicates that there is no one sized fits all approach. The agencies in the Bay Area exhibit a variety of different daily ridership – some a few dozen, some a few dozen thousand each day. Proper ridership collection then must be tailored to operator based on the following criteria:

1. Daily Ridership

Smaller operators can and should use manual technologies, while larger agencies should generally avoid such technologies. Operating costs however are very minute for small operators using APC, so such technologies should be considered if budgets permit large capital cost outlay. The use of onboard counters on sample routes for larger operators is especially important since the top four operators comprise nearly all of the Bay Area's ridership.

2. Service Area

Depending on service area, different passenger counting techniques work better than others. For some agencies it is easier is it to count riders manually, especially if in the case of freeway fliers they are all dropped off at one location –the Transbay Terminal in San Francisco. Agencies with fewer stops are also more likely to be able to better count passengers, especially if manual counting technologies are all that is available.

3. Technology Available

While certain agencies already possess high technology passenger counting devices such as faregates, automatic passenger counting technology, and electronic registering fareboxes, many remain as simple as pencil and paper. Those agencies with faregates that register all exits should use existing technologies on Spare the Air occurrences. Those agencies with electronic ticket machine technologies should also utilize the available data. Agencies should also keep in mind that perhaps most importantly management commitment is necessary and over-customization can prove counter productive (Boyle). Currently Golden Gate Ferry is the only participating agency in the smart card "TransLink" program but AC Transit, Golden Gate Buses, MUNI and BART are expected to follow in chronological respective order. While smart card technologies offer much promise, their implementation ultimately depends on the ability for agencies to transition to higher technologies which are time tested proven platforms that work for all agencies (Lobron).

4. Mode of Service

As mode of service varies so does appropriate passenger counting technique. While more automated services are contained by boarding stations and terminals such as rail and ferry, street-level services such as bus and light rail often are not constrained by stations, faregates, and terminals. Those systems utilizing faregates should perhaps institute "dummy cards" for periods when faregates are open in order to register passenger counts. Those agencies with less restricted access – where passengers must interact with a vehicle driver - should consider upgrading to APC and ERF technologies where financial constraints are not present. Less restricted access agencies may also chose to consider redundant approaches in order to double check data.

5. Procedure
As Boyle indicates, more so than the technologies in place or anticipated, ridership collection is most accurate if procedure is outlined in a clear manner between vehicle operators, fleet managers and operations planners. Such considerations trump many other factors related to ridership collection since ultimately humans are the ones collecting the data.

5.3 Proposed Ridership Analysis Methodology

Ridership analysis is intricately tied to the technologies used to gather the ridership, as well as agency size and budget, and to the complexities of the travel patterns on a given operating system. Ridership analysis also depends on travel patterns that are affected by a variety of events, holidays, and institutional closings.

Attention should be paid to holidays especially if agencies utilize monthly averages or averages of one certain day of the week for an entire month. In the summer of 2005 agencies that included the first Tuesday of July in their baseline average ridership tended to lower their average ridership increase compared to other agencies (AC Transit, WestCat). This was because this Tuesday was part of July 4th weekend for many travelers, and had a lower ridership. In the future agencies should pay attention to fluctuations resulting from holidays and adjust appropriately which comparison days to use. Due to other special occurrences such as A's and Giants baseball games, where transit is utilized significantly (BART, Muni, Caltrain) as well as institutional calendar dates – the end of a college semester (Santa Rosa), the effects of these events on ridership should be monitored in order to correct for such occurrences.

Agencies should also use direct time of day comparison as much as possible in order to avoid having to recalibrate p.m. ridership to a.m. ridership (BART, A.C. Transit, etc.). This goal can be achieved by either hiring or coordinating with passenger survey counters (especially for large agencies), creating some sort of "dummy fare card" to register riders on buses and on rail, or further utilization of manual hand counters.

Some agencies only collect ridership information on a limited basis to construct their baseline estimates. The times of year these are collected sometimes have very different ridership numbers than summer months, as in the case of Caltrain February ridership estimates. Ideally, operators should prepare summer ridership estimates based on weekly counts throughout the summer. If fiscal constraints prevent this, seasonal correction factors should be utilized. Correction factors taking into account general trends of either increasing or decreasing ridership should also be employed.

