IV. DESIGN OF SUCCESSFULLY DEMONSTRATED PROJECTS

As directed by the Board, the primary objective of the 1998 Addendum is to define the parameters of projects shown to be successful and to provide examples. This Addendum, which was undertaken in cooperation and collaboration with air districts, cities and counties and congestion management agencies, is intended to increase knowledge and awareness of how to design cost-effective projects.

The ARB in cooperation with the California Air Pollution Control Officers Association has provided Methods to Find Cost-Effectiveness of Air Quality Projects, January 1998 as a tool to be used by recipient agencies and project proponents to access cost-effectiveness.

The following examples illustrate design parameters recipient agencies should consider when evaluating projects. Each example contains a set of specific design parameters that achieve a cost-effectiveness of $10/lb ($20,000/ton) or less. These specific design parameters are based on actual project information. Evaluations of actual projects funded with motor vehicle registration fees that meet the $10/lb goal are included in Appendix A. The examples given in this document are not intended to be all inclusive of projects that achieve a cost-effectiveness of $10/lb.

Transit Bus Replacement Purchases

Description**:** Purchase new low-emitting alternative fueled transit buses in place of typical new diesel fueled vehicles that meet current certification standards.

Design Parameters**:** (1) Minimize project costs. Funding is typically limited to the cost difference between the lower-emitting bus and a typical new bus. (2) Select engines that run cleaner than applicable certification standards.

Emission benefits are predominately from nitrogen oxides (NOx) reductions. The NOx standard applicable to the 1998-99 funding cycle is 4.0 grams/brake horse power hour (g/bhp-hr). Engines certified by the ARB to NOx levels less than 4.0 g/bhp-hr have an emission benefit equal to the difference between the standard and the lower certification level.

During ARB engine certification testing, some vehicles emit less NOx than the official certification level indicates. Cost-effectiveness evaluations can be based on the lower level achieved during the ARB certification testing. For example, Cummins manufactures a heavy-duty L/CNG engine (280 hp) for urban bus service that is certified to 4.0 g/bhp-hr of NOx. During certification testing the engine emitted only 2.4 g/bhp-hr of NOx. Cost-effectiveness can be based on the 2.4 g/bhp-hr level.

For a transit bus purchase with a useful life of 12 years and annual vehicle miles traveled (VMT) of 40,000 miles, the following parameters yield project cost-effectiveness of $4 per pound:

Project funding	$40,000
NOx level of project engine	2.0 g/bhp-hr

Here's how changing one parameter changes the cost-effectiveness:

Increase project funding to $80,000	$ 8/lb
Increase project funding to $120,000	$13/lb
Increase NOx level to 2.5 g/bhp-hr	$ 5/lb

Implementation Information: Examples of manufacturers are:

Bus Engine Manufacturers--Caterpillar Inc./Power Systems Assoc., Cummins Engine Co., Detroit Diesel Corp.

Electric Bus Manufacturers--Advanced Vehicle Systems, APS Systems, Bus Manufacturing USA, Inc., Electric Vehicles International.

Hybrid Electric Bus Manufacturers--Nova BUS, Orion Bus Industries, APS Systems, Advanced Vehicle Systems, Blue Bird Body Company, BMI, Gillig, El Dorado National, Neoplan USA.

Fuel Cell Buses--Ballard Power Systems, Daimler-Benz.

School Bus Purchases

Description: Purchase new, low-emitting alternative fueled school buses in place of typical new diesel fueled vehicles that meet current certification standards.

Design Parameters: (1) Minimize project costs. Funding is typically limited to the cost difference between the lower-emitting bus and a typical new bus. (2) Select engines that run cleaner than applicable certification standards.

Emission benefits are predominately from NOx reductions. The NOx standard applicable to the 1998-99 funding cycle is 4.0 g/bhp-hr. Engines certified by the ARB to NOx levels less than 4.0 g/bhp-hr have an emission benefit equal to the difference in the standard and the lower certification level. For example, Cummins manufactures engines certified to 2.5 g/bhp-hr of reactive organic gases (ROG) + NOx for three engine classes.

