CHAPTER 3

BENEFITS AND COSTS

INTRODUCTION

Public policies are often examined relative to their overall costs and benefits, providing a general indication of the net economic impact of the policy. Applying that approach to the AQMP requires the full quantification of costs and benefits in monetary terms, i.e., dollars.[1] Equipment and materials which are required by control measures are purchased and sold in markets, and their prices can thus be used to measure the costs of implementing control measures. Cost quantification becomes more uncertain when control technologies cannot be specifically identified. Cheaper options may be deployed and marginal costs could be on the rise for the last few tons of emission reductions in order to reach attainment. On the other hand, the possibility of technology advancement and large scale production due to regulatory requirements may drive down control costs.

There is no direct way to measure benefits of clean air because clean air is not a market commodity. Placing a monetary value on reduced incidence of illness or loss of life is also difficult and more subjective than determining control equipment costs. This often results in incomplete assessments and underestimation of benefits.

This chapter presents aggregate benefits and costs for either the four-county area or by county. Chapter 5 has more detailed results for 19 sub-regions.

BENEFITS

Despite the uncertainty of assigning dollar figures to the benefits of attaining the federal $PM_{2.5}$ standard in 2014 and the eight-hour ozone standard in 2023 and making progress towards the state visibility standard, it is apparent that clean air will result in significant benefits to the four-county region. Partial assessments can be made for the impact of better air quality on crop yields, visibility, materials, morbidity, and mortality. However, the full assessment of air quality benefits in dollar terms is not possible until advances occur in human health, physical science, and economic disciplines, which will allow monetary estimates to be made for currently unquantifiable areas.

Quantified Benefits

Air quality continues to improve due to previously adopted regulations and implementation of many control measures from the 2003 AQMP. Implementation of short-term measures would lead to attainment of the federal $PM_{2.5}$ standard in 2014. Implementation of additional short- and long-term measures would bring the Basin into compliance with the federal ozone standard in 2023.

Although each attainment demonstration is performed with respect to the worst air quality site, the benefit assessment (except for the material benefit) herein is analyzed with respect to the changes in the projected year-long air quality concentrations between the expected control based on adopted regulatory programs and the 2007 AQMP for the benchmark years in each air

[1] All the dollars in this report are expressed in constant 2000 dollars for consistency.

quality modeling grid (5 kilometer by 5 kilometer). The total average annual quantifiable benefits associated with implementing the 2007 AQMP are projected to be $14.6 billion, which represents the currently quantifiable benefit of moving beyond today's regulations to the level needed to meet the federal standards. A breakdown of these benefits is shown in Table 3-1. The benefit ranges from $18 million for reduced damage to crops to $9.8 billion for reductions in morbidity and mortality.

TABLE 3-1
Quantifiable Benefits of 2007 AQMP
(millions of 2000 dollars)

Benefit	Average Annual (2007 to 2025)
Reduction in Morbidity	$634
Reduction in Mortality	9,139
Increased Crop Yields	18
Visibility Improvement	3,631
Reduced Materials Expenditures	204
Congestion Relief	966
Total	$14,592

<u>Health Benefit</u>

It is well-documented that smog can result in short-term and chronic illness. Figure 3-1 illustrates mostly short-term smog effects. Numerous studies have demonstrated an association between illness and ambient air pollutants. Based on analytical methods described in a draft report by Deck and Chestnut (2006) with some revisions in response to public comments and projected air quality data, the quantifiable health benefits of achieving at least the federal $PM_{2.5}$ and ozone standards are estimated to be $16 billion in 2023. This estimate represents the quantification of approximately 29 percent of the identified potential health impact areas (13 shaded cubes out of 45 in Figure 3-2).

FIGURE 3-1
Effects of Smog

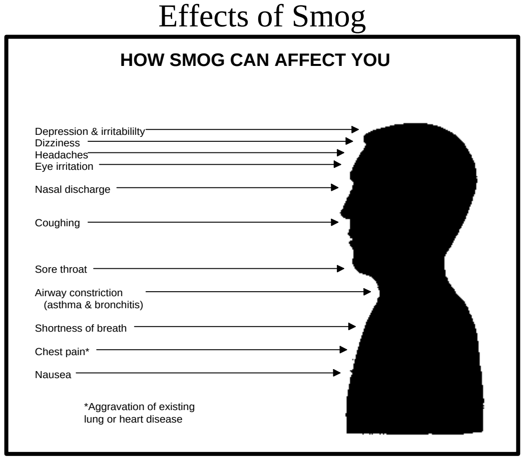
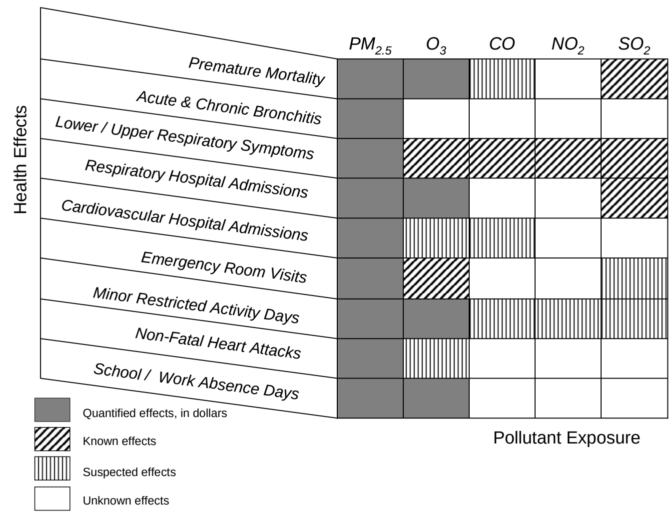


FIGURE 3-2
Health Effects of Criteria Pollutants



Quantification of health benefits requires the establishment of concentration-response functions for various symptoms and translation of health endpoints into dollar values. The latter step is needed in order to monetize known effects. Additional epidemiological studies are needed for unknown and suspected effects before developing concentration-response functions. Based on a thorough review of epidemiological literature, concentration-response functions for various health endpoints for ozone and $PM_{2.5}$ were selected. A health benefit model, BenMAP, was used to pool population, air quality data, and economic values of health effects for the health benefit analysis.

Air quality is expected to improve due to the implementation of the existing control strategy. The analysis herein focuses on the degree of improvement in future years due to the implementation of control measures in the 2007 AQMP by comparing the future baseline air quality (at the current level of regulations) to the future controlled air quality for the same year.

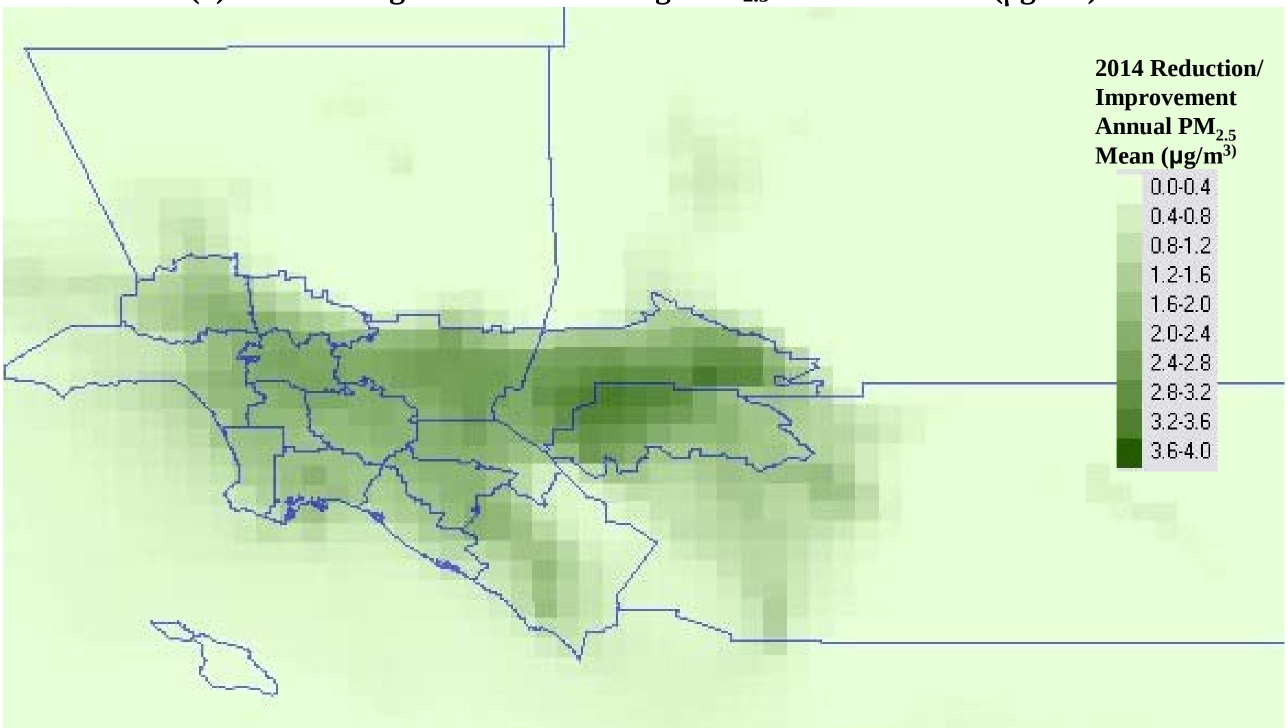
Health benefits for $PM_{2.5}$ and ozone, respectively, with and without thresholds are presented. Overall health benefits are positive even though some areas show higher ozone levels (but they are still below the federal standard). This is because the benefits from $PM_{2.5}$ reductions are greater than any negative impacts seen due to ozone increases (See Table 5-1).