Operators should strive to utilize average ridership estimates from no further than a month before or after the Spare the Air occurrence. Some operators indicated they used a baseline of multiple years of ridership data (Tri Delta Transit). Such a technique avoids seasonal variation and provides a distorted view of average ridership higher than it most likely was due to the fact that summers are lower than the rest of the year in ridership levels. Whereas large agencies intend to provide an accurate picture of their ridership they should measure their baseline as close to the Spare the Air occurrence as possible. San Francisco Muni should have measured ridership on the following Tuesday, but instead waited three weeks for August 16th, when more people were likely to be back from vacation and in school, skewing ridership increase estimates downward. In the case of Muni, the region's largest operator, more than one day should have been monitored for comparison data in order to increase data quality.

5.4 Proposed Ridership Reporting and Quality Control Methodology

Reporting of ridership can be done nearly instantaneously if technologies and proper channels of inter-agency communication are in place, or if a manual system is in place, up to a few days or weeks, depending on staffing size and budget at the agency. Also, depending on how ridership is analyzed, reporting time may vary. Lastly, ridership may simply just not be reported at all if an agency does not have a proper budget, as was the case with the free Emeryville Emery-Go-Round shuttle.

In an ideal world an agency will know if it has proper resources to conduct ridership analysis and if in need of further aid, should let Spare the Air coordinating agencies know in advance. In reality however, it is not always known how long an analysis will take, especially since nearly all agencies with the exception of BART and Wheels/LAVTA had never participated in the free morning commute aspect of Spare the Air. Such needs perhaps to hire a consultant in order to examine the data should be considered for the MTC's budget in future years if quick turnaround for ridership information is of high priority. These consultants can be deployed where necessary to take over these duties at agencies where human resources are limited.

The MTC may also want to prioritize quick ridership reporting turnaround in larger agencies, since the top four agencies comprise nearly 90% of ridership. Quick turnaround may be achieved through ridership collection by the utilization of electronic ticket purchases in the afternoon (Bart, Muni, VTA), morning faregate exits (Muni), or electronic farebox data (AC Transit). The MTC may want to consider hiring onboard survey administrators to conduct sample counts of riders in this case as well. Ridership analysis can be quickly achieved through obtaining comparison day data through either weekly reporting of ridership to the MTC or monthly ridership reporting during the summer Spare the Air season. Since Spare the Air days cannot be predicted more than 15 hours in advance, comparison data should be gathered as soon the Spare the Air day is issued, sometime near noon in the day before.

For quality control purposes data, if possible, should be double checked against all available forms of data collection within transit agencies. If automated passenger counting technologies are utilized, they should be matched with cash receipts to determine Spare the Air day ridership. If electronic ticket machines are utilized these should be matched with onboard passenger counts if available. If VTA electronic fareboxes register the same increase as electronic ticket machines, the better the quality of the data. The more redundancies in the data monitoring, the more accurate the results will be. As technologies are adapted such as the smart card, more accurate results should also be expected. New technologies are also likely to result in faster reporting, especially if smart card chips with radio devices are utilized.

6. RECOMMENDATIONS FOR APPROPRIATE TRANSPORTATION RELATED AIR QUALITY POLICY

6.1 Air Quality Strategies

Again, there is no one size fits all solution for such a variety of regions that are growing at different rates and densities, exhibit a variety of transit and automobile mode splits, contain different demographics, and operate over a varied geography including mountains, ocean, upstream and downstream currents. Some strategies however are worthwhile and are utilized nationally as many region's TCMs contain similar programs, while some are and should be tailored to regional particularities.

Proper air quality strategy should also consider whether its goals are long term or short term, whether or not costs are acceptable for a given program, and whether the public understands and is willing to participate in the program. Along with public support, agency support makes a difference as well. Effective leadership and vision can propel a program to many years of success.

Transportation related air quality strategy must also be multi-pronged, be willing to adapt to new changes in urban form and air quality standards, as well as trek into uncharted and untested program areas. Due to limited data on many transportation related air quality efforts, a willingness to test out new programs provides more data in order to evaluate whether or not a program works.

6.2 San Francisco Bay Area

The San Francisco Bay Area should continue with the Spare the Air/Free Morning Commute program for the reasons that it is a limited program of five days, acts as one of many air quality programs, and funds service that provides access to significant regional employment centers. Potential alternatives or additions to the existing program may include funding full days of transit, especially as a season nears its end and few or no days have been called. The AQMD may also consider hiking bridge fares during Spare the Air occurrences, create more stringent ozone standards if necessary, increase ridesharing requirements during Spare the Air days, and introduce special bus service on Spare the Air days to cater to specific markets.