Also, during ARB engine certification testing, some vehicles emit less NOx than the official certification level indicates. Cost-effectiveness evaluations can be based on the lower level achieved during the ARB certification testing. For example, if an engine certified to 4.0 g/bhp-hr emits only 2.0 g/bhp-hr during certification testing, the cost-effectiveness evaluation can be based on the 2.0 g/bhp-hr level. John Deere manufactures an engine for school buses that emits only 2.17 g/bhp-hr of NOx.

For a typical school bus purchase using useful life of 20 years and annual VMT of 15,000 miles, the following parameters yield project cost-effectiveness of $10 per pound:

Project funding	$45,000
NOx level of project engine	2.0 g/bhp-hr

Here's how changing one parameter changes the cost-effectiveness:

Increase project funding to $50,000	$12/lb
Increase project funding to $100,000	$23/lb
Increase NOx level to 2.5 g/bhp-hr	$14/lb

Implementation Information**:** Examples of manufacturers are:

Bus Engine Manufacturers--John Deere, Caterpillar Inc./Power Systems Assoc., Cummins Engine Co., Detroit Diesel Corp.

Electric Bus Manufacturers--Advanced Vehicle Systems, APS Systems, Bus Manufacturing USA, Inc., Electric Vehicles International.

Hybrid Electric Bus Manufacturers--Nova BUS, Orion Bus Industries, APS Systems, Advanced Vehicle Systems, Blue Bird Body Company, BMI, Gillig, El Dorado National, Neoplan USA.

Fuel Cell Buses--Ballard Power Systems, Daimler-Benz.

Heavy-Duty Truck Purchases and Re-powering

Description**:** Projects are: (1) Purchase of new heavy-duty alternative fueled trucks that have lower emissions than a typical new diesel truck. (2) Re-powering of a heavy-duty truck with a cleaner burning alternative fueled engine instead of a typical new diesel engine. In both cases, the alternative fueled engine would emit less NOx than the new diesel engine certified to 4.0 g/bhp-hr.

Design Parameters**:** (1) Minimize project costs. Funding is typically limited to the cost difference between the lower-emitting engine and the typical new or rebuilt engine. (2) Select engines that run cleaner than applicable certification standards.

Emission benefits are predominately from NOx reductions. The NOx standard applicable to the 1998-99 funding cycle is 4.0 g/bhp-hr. Engines certified by ARB to NOx levels less than 4.0 g/bhp-hr have an emission benefit equal to the difference in the standard and the lower certification level. During ARB engine certification testing, some vehicles emit less NOx than the official certification level indicates. Cost-effectiveness evaluations can be based on the lower level achieved during the ARB certification testing. For example, during certification testing an engine that was certified to 4.0 g/bhp-hr actually emitted only 3.0 g/bhp-hr of NOx. Cost-effectiveness evaluations can be based on the 3.0 g/bhp-hr level.

The following parameters yield project cost-effectiveness of $10 per pound to repower a heavy-duty truck with a cleaner burning engine instead of a new diesel engine certified at 4.0 g/bhp-hr and assuming the engine life is 290,000 miles:

Project funding	$ 35,000
NOx level of project engine	2.0 g/bhp-hr

Here's how changing one parameter changes the cost-effectiveness:

Increase project funding to $70,000	$20 /lb
Reduce NOx level to 1.5 g/bhp-hr	$ 9 /lb

<u>Implementation Information</u>**:** Examples of heavy-duty engine manufacturers are: Caterpillar Inc./Power Systems Assoc., Cummins Engine Co., Deere Power Systems Group, Detroit Diesel Corp., Mack Trucks, Inc., and Navistar International.

Off-Road Agricultural Equipment Purchase and Re-powering

<u>Description</u>**:** Replacing uncontrolled diesel engines in off-road agricultural equipment with lower emitting controlled diesel engines or alternative fueled engines. Repowering with cleaner new engines is done instead of rebuilding the old engine.