Figures 3-3 (a) and 3-3 (b) provide the differences in projections from CAMx (Comprehensive Air Quality Model with Extensions) between the simulated $PM_{2.5}$ baseline and controlled cases for 2014 (attainment demonstration) and 2020 over a 5 kilometer by 5 kilometer grid, adjusted to reflect over- and under-predictions with respect to the 2005 monitoring data.[2] Note, in each of the two plots, air quality improvements are denoted as a positive value.

[2] The 2005 $PM_{2.5}$ monitoring data were interpolated to grids with the Veronoi Neighbor Averaging weighting procedure, which identifies a set of monitors that surround a grid in all directions. Once the set of neighboring monitors are identified for that grid, a distance-weighted approach was used to estimate the average value for that grid.

FIGURE 3-3
Future $PM_{2.5}$ Concentration Changes

(a) 2014 Change in Annual Average $PM_{2.5}$ Concentrations (μg/m3)



(b) 2020 Change in Annual Average $PM_{2.5}$ Concentrations (μg/m3)

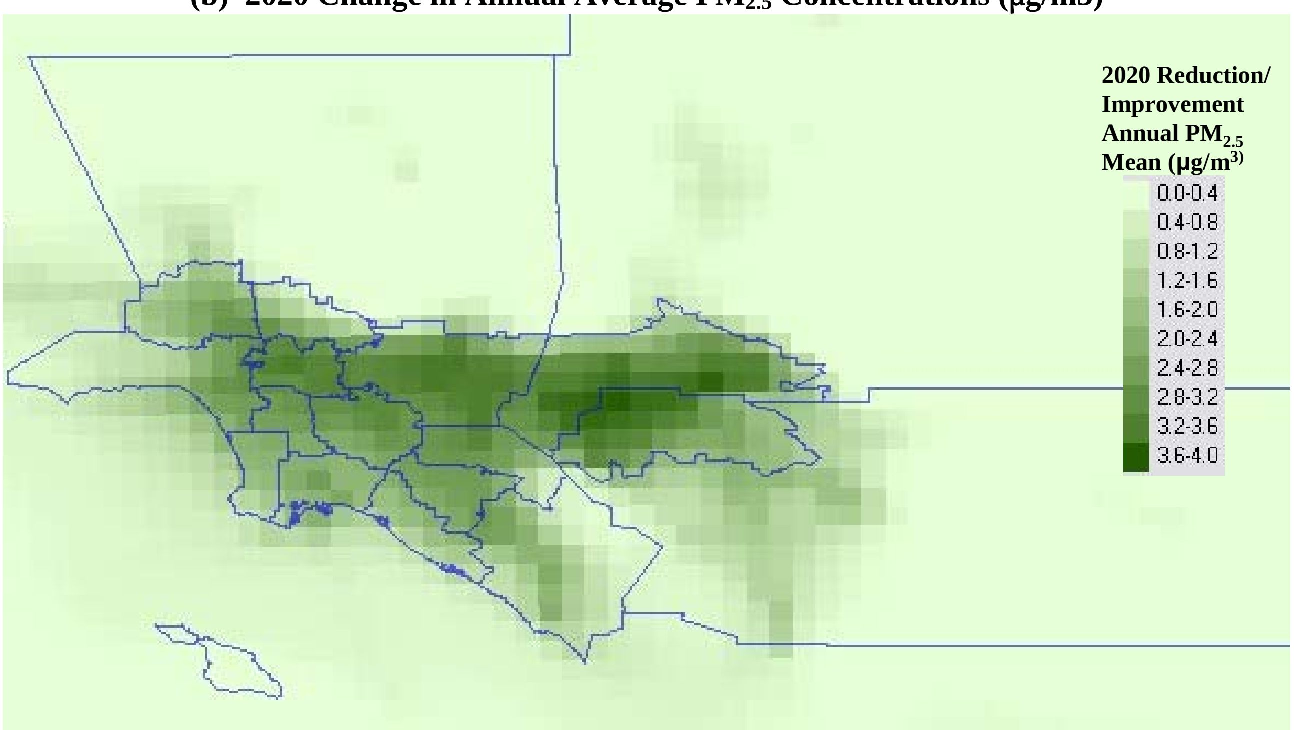


Figure 3-4 shows the change in average daily 1-hour maximum ozone concentrations between baseline and controlled emission scenarios which were projected from the grid interpolated ambient air quality data to the 2012 and 2023 model simulations.[3] It should be noted that ozone health benefits are also assessed in terms of 8-hour and 24-hour ozone concentrations. As with $PM_{2.5}$, ozone model simulations for 2005, 2009, 2012, 2020, and 2023 were used to develop a grid-based relative response factor (RRF) from 2005 to the future years. The factor is a non-dimensional multiplier that was applied to the observed 2005 data to project a future year concentration. RRFs are generated for each future year simulation (controlled and baseline) to determine the impact of the AQMP control strategy. It is important to note that the ozone analysis used only 19 episode days of model simulations to generate a set of hourly, grid level relative response factors. For this analysis, it was assumed that the RRFs generated from the 19 days can be applied throughout the year.

An assessment was made to determine if any bias was being introduced due to seasonal or diurnal variations in the response of ozone concentrations to implementation of the 2007 AQMP. The greatest seasonal variation observed in the RRF profile occurred in winter when the number of hours of daylight is at a minimum. Typically, implementation of the control in the 2007 AQMP shifted the hour of maximum concentration one to two hours earlier in the day. Despite this, the midday winter RRF pattern was similar to that of the remaining three seasons. The diurnal RRF profile, however, proved to be more critical to the future year benefit analysis.