As the Los Angeles region shows, benefits can be reaped from mandatory carpooling, although as is evident with Southern California, carpooling does not eliminate air quality problems in its entirety. Perhaps related is the fact that not all utilize rideshare because there are other options such as paying for emissions credits instead. Some level of mandatory carpooling may be necessary in the Bay Area as employment centers continue to spread even further, firm size decreases, and transit accessible jobs decrease. Combined with expansion of HOV facilities and the eventual implementation of HOT lane facilities such a strategy may prove effective, as Southern California has shown.

6.3 Los Angeles Area

As Los Angeles continues to grow, it should continue to focus on carpooling. Further carpool benefits can be reaped if the employee minimum is reduced to a more stringent level such as 100, considering that Los Angeles has a particularly high number of smaller businesses comprising its economy – 95 percent of firms smaller than 50 employees.[47] Through appropriate pricing, carpool rates can also be improved by perhaps increasing the cost of the opt-out payment beyond $60. Continuing to focus on technological improvements in fuel efficiency and catalytic converter standards is appropriate policy that focuses on the high number of automobile commuters.

Los Angeles may wish to take the marketing approach as suggested by Wachs and Cervero, tailoring to the individual particularities of various sub-markets for transit that may not be tapped. Such a strategy may include more rapid bus, with better amenities and stations to wireless Internet on buses as the Riverside Transit Authority has implemented on various routes. There may be markets for which other forms of luxury coaches that act as distributor and feeder service while operating along a busway or HOV lane trunk line may also prove auspicious. As Lewis Center survey data indicates, such markets may want to take advantage of the desire to improve frequency and routing.

Lastly for Los Angeles, a free transit promotion on poor air quality days may prove futile in terms of air quality benefits. Funding five out of 75 of the 8-hour ozone exceedances in 2005 with a likely low ridership increase could have proved disastrous politically for the AQMD as well. If attempted, a focus on the current lines heading into downtown areas with significant rapid transit linkages– Los Angeles, Pasadena, and Long Beach may provide limited ridership gains. If additional transit lines are created just for a Spare the Air occurrence tailoring to specific routes and markets, additional ridership gains may also be attained. Funding the heavily subsidized MetroLink may not however prove as effective in terms of cost, as an estimated 20,000 morning trips multiplied by an average $8 one way would cost the air district $160,000 for a.m. reimbursement or $320,000 for full day reimbursement per Spare the Air occurrence. Compared to how many cars could bed scrapped or engines replaced, this may not prove to be very worthwhile.

6.4 Washington, D.C. Area

Washington, D.C. may very well want to continue to utilize fare free suburban buses, many of which are feeders into the Metrorail system on Code Red days. The metropolitan Washington, D.C. region may also wish to consider free Metrorail rides on such

[47] Los Angeles Times. 2000. A Diversifying Area Economy. August 13, 2000.

occurrences, especially given that as of recent so few days have been forecasted However, the market for additional rail trips may be exhausted considering the high existing rates of Metrorail utilization, and the region may very well end up giving all current riders a free trip instead of inducing new trips. During Code Red days the region may wish to chose a strategy that mandates some level of carpooling as well to tap into other potential markets. Such a carpooling strategy may begin implementing a mandatory carpool program for very large employers, and eventually requiring large, and medium employers to follow suit.

While Los Angeles and the Bay Area begin smart card programs, Washington, D.C. has actually already had a program that has been in effect since 1999 called SmarTrip. A wireless chip controls faregates when swiped on Metrorail. As of 2004 there were 544,000 cards. SmarTrip use has recently expanded to nearly all buses in the region, but the card has its glitches still from vanishing fare values to poor customer service.[48] Such a system may very well offer up more information of travel routing and provide data to construct better suited transit lines to meet travel patterns. Deploying extra service that meets these travel patterns on Code Red days may be a fruitful strategy.

7. CONCLUSIONS

As demonstrated for ridership collection and transportation related air quality strategy, there is no one sized fits all solution.

Passenger counting, analysis, and reporting literature and experience tell us that process, internal communication, and preparation is far more important than technology. While smart cards have been on the horizon for many years with their eventual implementation we shouldn't expect them to solve all of our problems, and we shouldn't expect initial implementation to be glitch free as the Washington, D.C. cases indicate.