<u>Design Parameters</u>**:** (1) Minimize project costs. Funding is typically limited to the cost difference between the lower-emitting engine and a rebuild of the older engine. (2) Select engines that run as clean as possible given the needs of the application.

Emission benefits are predominately from NOx reductions. Prior to 1996, off-road heavy-duty engines were uncontrolled. The NOx standard applicable to the 1998-99 funding cycle for new off-road engines is 6.9 g/bhp-hr.

The average uncontrolled engine emits 11 to 13 g/bhp-hr. When these old engines are rebuilt they should run more efficiently and emit fewer emissions; however, there are little data to establish emission levels or the duration of these benefits. Therefore, for the purposes of evaluation, we will assume that a rebuilt engine emits the same level of emissions on average, as before the rebuild. This establishes the baseline for evaluating the re-powering of the vehicle with a cleaner, newer engine.

Uncontrolled CNG engines for off-road applications emit 9 g/bhp-hr. Cleaner CNG engines can be considerably cleaner, for example 2.5 g/bhp-hr. The following table provides conservative default values for an off-road agricultural application.

Operating hours can range from 110 to 814 hours per year and the load factor can vary between 0.48 and 0.7.

Engine Category (hp)	Agricultural Equipment				
	Operational Hrs (Hrs/yr)	Load (%)	Uncontrolled Diesel NO_x (g/bhp-hr)	NOx Standard (g/bhp-hr) Applicable 1998-2000	Uncontrolled CNG NO_x (g/bhp-hr)
50 to 175	110	0.50	13	6.9	9
176 +	110	0.50	11	6.9	9

Source: ARB's Mobile Source Control Division Off-Road Model, 1997

The following is a sample evaluation of an off-road project with parameters that yield a cost-effectiveness of $10/lb:

An agricultural sprayer with 150 hp, average operational hours are 110 hrs/yr, load is 0.5, useful life is 10 years, and funding is $11,000. The uncontrolled, old diesel engine if rebuilt is assumed to emit 13 g/bhp-hr. The new diesel repowering emits only 6.9 g/bhp-hr.

NO_x reduced (lbs) = [hp * Load * Operational Hours * (Uncontrolled Diesel NO_x emissions – Controlled Diesel NO_x emissions or Uncontrolled CNG NO_x emissions or Certified NO_x emissions)] * Useful Life / 454 g/lb

= [150 hp * 0.5 * 110 hrs/yr * (13 g/bhp*hr – 6.9 g/bhp*hr)] * 10 yrs / 454 g/lb = 1108 lbs.

Here's how changing one parameter changes the cost-effectiveness:

Reduce project funding to $6,000	$ 5/lb
Increase project funding to $20,000	$ 18/lb
Reduce NOx level to 2.5g/bhp-hr	$ 6/lb

Implementation Information: Examples of manufacturers that sell CNG and/or diesel agricultural equipment are: Alturdune, Baytech Corp, Caterpillar Inc. /Power Systems Assoc., Cummins Engine Co., Deere Power Systems, Detroit Diesel Corp., Navistar International, TecoDrive/Crusader Engines, Thermo Power Corp.

Off-Road Construction Equipment Purchase and Re-powering

Description: Replacing uncontrolled diesel engines in off-road construction equipment with lower emitting controlled diesel engines or alternative fueled engines. Repowering with cleaner new engines is done instead of rebuilding the old engine.

Design Parameters: (1) Minimize project costs. Typically, funding is limited to the cost difference between the lower-emitting engine and a rebuild of the older engine. (2) Select engines that run as clean as possible given the needs of the application.

Emission benefits are predominately from NOx reductions. Prior to 1996, off-road heavy-duty engines were uncontrolled. The NOx standard applicable to the 1998-99 funding cycle for new off-road engines is 6.9 g/bhp-hr.