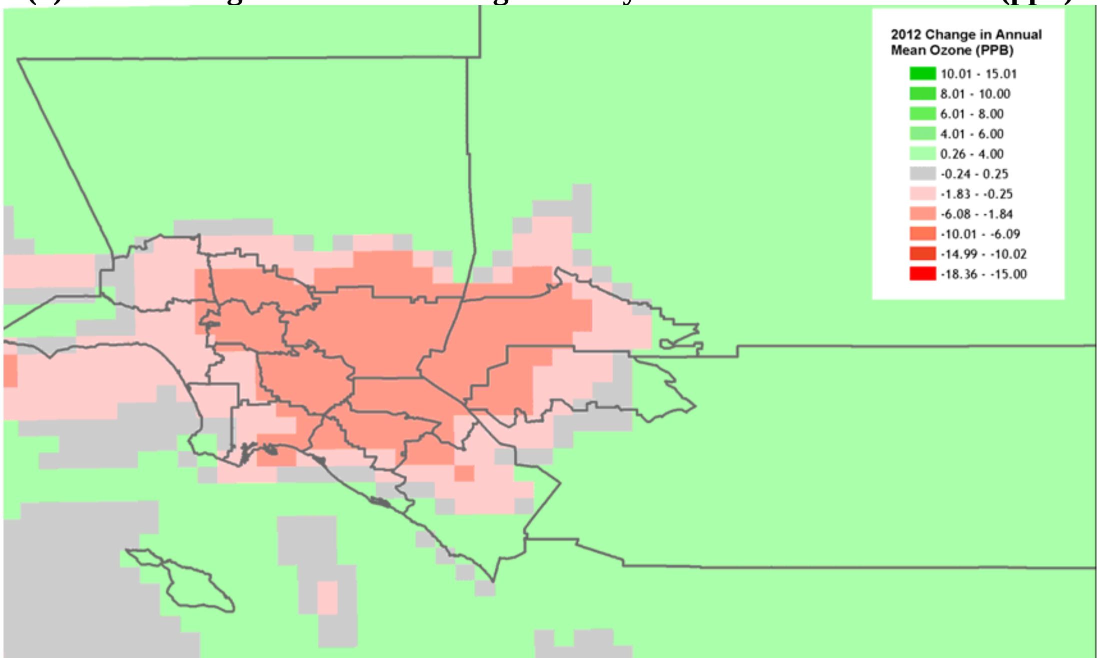
A review of the ozone simulations used in the attainment demonstrations for 2005 and 2023 revealed the potential for exaggerated nighttime ozone existed in the RRF calculation. In 2005, significant ozone titration was occurring in the nighttime and early morning hours of the day, thus reducing concentrations from near background concentrations (roughly 40 ppb) to less than 10 ppb. The 2023 analysis displayed less titration and ozone levels remained at roughly the background level. In essence, ozone was not being generated at night in 2023; it was just not being scavenged. The nighttime hourly net difference in ozone concentrations simulated between the two model years (i.e., 2005 and 2023) was typically less than 30 ppb. However, when the RRFs were calculated and applied to the 2005 interpolated monitoring data, this difference could amount to a factor of four increases, thereby greatly exaggerating nighttime projections of future year ozone to levels nearing Stage-1 episode concentrations at a time of day when sunlight is not available to generate ozone.

To eliminate the potential for artificially generating nighttime ozone concentrations, a minimum value of ozone of 30 ppb was set for the RRF calculation. Any ozone concentration simulated to be less than 30 ppb (in either 2005 or 2023) was raised to that level for the RRF calculation. The 30 ppb threshold is most likely conservative since that concentration is lower than boundary concentrations used in the simulations. This adjustment minimized the exaggerated nighttime ozone impact. Some areas of Central Los Angeles continued to experience a minor dis-benefit. Selection of a different set of modeling episodes or a more robust number of episode days could alter the outcome of the impact analysis.

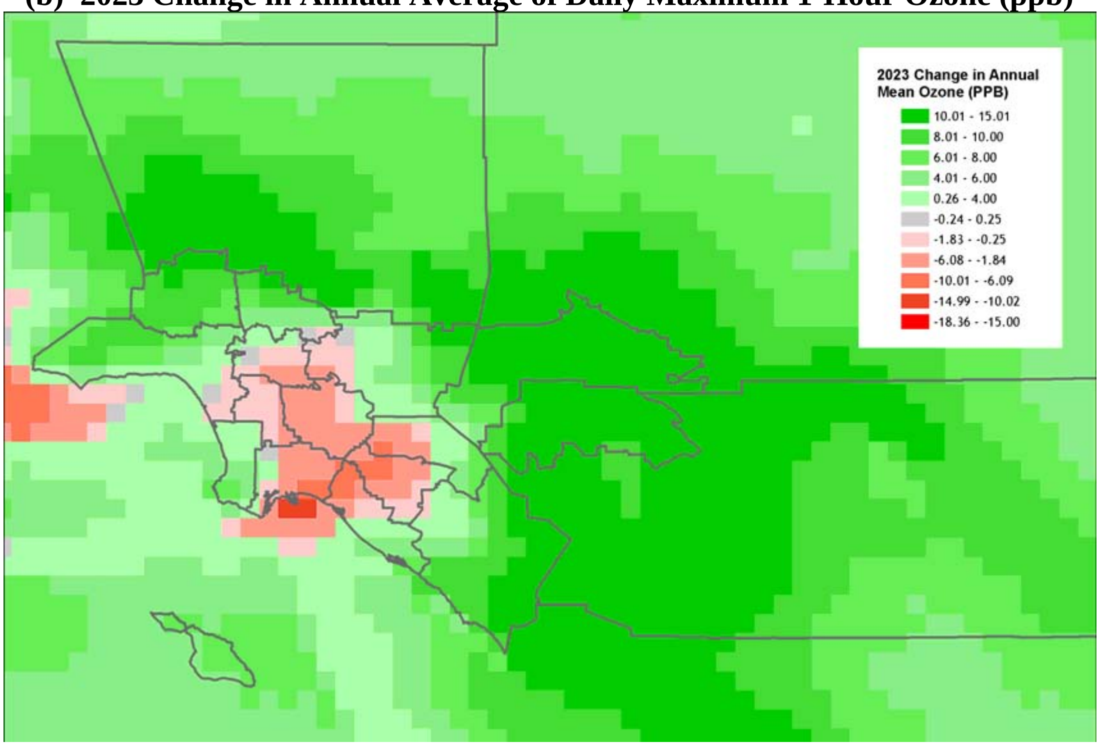
[3] Ozone concentrations were based on interpolated values of 2005 monitoring data. The four closest monitoring stations were chosen for each grid and the inverse of the squared distance from each monitoring station to the centroid of the grid was used as the weight in the interpolation scheme. Other schemes, such as kriging, are also available for interpolation. Interpolated values may vary by scheme.

FIGURE 3-4
Future 1-Hour Ozone Concentration Changes

(a) 2012 Change in Annual Average of Daily Maximum 1-Hour Ozone (ppb)



(b) 2023 Change in Annual Average of Daily Maximum 1-Hour Ozone (ppb)



As depicted in Figure 3-4, the areas to the east and north of metropolitan Los Angeles improve the most. Because the ozone strategy focuses on a "NOx-heavy approach," the metropolitan Los Angeles areas of the Basin will experience a nominal increase in 1-hour maximum daily ozone. Ozone titration, caused by the reaction with NOx, will be reduced in the metropolitan area. However, this portion of the Basin is typically the cleanest area and the nominal increase in concentration is not projected to cause a violation of the federal air quality standard. Figure 3-5 shows the change in average daily 8-hour maximum ozone concentrations between baseline and controlled emission scenarios which were projected from the grid interpolated ambient air quality data to the 2012 and 2023 model simulations.

The majority of the region's population is currently exposed to unhealthful air. Ozone can permanently scar lung tissue, cause respiratory irritation and discomfort, and make breathing more difficult during exercise. Children, the elderly, and persons who exercise heavily incur a higher rate of health effects. Assessments were made for changes in premature mortality and minor restricted activity days (MRAD) from reductions in daily 1-hour maximum ozone concentrations; respiratory hospital admissions from reductions in annual average 24-hour ozone concentrations; and school absence days from reductions in annual average of daily maximum 8-hour (9:00 a.m. to 4:00 p.m.) ozone concentrations for the benchmark years 2009, 2012, 2020, and 2023 between the Plan and the base case where no additional control beyond today's level is employed.

The ozone health benefit assessment herein was performed without any threshold since there is no clear threshold below which no adverse health effects are observed. A sensitivity test for evaluating ozone benefits relative to the California standards was conducted. The thresholds for each category of ozone measurements in health functions are listed in Table 3-2. In 2023, the benefit of a threshold analysis would be 7 percent of the benefit of a no-threshold analysis.