Air quality program literature and experience shows that while limited in data, there is much to learn from Spare the Air and Code Red Air Quality Alerts. These programs should be continued with careful monitoring in order to collect more data. Overall, fare free transit costs are not that significant considering the programs fund only a handful of days per year and the full number of funded days is rarely exceeded. Although more expensive than some other air quality programs - 17 times more than Carl Moyer clean engine replacement, 3.4 times more than the smoking vehicle retrofit program, and 4.5 times more than the vehicle buyback program - with public experience and increased awareness, utilization fare free programs provide a multi-pronged air quality approach, especially when other programs have "maxed out" on their ability to find additional older vehicles to scrap or engines to replace.

While Los Angeles does not fund free transit promotional programs, there are still lessons to be learned from the Los Angeles transportation based air quality strategy. Regulation 2202 has most likely had an effect on the higher carpool rates in Los Angeles compared

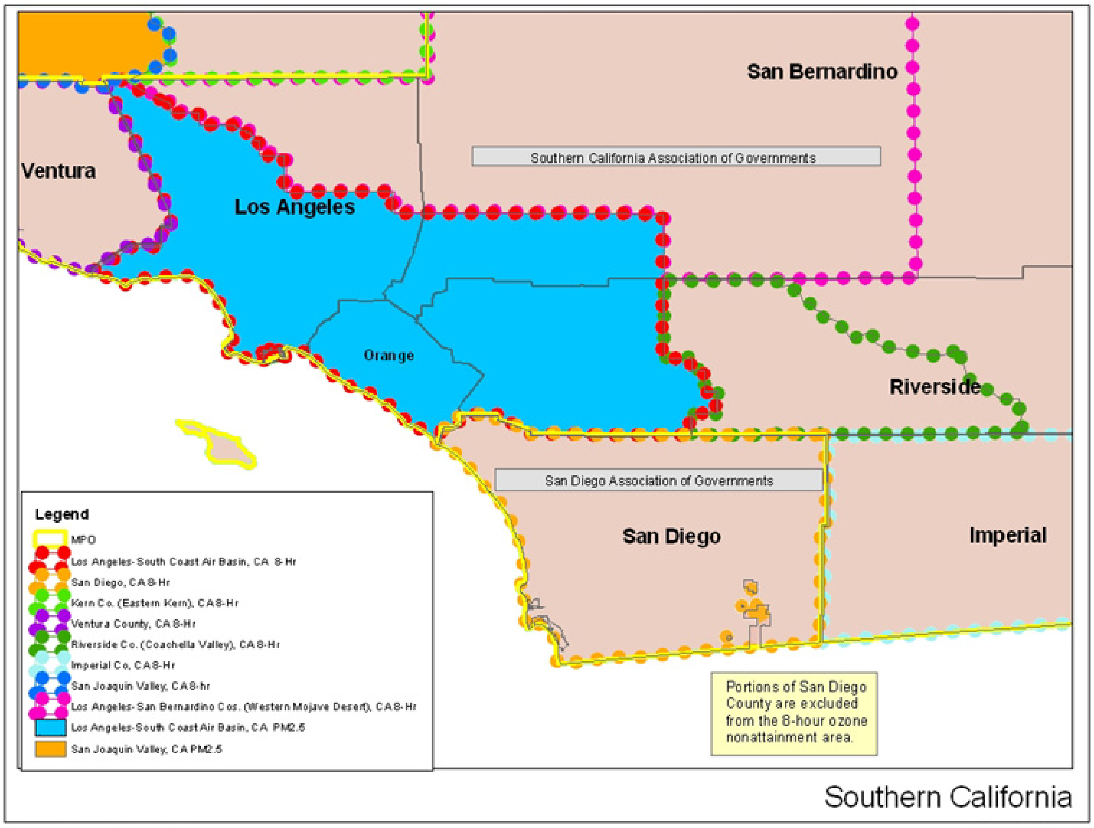
[48] Washington Post. 2004. "Metro Forced To Halt Sale Of SmarTrip." June 23, 2004.

with metropolitan San Francisco and Washington, D.C. Such a program in concert with carpool lanes provides a lower cost alternative to certain types of capital-intensive transit projects while tailoring to the variations in employment densities and transit accessibility. Compared to fare free projects, ridesharing is more cost effective, but only by 17 percent as shown by the BAAQMD for the Bay Area in Table 2.