The average uncontrolled engine emits 11 to 13 g/bhp-hr. When these old engines are rebuilt they should run more efficiently and emit fewer emissions; however, there are little data to establish emission levels or the duration of these benefits. Therefore, for the purposes of evaluation, we will assume that a rebuilt engine emits the same level of emissions on average, as before the rebuild. This establishes the baseline for evaluating the re-powering of the vehicle with a cleaner, newer engine.

Uncontrolled CNG engines for off-road applications emit 9 g/bhp-hr. Cleaner CNG engines can be considerably cleaner, for example 2.5 g/bhp-hr. The following table provides conservative default values for an off-road construction application. Operating hours can range from 130 to 1836 hours per year and the load factor can vary from 0.43 to 0.78.

	Construction Equipment				
Engine Category (hp)	Operational Hrs (Hrs/yr)	Load (%)	Uncontrolled Diesel NO_x (g/bhp-hr)	NOx Standard (g/bhp-hr) Applicable 1998-2000	Uncontrolled CNG NO_x (g/bhp-hr)
50 to 175	130	0.68	13	6.9	9
176 +	130	0.68	11	6.9	9

Source: ARB's Mobile Source Control Division Off-Road Model, 1997

The following is a sample evaluation of an off-road project with parameters that yield a cost-effectiveness of $10/lb:

A concrete paver with 300 hp, average operational hours are 130 hrs/yr, load is 0.68, useful life is 10 years, and funding is $25,000. The uncontrolled, old diesel engine if rebuilt is assumed to emit 11 g/bhp-hr. The new diesel re-powering emits only 6.9 g/bhp-hr.

NO_x reduced (lbs) = [hp * Load * Operational Hours * (Uncontrolled Diesel NO_x emissions – Controlled Diesel NO_x emissions or Uncontrolled CNG NO_x emissions or Certified NO_x emissions)] * Useful Life / 454 g/lb

= [300 hp * 0.68 * 130 hrs/yr * (11 g/bhp*hr – 6.9 g/bhp*hr)] * 10 yrs / 454 g/lb = 2395 lbs.

Here's how changing one parameter changes the cost-effectiveness:

Increase project funding to $50,000	$ 21/lb
Decrease project funding to $10,000	$ 4/lb
Reduce NOx level to 2.5g/bhp-hr	$ 5/lb

Implementation Information**:** Examples of manufacturers that sell CNG and/or diesel construction equipment are: Alturdune, Baytech Corp, Caterpillar Inc. /Power Systems Assoc., Cummins Engine Co., Deere Power Systems, Detroit Diesel Corp., Navistar International, TecoDrive/Crusader Engines, Thermo Power Corp.

Voluntary Early Retirement of Light-Duty Vehicles

Description: Implement a voluntary program for early retirement of light-duty vehicles. These programs provide short-term emission reductions because older vehicles have less emission control than newer models and are typically more polluting.

Design Parameters**:** ARB has provided guidance on voluntary accelerated retirement of older vehicles in the document, *Mobile Source Emission Reduction Credits Guidelines* (February 1996). Vehicles that qualify for early retirement are typically driven in the program area, are registered with the California Department of Motor Vehicles, and must be permanently dismantled. There are other recommended requirements discussed in the guidelines document. Effective programs follow these guidelines and air district regulations very carefully and work closely with auto dismantlers to insure against fraud.

In December 1998, ARB will adopt statewide regulations governing voluntary "scrappage" programs. The law requires that ARB conduct a pilot voluntary scrappage program and evaluate its potential to reduce emissions. This work should be completed in 1999 and will shed more light on the effectiveness of voluntary scrappage programs in clean air plans. ARB's efforts are targeted primarily to implementing the 1994 California SIP measure M-1 to reduce light-duty motor vehicle emissions in the South Coast AQMD.

The cost-effectiveness of voluntary scrappage programs is typically under $5 per pound; however, the emission reductions are available for only 3 years as a result of the natural turnover of the vehicle fleet. Before setting funding priorities, it is important to evaluate the need for short-term emission reductions compared to long-term strategies within the context of clean air plans for each area.