TABLE 3-2

Thresholds for Ozone Analysis

Annual	Thresholds Parts Per Billion (ppb)
Daily 1-hour maximum	90*
Daily 8-hour average	70*
Daily 24-hour average	30**

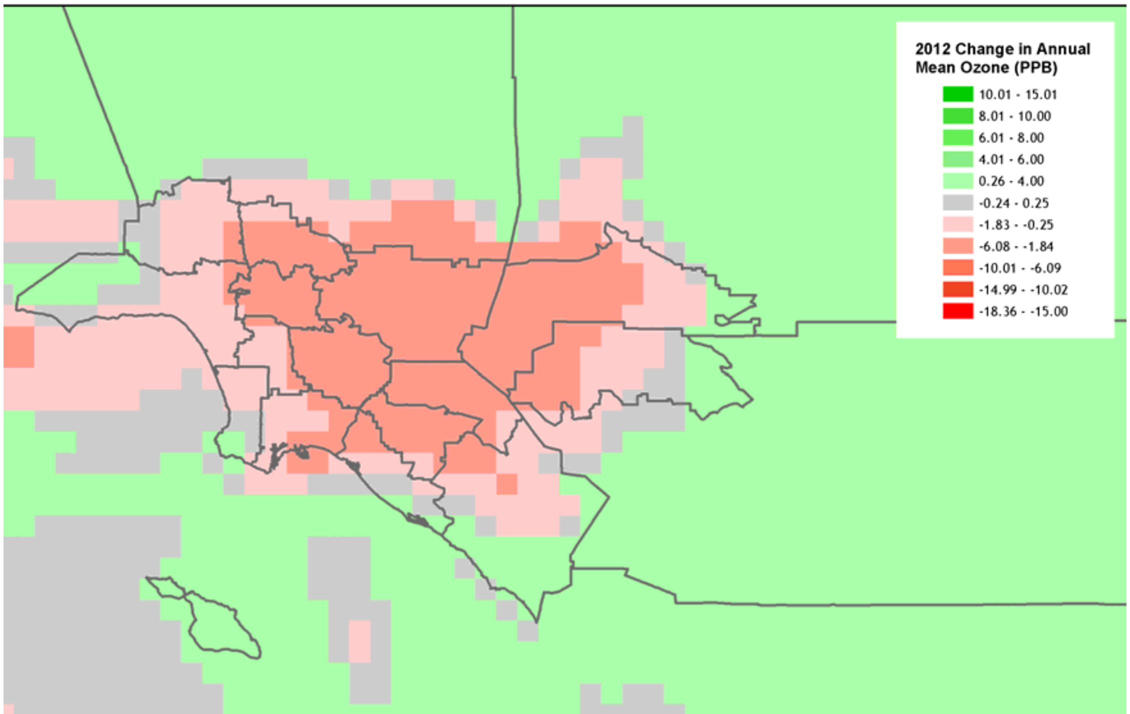
* California state standards

** Background level

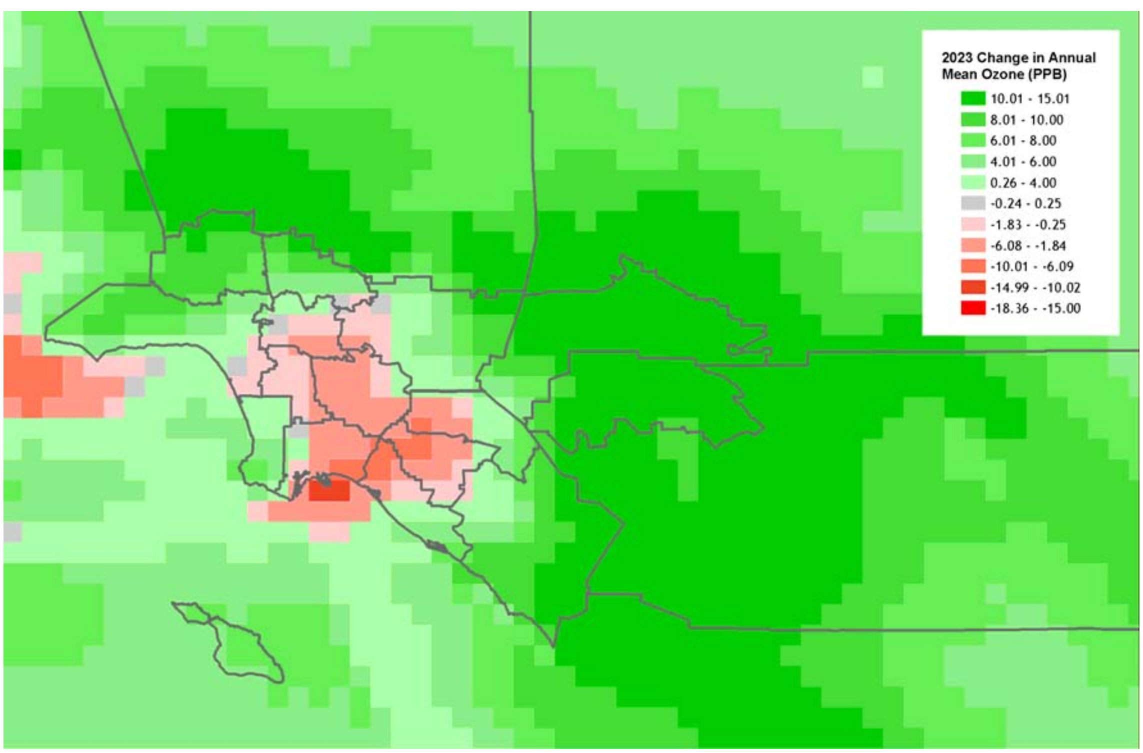
The main improvement in ozone air quality is projected to occur in the less populated northern and eastern portions of the Basin. When evaluated against the baseline ozone projections, implementation of the control measures is estimated to result in a nominal increase in ozone in the more densely populated western Basin. Despite the increase in ozone, those areas are expected to remain below the federal standard under the 2007 AQMP. Regardless, areas experiencing an increase in ozone concentration would incur a dis-benefit. This is due to the fact that significant NOx reductions are necessary to achieve $PM_{2.5}$ attainment throughout the region and also ozone attainment for the downwind area. If a different attainment strategy with more VOC controls (e.g., VOC/NOx Combined Alternative) is selected, the ozone dis-benefit would be reduced, but would still be inevitable. When $PM_{2.5}$ benefits are considered, overall

FIGURE 3-5
Future 8-Hour Ozone Concentration Changes

(a) 2012 Change in Annual Average of Daily Maximum 8-Hour Ozone (ppb)



(b) 2023 Change in Annual Average of Daily Maximum 8-Hour Ozone (ppb)



health benefits are positive even though some areas show higher ozone levels (but they are still below the federal standard). This is because the benefits from $PM_{2.5}$ reductions are greater than any negative impacts projected due to ozone increases.

$PM_{2.5}$ causes effects as extreme as premature death, as well as increased respiratory infection, asthma attacks, and other related health effects. Groups that are most sensitive to the effects of $PM_{2.5}$ are children, the elderly, and people with certain respiratory and heart diseases. Assessments were made for reductions in premature deaths and chronic bronchitis resulting from reductions in annual average $PM_{2.5}$ concentrations; and reductions in respiratory and cardiovascular hospital admissions, emergency room visits, asthma symptom days, MRAD, acute respiratory symptom days, and non-fatal heart attacks from reductions in daily $PM_{2.5}$ concentration for the benchmark years 2014 and 2020.[4] The $PM_{2.5}$ benefit assessment herein has no threshold employed. Based on an annual average $PM_{2.5}$ threshold at 12 micrograms per cubic meter ($\mu g/m^3$) and a (daily) 24-hour $PM_{2.5}$ threshold at 35 $\mu g/m^3$ (California standards) $PM_{2.5}$ health benefits would be reduced by 30 percent in 2014 and by 39 percent in 2020, compared to the no threshold analysis.

Table 3-3 shows the number of avoided cases by health effect when the Basin attains $PM_{2.5}$ and ozone standards. Reductions in health effects are translated into monetary terms based on the cost of illness (medical costs and work loss) or willingness to pay associated with each effect. The unit value of each health effect may vary by age, year, symptom, and/or county. There are three mortality functions (all ages) for ozone which give rise to three separate mortality estimates, i.e., low, central, and high numbers. For example, in 2023, ozone health benefits from decreases in premature deaths would range from a low of $647 million to a high of $1,930 million. Throughout the report, the central estimate is used. As summarized in Table 3-5, overall health benefits are positive even though some areas show higher ozone levels (but they are still below the federal standard).