There are also lessons from the elasticity literature from understanding the complexity of the relationship between fares and ridership and other external forces, to understanding that utilizing premium markets may also perhaps have a great influence on transit ridership. Such premium markets could take the form of luxury coaches with feeder and distribution service as well as wireless internet technologies on transit vehicles.

Taking such variations of markets, mode splits, demographics, growth rates, and severity of air quality problems should prove to be the most effective strategy, tailoring the air quality approach and passenger tracking approach as necessary.

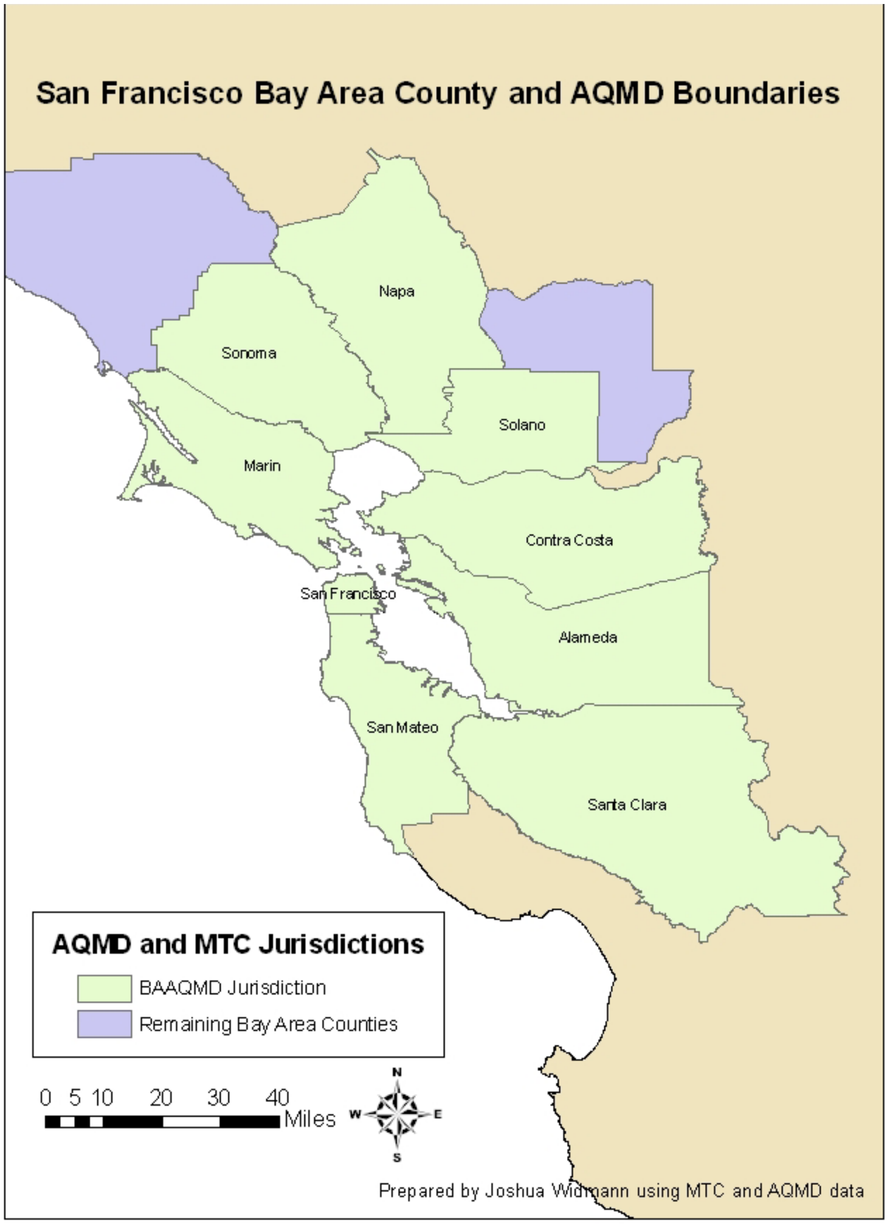
Appendix A: Los Angeles Area Air District and SCAG/CMSA Boundaries



Prepared by FHWA - HEPN-40 April 2005

Source: FHWA. 2005. “Los Angeles South Coast Air Basin PM2.5 Nonattainment Area Map”
Note: Air District region is in blue. SCAG/CMSA boundaries are all pictured counties with the exception of San Diego County. Outer boundaries of San Bernardino, Riverside, Imperial, and Ventura County are not shown.