Implementation Information: Most recipient agencies will want to take advantage of voluntary scrappage programs already operated by large air districts. This is not the type of program that can easily be implemented by small rural air districts or cities.

Long-Distance Commuter Bus Projects

Description: Funding to subsidize the capital and operating expenses of a long-distance commuter bus service.

Design Parameters: (1) Reduce long-distance commute vehicle trips, (2) use low-emitting buses, (3) achieve high average ridership, and (4) control costs. For example, the cost-effectiveness of the following long-distance commuter bus is $10 per pound.

Average commute distance	55 miles
Type of bus	CNG (compressed natural gas)
NOx level of bus engine	2.0 g/bhp-hr
Average daily ridership	40
Capital funding per bus	$250,000
Operating funding per bus per year	$13,250

Supporting assumptions: 250 days of operation per year; 80% ex-solo drivers; and 50% access trips of 5 miles; operating costs assume $245/day for fuel, maintenance, insurance and driver salary, minus $100/month fee per rider; project life 15 years due to highway use of bus; emission factors for auto trips eliminated are ROG 0.36 g/mi and 3.26 g/trip, NOx 0.71 g/mi and 1.56 g/trip, PM10 0.45 g/mi (source: Methods to Find Cost-Effectiveness of Air Quality Projects, January 1998, Table 3, commute trips); emission factors for CNG bus are ROG 1.10 g/mi, NOx 6.30 g/mi, PM10 0.50 g/mi (source: EMFAC/BURDEN7G with 2 g/bhp-hr NOx, average speed 45 mph).

Here's how changing one parameter changes the cost-effectiveness:

Increase average commute distance to 80 miles	$ 7/lb.
Use Diesel bus (NOx 4.0 g/bhp-hr) instead of CNG bus	$12/lb.
Decrease average ridership to 30	$19/lb.
Decrease operating funding per bus by 50%	$ 8/lb.
Decrease capital funding per bus to cost difference between CNG bus compared to diesel bus ($40,000)	$ 4/lb.

Along with determining average daily ridership and commute distance, commuter bus riders should be surveyed to assess what percentage previously used alternative modes, what percentage drive to the commuter bus stop, and the average length of access trips. Costs generally include vehicle purchase or lease, insurance and maintenance, and operating costs, along with marketing and administration expenses. Operating cost offsets include per month passenger fee.

Implementation Information: Contracts for vehicle lease/purchase, insurance, maintenance and fuel are usually coordinated by larger regional agencies (e.g., air districts, transportation or transit agency), while marketing and subscription services are often performed by local grassroots commuter transportation organizations (e.g., transportation management associations (TMA's)). Projects are typically initiated only upon commitment of a predetermined number of riders.

Long-Distance Commute Vanpool Programs

Description: Funding to subsidize the cost of developing and operating long-distance commute vanpools.

Design Parameters: (1) Reduce long-distance commutes, (2) use low-emitting vans, (3) achieve high average ridership, and (4) control costs. For example, the cost-effectiveness of the following vanpool is $10 per pound.

Average commute distance	25 miles
Model year of van	1997
Average daily ridership	10
Funding per van per year	$4,000

Supporting assumptions: Subsidy to vanpool is $300/mo plus 10% administration costs; vanpoolers pay remaining costs; 250 days of operation per year; 70% of participants drove alone to work prior to joining vanpool; 50% of the ex-solo drivers drive an average of 2 miles to the vanpool access point; project life 1 year; emission factors for auto trips eliminated are ROG 0.55 g/mi and 4.98 g/trip, NOx 1.02 g/mi and 2.05 g/trip, PM10 0.45 g/mi; emission factors for van are ROG 0.36 g/mi and 3.26 g/trip; NOx 0.71 g/mi and 1.56 g/trip, PM10 0.45 g/mi (source: Methods to Find Cost-Effectiveness of Air Quality Projects, January 1998, Table 3 commute trips and Table 2 van model year 1997).