TABLE 3-3

Changes in Number of Symptoms for Future Years*

Health Effect	Number of Avoided Cases: $PM_{2.5}$ (2014)	Number of Avoided Cases: Ozone (2023)	Unit Value
Mortality (Adult& Infant)	1,500	200	$5.4 - $6.5 million
Acute Bronchitis	2,700	N/A	$404
Chronic Bronchitis	800	N/A	$438,000
Non-Fatal Heart Attacks	1,300	N/A	$68,584 - $145,843
Lower & Upper Respiratory Symptoms	57,300	N/A	$18 - $28
Emergency Room Visits	500	N/A	$298
Hospital Admissions	600	1,200	$16,800 - $34,500
Minor Restricted Activity Days (MRAD)	1,061,300	842,700	$57
Work Loss Days	185,000	N/A	$126 - $152
School Absence Days	N/A	888,200	$75

*Changes reflect differences in base and control cases for a given year. Positive numbers are reductions in symptoms due to the 2007 AQMP. Negative numbers indicate increases in symptoms.

[4] The health function was applied daily and aggregated to 365 days for each benchmark year.

The avoided premature deaths for $PM_{2.5}$ in Table 3-4 include a pooled estimate from three $PM_{2.5}$ adult mortality functions. The baseline deaths represent the total number of expected deaths among the population 30 and above. The STMPRAG (Scientific, Technical and Modeling Peer Review Advisory Group) members did not reach consensus on how to weigh the three different studies related to $PM_{2.5}$ mortality. Some members wanted to give more weight to the Jerrett el al. study (2005) because it was performed using the Los Angeles monitoring data. Table 3-4 shows the range of avoided premature deaths from the three mortality functions for 2020 relative to the baseline number of deaths in the four-county area. A sensitivity analysis indicates that if the Jerrett et al. study was used, the number of avoided premature deaths would be 2,985. The Jerret et al. study would increase the health benefit for $PM_{2.5}$ by approximately 40 percent. However, other STMPRAG members recommended not using the Jerrett et al. study until it is replicated and corroborated by other researchers.

TABLE 3-4

$PM_{2.5}$ Premature Deaths by Adult Mortality Function in 2020

	Pooled Estimates	Pope et al.	Jerrett et al.	Laden et al.
No. of Avoided Deaths	2,017	1,128	2,985	2,826
% of Baseline Deaths	0.67%	0.37%	0.99%	0.93%

Table 3-5 shows the quantifiable health benefit of improved air quality associated with the 2007 AQMP for ozone and $PM_{2.5}$ morbidity and mortality relative to air quality without the Plan. The total health benefit is projected to reach $16 billion in 2023. On average, the annual benefit from 2007 to 2025 is approximately $9.8 billion. The $PM_{2.5}$ health benefit significantly outweighs the ozone benefit.

TABLE 3-5

Quantifiable Health Benefits

(millions of 2000 dollars)

Category	2014	2020	2023	Average Annual (2007-2025)
Ozone Morbidity	-$46	-$20	$143	$16
Ozone Mortality	-236	-21	1,291	237
$PM_{2.5}$ Morbidity	587	827	947	618
$PM_{2.5}$ Mortality	8,470	11,910	13,631	8,902
Total	$8,775	$12,696	$16,011	$9,773

Ozone benchmark years are 2009, 2012, 2020, and 2023. $PM_{2.5}$ benchmark years are 2014 and 2020. Benefits for non-benchmark years are linearly interpolated based on benchmark year estimates.

Agricultural Benefit

Ozone has been recognized to damage vegetation and many crops more than all other pollutants combined. Since the early 1970s, numerous studies have shown that ozone inhibits crop productivity and results in potential reductions in crop yield.

Based on published ozone damage functions (Olszyk and Thompson, 1989; Randall and Soret, 1998) for many crops (i.e., grapes, oranges, lemons, tangerines, beans, field corn, sweet corn, melons, watermelon, potatoes, spinach, tomatoes, cotton, alfalfa, wheat, and avocados) and the gridded air quality data, the cash value of increased crop yield from implementing 2007 AQMP was estimated for each air quality grid.

The location of the agricultural crops and acreage were plotted by spatially joining the Public Land Survey (PLS) grid system (1 mile by 1 mile)—which covers the township, range, and sections—and information on crop acreage (which refers to the PLS) from the 2004 California Department of Pesticide Regulation (CDPR) for the four county area. The result was then overlaid on top of the air quality modeling grid system (5 kilometer by 5 kilometer). The land area of grids was used to allocate crop acreage of a PLS grid that crosses more than one air quality grid. County crop acreage totals from the 2005 County Crop Report were used to normalize crop acreage at the air quality grid level.

Implementation of the 2007 AQMP is projected to increase the yield of 16 crops by $17.5 million in 2012 and $23.2 million annually in 2023, respectively. Of the 16 crops assessed, melons, beans, and grapes are the most sensitive to ozone. Table 3-6 shows the annual value of increased yield by county. Cash values for interim years were interpolated based on those for benchmark years. The analysis does not include the potential loss of agricultural land to urban sprawl.

TABLE 3-6
Cash Value of Increased Crop Yields
(millions of 2000 dollars)

County	2009	2012	2020	2023	Average Annual (2007 to 2025)
Los Angeles	$0.0	$0.0	$0.1	$0.2	$0.1
Orange	1.2	1.1	1.1	1.6	1.2
Riverside	15.5	16.0	17.5	20.5	16.6
San Bernardino	0.3	0.3	0.5	0.8	0.5
Total	$17.1	$17.5	$19.2	$23.2	$18.4

Visibility Aesthetic Benefit

It has been shown that visibility—the ability to see distant vista—has an impact on property values. To examine this relationship, researchers correlated sales prices of owner-occupied single-family homes between 1980 and 1995 with socioeconomic and housing characteristics of these homes and visibility data at the census tract level to arrive at a willingness to pay value for visibility (Beron et al., 2001).[5] The research was performed for Los Angeles, Orange, Riverside, and San Bernardino Counties. Results indicated that the marginal willingness to pay for visibility (or price of visibility) was related to the percentage of college degrees for people

[5] Property prices were used as a conduit to arrive at the willingness to pay for improved visibility, which is a function of visibility, the percentage of college degree of people over 25 years old, and net income. The recent rise in property prices may or may not change the relationship between these independent variables and the willingness to pay amount for visibility. Additional research is required to arrive at a definitive conclusion.

25 years or older, net income (household income minus housing cost), and visibility (in miles) at each location.[6]

Using visibility data for the benchmark years 2014 and 2020 and the projected net income and percentage of the college degree population (age 25 and above) at the sub-region level, the average monetary value of visibility improvements per household from the 2007 AQMP was calculated for each sub-region. These values were then annualized over a 50-year period at the four-percent real interest rate, which was then multiplied by the number of households to arrive at total values of visibility benefits. These totals were further adjusted downward by 55 percent to reflect visibility aesthetics only to avoid the potential aggregation of health and visibility embedded in the willingness to pay (Loehman et al., 1994).

The benefit for visibility improvements in 2025 was estimated using visibility data in 2020 and projected 2025 net income and percentage of the college degree population. Benefits for visibility improvements during non-benchmark years were linearly interpolated based on the benefits for benchmark years. The average annual visibility aesthetic benefit between 2007 and 2025 is projected to be $3.6 billion. Table 3-7 shows the visibility aesthetic benefit by county.

TABLE 3-7
Visibility Aesthetic Benefit by County
(millions of 2000 dollars)

County	2014	2020	Average Annual (2007-2025)
Los Angeles	$1,999	$3,220	$2,231
Orange	771	1,265	870
Riverside	260	386	283
San Bernardino	223	354	247
Total	$3,253	$5,224	$3,631

Material Benefit

Research has shown that ozone results in damage to rubber products such as tires (McCarthy et al., 1984). Damage from $PM_{2.5}$ to residential and commercial materials include accelerated wear and breakdown of painted wood and stucco surfaces of residential and commercial properties (Murray et al., 1985). In addition, $PM_{2.5}$ exposure will lead to additional household cleaning costs (Cummings et al., 1985).