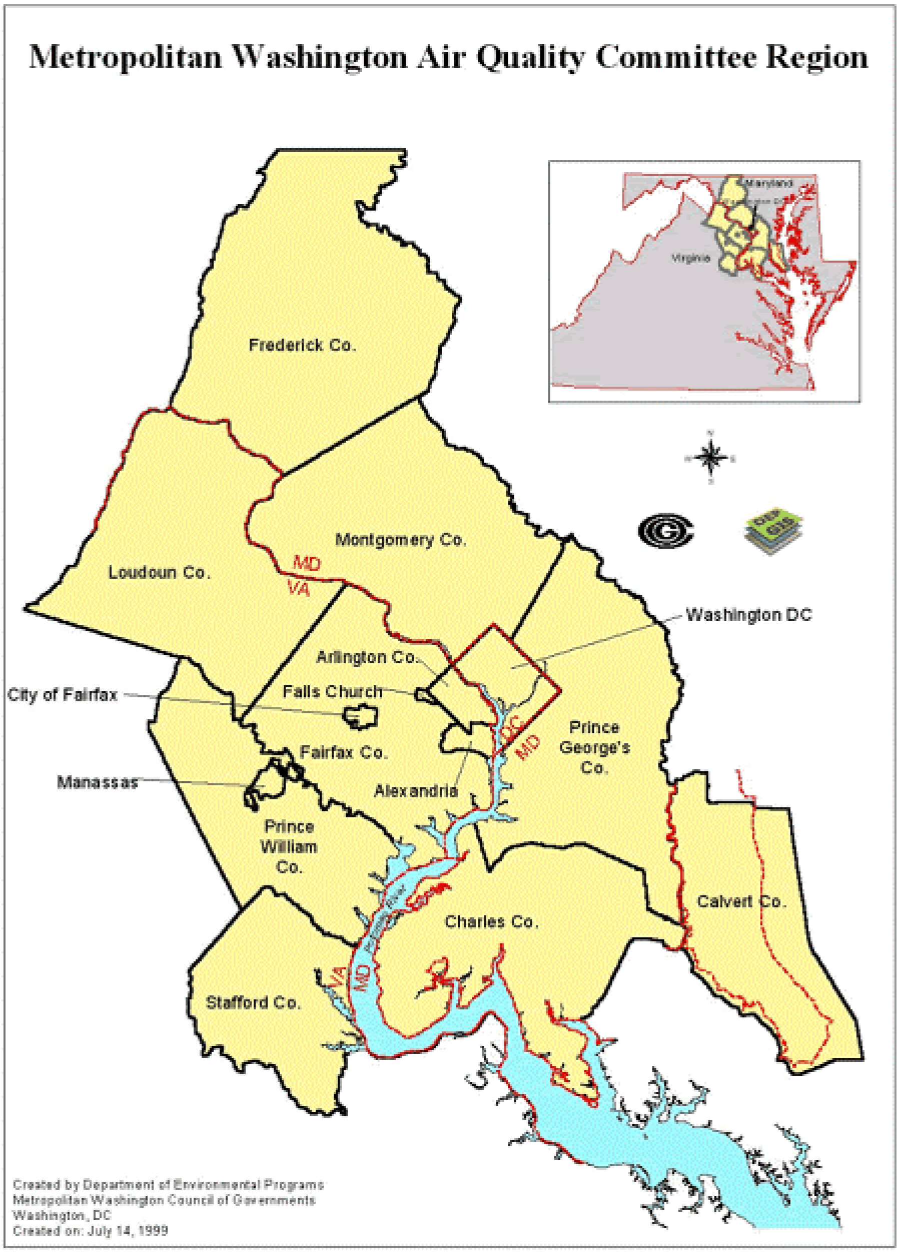
Appendix B: San Francisco Bay Area CMSA/MTC and AQMD Boundaries



Appendix C: Washington, D.C. MSA Boundaries

Source: National Capital Region Transportation Planning Board. 2000. *Update to the Financially Constrained Long-Range Transportation Plan for the National Capital Region.* Washington, DC: MWCOG. pg "3-2"

Appendix D: Washington, D.C. Air Quality Committee Region Boundaries



Source: Metropolitan Washington Air Quality Committee Region. 2006. Online Access:
<http://www.mwcog.org/environment/air/mwaqc1a.asp>