Here's how changing one parameter changes the cost-effectiveness:

Decrease commute distance to 15 miles	$17/lb.
Increase commute distance to 40 miles	$ 6/lb.
Use older vans - 1990 model year	$12/lb.
Decrease average ridership to 6	$18/lb.
Increase average ridership to 14	$ 7/lb.
Decrease funding to $2600 per year per van ($200/mo plus 10% admin.)	$ 7/lb.

Along with determining average daily ridership and commute distance, vanpoolers should be surveyed to assess what percentage previously used alternative modes, what percentage drive to the vanpool access point, and the average length of access trips. Costs generally include vehicle purchase or lease, insurance and maintenance, and operation costs, along with marketing and administration expenses.

Implementation Information: Contracts for vehicle lease/purchase, insurance and maintenance are usually coordinated by larger regional agencies (e.g., air districts, transportation agencies, regional ridesharing agencies), while marketing and vanpool formation is usually handled by local grassroots commuter transportation organizations (e.g., TMAs). In cost-effective projects, average ridership has been high due largely to TMAs providing initial marketing groundwork, carpool/vanpool formation experience and the motivated assistance of TMA employer-members.

Transit Use Subsidies

Description: Funding to provide subsidies for transit riders.

Design Parameters: (1) Reduce vehicle trips by increasing transit use, (2) target longer trips, and (3) maximize the subsidy's value. For example, the cost-effectiveness of the following transit use subsidy program is $10 per pound.

Subsidy per transit rider	$26 per month
Average length of vehicle trip reduced	15 miles

Supporting assumptions: 250 commute days per year; 75% of participants drove alone to work prior to obtaining the transit subsidy; 25% of the ex-solo drivers drive an average of 2 miles to the bus stop; project life 1 year; emission factors for auto trips eliminated are ROG 0.55 g/mi and 4.98 g/trip, NOx 1.02 g/mi and 2.05 g/trip, PM10 0.45 g/mi (source: Methods to Find Cost-Effectiveness of Air Quality Projects, January 1998, Table 3 commute trips).

Here's how changing one parameter changes the cost-effectiveness:

Increase subsidy to $50/month per transit rider	$20/lb.
Increase subsidy to $30/month per transit rider	$12/lb.
Decrease subsidy to $20/month per transit rider	$ 8/lb.
Decrease trip length to 10 miles	$14/lb.
Increase trip length to 20 miles	$ 8/lb.

Along with determining the number of participants in the program, transit riders should be surveyed to assess what percentage previously used alternative modes, what percentage drive to the transit stop and average length of access trips. Project costs generally include the cost of the subsidies, plus marketing and administrative costs.

Implementation Information: Funding and coordinating agencies are typically air districts and regional transit and transportation agencies. Participating employers are also funding sources for commute transit subsidy programs. Implementing agencies are often regional rideshare agencies and transportation management associations.

Maximizing the subsidy's value: Funding a project that has an infrastructure of marketing, administrative functions and transportation management already in place will increase cost-effectiveness by allowing the bulk of the funds to be used for actual transit subsidies. The market must also be analyzed to determine if subsidies will attract new transit riders. If transit isn't available and convenient in the target area, or if transit information is not readily available to potential users, a subsidy program may have little effect. Marketing that emphasizes long-distance express routes can also increase project cost-effectiveness. If parking is scarce and/or expensive, a monthly transit subsidy has more value than if parking is plentiful and cheap. Funding transit subsidies for worksites where parking is heavily subsidized would not be cost-effective.

Employee Trip Reduction Programs

Description: Funding for rideshare incentives and major program elements of employee trip reduction programs.

Design Parameters: (1) Reduce vehicle commute trips, (2) target longer commute trips, and (3) maximize value of incentives. For example, the cost-effectiveness of the following employee trip reduction program is $10 per pound.

Funding per round trip reduced	$1.80 / day
Average round trip commute trip length	30 miles

Supporting assumptions: 250 commute days per year; project life 1 year; emission factors for auto trips eliminated are ROG 0.55 g/mi and 4.98 g/trip, NOx 1.02 g/mi and 2.05 g/trip, PM10 0.45 g/mi (source: Methods to Find Cost-Effectiveness of Air Quality Projects, January 1998, Table 3 commute trips).