The avoided damage to tires was calculated based on the peak 1-hour ozone concentration relative to the July 19, 2005 episode day in the ozone modeling domain (defined as 65 x 40 grids with 25 square kilometers per grid) and the total population in each county. The annual

[6] The marginal willingness to pay (MWTP) equation used for this assessment is:

$$MWTP = 9032.42 + 0.09Y + 200.73\,(COLLEGE) - 425.33V$$

Where Y stands for net income, COLLEGE for percentage of population with a college degree, and V for visibility.

The total willingness to pay (TWTP) for a specific reading of visibility is arrived at by integrating the above equation with respect to V:

$$TWTP = 9032.43V + 0.09YV + 200.73\,(COLLEGE)V - (\tfrac{1}{2})\,425.33V^2$$

average $PM_{2.5}$ concentrations at eight locations (five in Los Angeles County and one in each of the three other counties) were used to calculate the avoided household cleaning and damage to wood and stucco surfaces of residential properties that were projected to grow proportionately with the growth of housing units.[7] The avoided damage to commercial properties was assessed at three percent of that to residential properties. The analysis was performed at the county level for the benchmark years 2014 and 2020 for $PM_{2.5}$ and 2009, 2012, 2020, and 2023 for ozone. The 2025 avoided damage to tires was assessed based on the 2023 ozone data. The total avoided damage from all sources was linearly interpolated for interim years between 2007 and 2025 and allocated to each sub-region according to its proportion of population or housing units within a county.

The total benefit associated with the decrease in costs for repainting stucco and wood surfaces, cleaning, and replacing damaged materials is projected to be $188 million in 2014 and $308 million in 2023. Table 3-8 shows material benefits by county for selected years.

TABLE 3-8
Material Benefit by County
(millions of 2000 dollars)

County	2014	2020	2023	Average Annual (2007-2025)
Los Angeles	$111	$176	$181	$120
Orange	37	58	59	39
Riverside	25	40	42	27
San Bernardino	16	25	26	17
Total	$188	$299	$308	$204

Ozone benchmark years are 2009, 2012, 2020, and 2023. $PM_{2.5}$ benchmark years are 2014 and 2020.
Benefits for non-benchmark years are linearly interpolated numbers based on benchmark year estimates.

Traffic Congestion Relief Benefit

The four-county region is the most heavily congested area in the nation due to its urban sprawl and lack of affordable housing (Surface Transportation Policy Project, 2003). An estimated 85 percent of the freeway lane miles in the four-county region are congested, resulting in the loss of fuel, time, and productivity.

Implementation of SCAG transportation control measures (TCM) will reduce daily vehicle miles traveled (VMT) and daily vehicle hours traveled (VHT) in the four-county region, amounting to an average annual benefit of $966 million from 2007 to 2025 (Tables 3-9 and 3-10). TCMs include a wide variety of transportation projects such as arterials, grade crossing improvements, high occupancy vehicle lanes, mixed flow lanes, hot lanes/tollways, transit, intelligent transportation systems, truck lanes, commuter rail, high speed rail, and others. These projects have a combination of public and private funding.

[7] The 3.96 ratio of TSP to $PM_{2.5}$ was used to convert $PM_{2.5}$ to TSP, which was used in the original material benefit assessment (Murray et al., 1985). The household cleaning coefficient was adjusted downward by multiplying the proportion of soiling in the total contingency valuation (0.088).

Traffic congestion relief benefits were assessed for reductions in daily VMT for the period between 2007 and 2025. Reductions were calculated as the difference between baseline (without SCAG TCMs) and control (with SCAG TCMs) conditions for the benchmark years 2014, 2020, and 2023. Reductions in VMT were distributed to the 5 kilometer x 5 kilometer grid cell level using brake and tire wear in grams per mile and then aggregated up to the sub-regions in the four-county area. Daily VMT reductions were converted to an annual reduction by multiplying by 250 working days per year.

Implementation of the TCMs is projected to reduce VMT by 2.9 million miles in 2014 and 925,000 miles in 2020 and to increase VMT by 340,000 miles in 2023. The increase in VMT is due to the completion of new and improved roadways, which also increases traveling speed. VMT changes were allocated to three types of vehicles: passenger and light duty (86 percent), medium duty (7 percent), and heavy duty (7 percent) according to the baseline VMT associated with each type of vehicle. VMT reductions (or increases) for each vehicle type were allocated to each sub-region, which was then multiplied by the operating and maintenance cost per mile of that vehicle type to arrive at the benefit of reduced travel. The operating and maintenance costs for passenger and light duty vehicle were assumed to be 17.5 cents per mile (SCAG, 2004). Operating and maintenance costs for medium-duty and heavy-duty trucks were assumed to be 30.2 cents per mile (SCAG, 2004).

In the year 2014 an estimated $113 million of savings on vehicle operation and maintenance is expected, as shown in Table 3-9. By the year 2023, there would be an additional cost of $13 million on vehicle operation and maintenance because of the projected increase in vehicle miles traveled from the baseline. New and improved roadways accelerate speed of travel, which cannot be quantified here. On the other hand, they tend to attract additional traffic as well.

TABLE 3-9

Reduced Vehicle Operating and Maintenance Costs by Type of Vehicle
(millions of 2000 dollars)

Type of Vehicle	2014	2020	2023	Average Annual (2007-2025)
Passenger/Light Duty	$88	$28	-$10	$39
Medium-Duty Trucks	12.5	4	-1.5	5.5
Heavy-Duty Trucks	12.5	4	-1.5	5.5
Total	$113	$36	-$13	$50

Implementation of TCMs is projected to reduce VHT for business and commute trips by over 231,400 hours in 2014 and 361,600 hours in 2023. For the purpose of this analysis, it was assumed that 39 percent of VHT reductions were for business and commute trips and 61 percent were for personal trips (SCAG, 2004). Only VHT reductions for business and commute trips were included in the benefit assessment. Of the 39 percent reductions in business and commute trips, it was further assumed that 11 percent was for business and 28 percent was for commute trips (SCAG, 2004).

The benefit of VHT reductions for the sub-regions was calculated by multiplying the share of VHT within the sub-region by the appropriate hourly wage rate. Daily VHT reductions associated with commute trips were multiplied by an annual conversion rate of 250 and an hourly wage rate of $10.61, which is half of the average wage rate (BLS, 2006), to arrive at the annual benefit of spending less time on commuting. Daily VHT reductions from business trips were also multiplied by an annual conversion rate of 250 and an hourly wage rate of $24.26 for truck drivers (FHWA, 2004) to arrive at the annual benefit from VHT reductions for business trips. Savings from reduced travel time for business and commute trips is estimated at $826 million for 2014 and at $1.4 billion for 2023, respectively, as shown in Table 3-10.

TABLE 3-10
Savings from Reduced Travel Time by Trip Type
(millions of 2000 dollars)

Type of Trip	2014	2020	2023	Average Annual (2007-2025)
Business	$323	$537	$532	$358
Commute	503	837	829	558
Total	$826	$1,374	$1,362	$916

Unquantified Benefits

Areas in which benefits from improved air quality have been identified but not fully quantified include human health, building materials, plant life and livestock, and reductions in vehicle hours traveled for personal trips. Each of these areas is discussed below.

Health Benefit

The quantifiable health benefits associated with improved air quality were assessed relative to reduced morbidity and mortality from ozone and $PM_{2.5}$. The present state of knowledge does not allow all adverse health effects that have been identified to be measured and valued in dollars. Only 29 percent of the potential health impact areas (13 shaded cubes out of 45 in Figure 3-2) can be quantified at this time. It should be noted that many health effects cannot be valued in dollars mainly because sufficient data are not available to establish a quantitative relationship between pollutant level and health effect. Hence quantification of health effects may be underestimated.

Agricultural Benefit

There are several categories of crops where the effects of ozone have not been determined (e.g., dates, nectarines, peaches, walnuts, and plums). Based on studies conducted at the Los Angeles Arboretum, half of the plants tested showed visible improvements resulting from reduced ozone levels. In the four-county area, the nursery stock industry represented $626 million (2000 dollars) in wholesale values in 2005.[8] However, data limitations do not allow quantitative assessments from improved air quality for these plants.