A trip reduction program funded at $62,250 per year and reducing an average of 145 vehicle round trips per day would have a $10 per pound cost-effectiveness. (Reducing 145 round trips per day is the equivalent of a 1,000-employee worksite increasing average vehicle ridership (AVR) from 1.15 to 1.38.)

Here's how changing one parameter changes the cost-effectiveness:

Decrease funding to $1.25 / day per round trip reduced	$ 7/lb.
Increase funding to $3.00 / day per round trip reduced	$ 17/lb.
Increase average round trip commute length to 38 miles	$ 8/lb.
Decrease average round trip commute length to 25 miles	$ 12/lb.

To determine vehicle trips and miles reduced, baseline and ongoing employee commute surveys should be administered which gather information on commute mode and length of commute, as well as any access trips and their length (e.g., drive alone two miles to express bus stop). Costs generally include administrative costs, marketing, and rideshare incentives.

Implementation Information: Employee trip reduction programs are no longer required in most regions. Air districts and transportation agencies typically co-fund rideshare program elements, with employers bearing the major costs of the program. Motor vehicle registration fee revenues subvened to cities and counties are used by some to support government facility-based trip reduction programs with services or incentives. Private firms, regional ridesharing agencies, and transportation management associations are often contracted to provide program analysis and support services.

Although there are no “one-size-fits-all” program designs, the majority of cost-effective programs do have a few common elements, which include assessment of employee travel needs, parking management and pricing, alternate commute subsidies and incentives, and ongoing rideshare support and coordination.

Commuter-Oriented Bicycle Paths, Lanes, and Routes

Description: Construct bicycle paths, lanes, or routes (Class I, II, or III) targeted to reduce commute and other non-recreational auto travel by increasing the use of bicycles to meet basic transportation needs. In particular, bicycle facilities that complete missing links to area-wide bicycle circulation plans are critical to increasing overall usage of bicycles to meet multi-purpose travel needs. Class I facilities are physically separated from motor vehicle traffic. Class II facilities are striped bicycle lanes giving preferential or exclusive use to bicycles. Class III facilities are bicycle routes identified by signs.

Design Parameters**:** Projects with the greatest benefit for air quality connect residential areas with employment centers, schools and colleges, transit centers, downtown areas, and other major activity centers. Safety and bicycle storage are also important. The following parameters yield project cost-effectiveness of $10 per pound for a one-mile Class II bicycle project:

Construction funding	$150,000 per mile of bike lane
Annual maintenance funding	$ 2,000 per mile of bike lane
Annual vehicle trips reduced	65,000 trips per mile of bike lane
Average bicycle trip length	1.8 miles (Source: National Personal Travel Survey, 1990)

Supporting assumptions: project life 15 years; emission factors for auto trips eliminated are ROG 0.36 g/mi and 3.26 g/trip; NOx 0.71 g/mi and 1.56 g/trip, PM10 0.45 g/mi (source: Methods to Find Cost-Effectiveness of Air Quality Projects, January 1998, Table 3 commute trips).

Here’s how changing one parameter changes the cost-effectiveness:

Increase construction funding to $200,000	$13/lb
Increase vehicle trips reduced to 150,000	$ 4/lb
Increase bicycle trip length to 4 miles	$ 7/lb

It is difficult to estimate the number and length of vehicle trips reduced from bicycle projects. The most accurate evaluations are based on bicycle rider surveys. The methodologies provided in “Methods to Find the Cost-Effectiveness of Air Quality Projects, April 1997” and in “Emission Reduction Calculation Methodologies for

Congestion Mitigation and Air Quality Improvement (CMAQ) Program Projects" provide conservative estimates in the absence of survey data.

Implementation Information**:** Bicycle projects implement bicycle transportation plans targeted at reducing commuter trips, school trips, and other regularly made vehicle trips. Projects should be supported by livable community development designs and street calming.