[8] 2005 Crop and Livestock Report, 2005 Orange County Crop Report, and 2005 Agricultural Production Report.

In addition, air contaminants can also damage livestock, just as they do human beings. In 2005, the total value of livestock products in the four-county area amounted to $102 million and $617 million (in 2000 dollars), respectively.[9]

Material Benefit

In addition to the quantifiable materials damage caused by ozone and $PM_{2.5}$, a link exists between several pollutants (ozone, sulfur dioxide, $PM_{2.5}$, and nitrogen oxides) and ferrous metal corrosion; erosion of cement, marble, brick, tile, and glass; and the fading of fabric and coated surfaces. The damages and conversely the potential benefits from reducing the exposure currently cannot be quantified and valued in dollars.

Traffic Congestion Relief Benefit

Implementation of on-road control measures is projected to reduce daily VHT by 361,864 hours in 2014 for personal trips, relative to the 2014 baseline projections for VHT. Savings resulting from reduced travel time are difficult to quantify due to the variation of the value of time from one individual to another and were not included in this benefit calculation. Based on one-half of the average hourly wage rate ($10.61), savings from reduced travel time for personal trips is estimated at $1.1 billion (2000 dollars) for the year 2014. This could bring the total traffic congestion relief benefit to approximately $2 billion in 2014.

COSTS

The cost of attaining clean air in the four-county area includes expenditures on control equipment, low-polluting materials, and infrastructure investments. To quantify these costs, the two-step methodology described in Chapter 1 was applied. The majority of these costs are estimated based on currently available technology. Advancements in technology could lower these costs in the future. The costs associated with control measures for 47 percent of the emission reductions for the 2007 AQMP can be quantified. The cost for the remaining 53 percent emission reductions can only be approximated due to the lack of data on these control strategies.

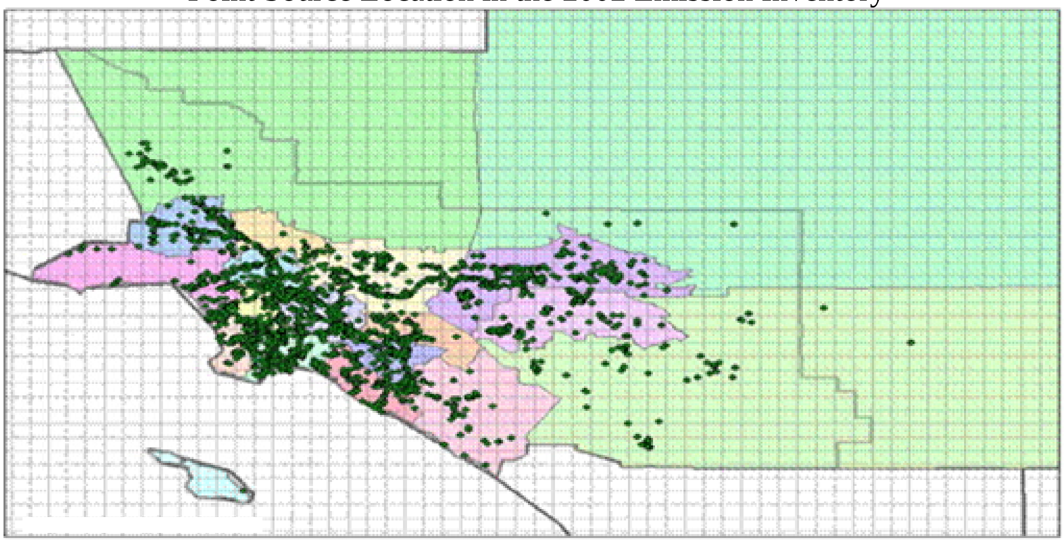
Quantifiable Measures

For each quantified point source control measure, cost data was developed for the entire District and then allocated to the industries and sub-regions to which the affected point sources belong based on the projected emission reductions in the 2007 AQMP and the 2002 emissions inventory data. Figure 3-6 shows the distribution of point sources in the 2002 emission inventory. Point sources include stationary, identifiable sources of emissions that release over four tons or more of VOC, NOx, SOx, or PM or emitting more than 100 tons of CO per year. For area, on-road, and off-road sources, the cost for each measure was assessed for affected industries in the District and then allocated to the 19 sub-regions based on emission reductions at each air quality grid and the correspondence between grids and sub-regions. The cost of each control measure is comprised of the annual operating and maintenance expenditure and capital

[9] Ibid.

expenditure annualized over the economic life of equipment at the 4-percent real interest rate. The cost of stationary source control measures does not include contingency, construction associated with the re-design of a facility to accommodate the new required device and permitting. The cost associated with these categories will be considered during rulemaking process.

FIGURE 3-6
Point Source Location in the 2002 Emission Inventory



Of the 199 public and private projects listed in the transportation control measures by SCAG (2006), 130 TCMs that have not been completed to date were quantified. Affected sub-regions are identified for each project via the use of ArcGIS, a geographical information system software developed by ESRI that incorporates layers of spatial data organized by a common geographical framework. ArcGIS was used to create maps of District and sub-region boundaries with the locations of key highways, streets, and cities. Annualized capital cost and annual operating and maintenance costs were calculated for each project within its implementation period. SCAG also identified public funding sources for these public projects such as local sales tax, state or federal sales tax on gasoline sales, alternative fuel tax, and motor vehicle tax. Private funding includes user fees in the form of toll or fare revenue and bonds. The cost burden is distributed to each county according to the proposed tax share in each county. Within each county the burden is distributed to each sub-region based on the proportion of sub-region population in the county.

The average annual control cost of all quantifiable control measures is projected to be approximately $1.8 billion from 2007 to 2025, of which SCAG TCMs have a cost of $430 million. Figure 3-7 shows the annual cost trend of quantified measures. The high costs in 2008 and 2009 came from SCAG TCMs as public funding for a number of construction projects is unleashed at once. The annual cost begins to climb up in 2012 as the implementation of mobile source measures is ratcheted up. Table 3-11 shows the distribution of control costs for quantified measures among various industries. The share of these control costs relative to industry output is also presented in Table 3-11. Among all the private sectors, the construction and water transportation sectors would experience the highest costs ($208 and $99 million, respectively) due to proposed controls on construction equipment, ships, marinas, and pleasure craft. The water transportation sector's cost would be approximately 15 percent of its output. The high cost for the government sector is because the implementation of several mobile control measures relies on incentives provided by governments. A number of manufacturing and non-manufacturing sectors have relatively low control costs. This is because a few measures affect almost all the industries in the district and their implementation costs were distributed according to the employment shares of these industries. Consumers would also experience a relatively large share of the costs since a number of measures, especially SCAG TCMs, are assumed to be financed by increases in various taxes.

FIGURE 3-7
Control Cost by Year

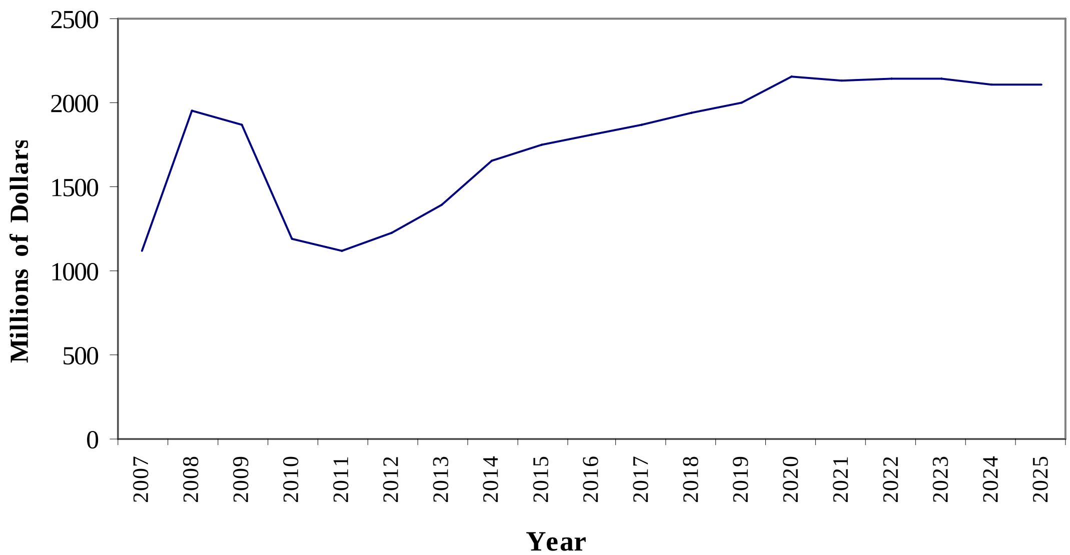


TABLE 3-11
Average Annual Control Cost by Industry and
as a Percentage of Industry Output (2007-2025)

Industry	NAICS	Cost (Million of 2000$)	Percent of Output
Agriculture, Forestry, Fishing, and Hunting	113-115	1	0.11%
Utilities	22	2	0.02%
Construction	23	208	0.45%
Wood Product Mfg.	321	1	0.02%
Nonmetallic Mineral Product Mfg.	327	2	0.04%
Primary Metal Mfg.	331	1	0.03%
Fabricated Metal Product Mfg.	332	3	0.02%
Computer and Electronic Product Mfg.	334	1	0.00%

TABLE 3-11 (Continued)

Industry	NAICS	Cost (Million of 2000 $)	Percent of Output
Motor vehicle and Transportation Equipment Mfg.	3361-3369	35	0.15%
Furniture and Related Product Mfg.	337	1	0.02%
Miscellaneous Mfg.	339	1	0.01%
Food Mfg.	311	1	0.00%
Beverage and Tobacco Product Mfg.	312	1	0.02%
Textile and Textile Products Mills	313-314	1	0.01%
Paper Mfg.	322	1	0.03%
Printing and Related Support Activities	323	1	0.02%
Petroleum and Coal Products Mfg.	324	28	0.23%
Chemical Mfg.	325	2	0.01%
Plastics and Rubber Products Mfg.	326	4	0.05%
Wholesale Trade	42	5	0.01%
Retail Trade	44-45	6	0.01%
Air Transportation	481	1	0.01%
Rail Transportation	482	30	1.67%
Water Transportation	483	99	14.63%
Truck Transportation; Couriers and Messengers	484,492	30	0.23%
Pipeline Transportation	486	1	0.07%
Scenic and Sightseeing Transportation	487-488	1	0.01%
Warehousing and Storage	493	1	0.04%
Motion Picture and Sound Recording Industries	512	1	0.00%
Monetary Authorities	521,522,525	1	0.00%
Securities, Commodity Contracts, Investments	523	1	0.00%
Insurance Carriers and Related Activities	524	1	0.00%
Real Estate	531	2	0.00%
Professional and Technical Services	54	5	0.01%
Management of Companies and Enterprises	55	1	0.00%
Administrative and Support Services	561	4	0.01%
Educational Services	61	1	0.02%
Ambulatory Health Care Services	621	2	0.01%
Hospitals	622	1	0.01%
Nursing and Residential Care Facilities	623	1	0.02%
Social Assistance	624	1	0.02%
Performing Arts and Spectator Sports	711	1	0.01%
Amusement, Gambling, and Recreation	713	7	0.10%
Accommodation	721	1	0.01%
Food Services and Drinking Places	722	4	0.02%
Repair and Maintenance	811	3	0.03%
Personal and Laundry Services	812	1	0.01%
Membership Associations and Organizations	813	1	0.02%
Private Households	814	1	0.11%
Government[1]	92	728	
Consumer		530	
Total		1772	

[1] There are no published dollar estimates for the output of the government sector.

Cost by County

Table 3-12 shows how the potential control costs are distributed among the four counties for the quantifiable measures. Los Angeles County could incur an annual cost of about $1,084 million, or approximately 61 percent share of the total cost. This is because most of the affected emission sources are located in Los Angeles County.

TABLE 3-12
Average Annual Control Cost by County
(millions of 2000 dollars)

County	Control Cost	% Share
Los Angeles	$1,084	61%
Orange	324	18%
Riverside	182	10%
San Bernardino	181	10%
TOTAL	$1,772	100%

The sum does not add to the total due to rounding.

Unquantifiable Measures

Thirty-three short-term measures are quantified with costs, which include 10 District stationary and area source measures, 10 CARB mobile source measures, and 13 District mobile source measures (two of which are clean fuel measures). The mobile source measures include both on- and off-road sources. Additionally, there are a total of 130 transportation projects in SCAG transportation control measures which were individually quantified. The weighted cost effectiveness by source category for these quantified measures is shown in Table 3-13.[10] The weights are emission reductions of individual measures within each source category.

TABLE 3-13
Cost Effectiveness (2000$/ton) by Measure Type

Control Measure Type	Weighted CE	Range of CE*
District Stationary & Area Source Measures	$6,843	$836 to $15,888
All Mobile Source Measures	$12,470	$456 to $25,337

* Proposed Modifications to the 2007 AQMP

On average, the total estimated cost for the unquantified portion of the Plan is projected to be $523 million annually. The cost of unquantified measures was estimated based on the weighted

[10]Control Measures TCM-1A, TCM-1B, and TCM-1C, which are part of the Regional Transportation Improvement Plan (RTIP), were not included in the calculation. This is because these measures were proposed not only for air quality benefit but for regional mobility. Therefore, emission reductions alone are not sufficient to capture the entire benefit of these measures.

The cost effectiveness value of the newly added Control Measure BCM-05 (Under-fired Charboilers) was not included in Table 3-13.

cost effectiveness of quantified measures by source category and the annual emission reductions of unquantified measures. The estimation also considers the implementation period of each unquantified measure. These estimates are rough projections and actual costs could be lower or higher.

A sensitivity analysis was performed by selecting the lowest and highest cost effectiveness values from each category of control measures listed in Table 3-13 to approximate the cost of unquantified measures. The sensitivity test shows that the total cost of these unquantifiable measures could range from $21 million to $1.1 billion annually.

SUMMARY

The 2007 AQMP projects the attainment of the federal air quality standards of $PM_{2.5}$ in 2014 and ozone in 2023, respectively. The total quantified benefit in 2014 is estimated to be $13.2 billion and increases to $23.3 billion in 2023 (Table 3-14). The quantified health benefits have not accounted for the reduction in all adverse health effects due to the implementation of the 2007 AQMP. In addition, benefits have not been quantified for reductions in vehicle hours traveled for personal trips; and reductions in damages to plants, livestock, and forests as a result of implementing the 2007 AQMP. If all these factors were considered, the estimated benefits would be higher than the estimates presented in this analysis.

TABLE 3-14
Total Costs and Benefits of the Plan
(millions of 2000 dollars)

	2014	2020	2023	Average Annual (2007 - 2025)
Total Costs	$1,710	$2,500	$3,963	$2,294
Quantified Measure Costs	1,655	2,160	2,138	1,772
Unquantified Measure Costs	55	340	1,825	523
Total Quantified Benefits	$13,173	$19,644	$23,277	$14,592

The total cost of the Plan is projected to be at $1.7 billion in 2014 and increase to $4 billion in 2023. The cost of quantified measures was based on the prices of equipment and materials that would be required for the implementation of these measures. The cost of unquantified measures was extrapolated based on the average cost effectiveness of quantified measures. Ninety-five percent of the emission reductions from short-term measures have been quantified with costs. A sensitivity test rendered on the unquantified measures shows that the total cost of the Plan (quantified and unquantified measures) could range from a low of $1.8 billion to a high of $2.8 billion annually, on average.

Since 53 percent of the intended total emission reductions belong to the unquantified measures, uncertainty exists regarding how reliable the average cost effectiveness of quantified measures would be in projecting the relatively large size of long-term measures. This is because as the District comes closer to its attainment goals for various pollutants, the cost in achieving the final increment towards attainment might actually result in higher costs than projected. It is also not clear whether the costs associated with maintaining attainment of various pollutants will be reflective of the currently projected costs. Historically, in many instances actual control costs are shown to be lower than projected costs due to cost reductions resulting from technological advancements over time. However, actual costs could be higher than projected costs if modifications to existing plant structure are required.

Further research is needed relative to quantifying the known health effects. Relative to costs, additional efforts will be made to work with the CARB and EPA to quantify the costs associated with long-term measures.