Air Quality in Southern California – Time for a Paradigm Shift

by Arthur Winer

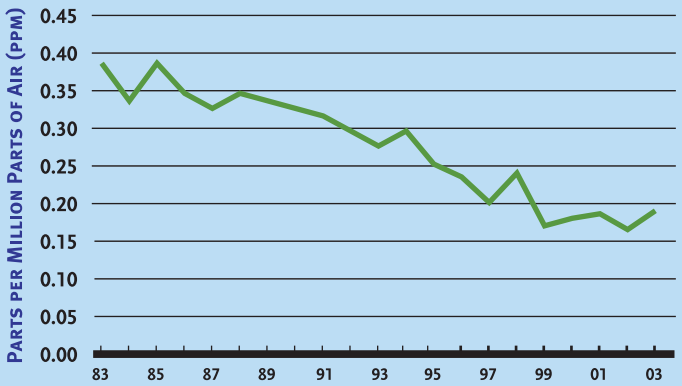
INTRODUCTION

As the result of an unprecedented and aggressive long-term air pollution control program for both mobile and stationary sources, the Southern California region can look back on thirty years of dramatically improved air quality and claim for itself one of the most remarkable environmental success stories anywhere in the world. Despite enormous growth – a doubling of population and a near tripling of vehicle miles traveled – the region now meets the federal air quality standards for four of the six pollutants originally regulated by the 1970 Clean Air Act, has eliminated all first, second and third stage air pollution alerts, and has reduced peak ozone levels by more than two-thirds.

These stunning achievements represent a triumph of government at every level, supported by an insistent public demand for clean air, and the sometimes reluctant but resourceful ability of business and industry to respond innovatively to stringent, technology-forcing measures adopted by the California Air Resources Board (ARB) and the South Coast Air Quality Management District (SCAQMD). The creation of the SCAQMD was itself a rare triumph of regional government in Southern California when in 1976 the counties of Los Angeles, Orange, Riverside and San Bernardino merged into this single regional air quality agency, implicitly recognizing that air pollution did not respect political boundaries.

However, despite thirty years of impressive progress – including improved visibility, lowered concentrations of harmful gases and particles, and elimination of eye irritation – there remains the potential that continued growth in population, emission sources, and vehicle miles traveled may endanger this record. Indeed, until the 2004 smog season, with its exceptionally clean meteorology and significantly lower pollution levels, the air quality records of the preceding five years suggested that improvements in levels of ozone and other pollutants were stalling (Figure 1), and that the region faces new challenges if we are to maintain our clean-air initiatives.

Figure 1
Ozone Pollution in the South Coast Air Basin
(Maximum One-Hour Concentrations)



** Federal ozone one-hour standard is 0.12 ppm*

Source: California Air Resources Board

This essay discusses two main hypotheses concerning Southern California's air quality issues. First, although it is essential to continue to implement the most cost-effective clean-air technologies available, technology alone is unlikely to rescue us from the pressures of continued growth to the degree it has in the past. Instead, if long-term air quality solutions are to be found, they are likely to be more dependent on other critical regional issues, including transportation, land-use planning, smart growth, energy conservation, fuel choices, and environmental justice. Second, while it is essential to continue our efforts to address the well-understood *regional* problem of photochemical smog, we need to confront a major new air quality concern on a completely different spatial scale, namely the *highly localized* health impacts of directly-emitted vehicle emissions. These health impacts – which are not yet well recognized by regional policy-makers – are a function of traffic densities and proximity to major roadways, and will further complicate land-use, transportation, smart growth and environmental justice policies in the region. We will show that the same set of regional planning issues is inextricably bound into both of these major air pollution problems, and that a new paradigm is required to address them effectively.

We begin by presenting a summary of the growing literature on the health impacts of direct exposure to vehicle exhaust, discuss what "close proximity" to roadways means, and describe implications for environmental justice concerns and for in-vehicle exposures. We then suggest a number of strategies for reducing exposures to vehicle emissions but also discuss the current limits of technological fixes, and the necessity for more effective transportation, land-use, and smart growth policies with respect to air quality issues. Finally, we suggest additional policy measures for improving regional air quality and note direct evidence of the benefits of further reducing exposure to vehicle emissions and to photochemical smog, and conclude with an appeal for greater cooperation between all of the relevant stakeholders.

PROXIMITY TO VEHICLE EMISSIONS AND HUMAN HEALTH

It has been well understood for decades that smog constituents such as ozone and secondary particles, the most serious regional pollutants, are formed in the atmosphere photo-chemically from volatile organic compounds (VOC) and NOx emitted primarily from mobile sources. Recently, however, atmospheric scientists and health researchers have come to understand the critical importance to public health of motor vehicle emissions at the other end of the spatial scale – within about 650 feet (or 200 meters) of freeways and other major arterials.

Over the past decade, studies from all over the world have shown that spending time in close proximity to heavy traffic, especially diesel vehicle traffic, is associated with a wide range of health impacts, including increased mortality.

For example, a study of 700 subjects in Germany found an association between exposure to traffic and the onset of a myocardial infarction within one hour. In England and Wales, an investigation of nearly 200,000 deaths from stroke showed that men living within 650 feet of a main road had a 7% higher stroke mortality than men living more than 3000 feet away from such a road. (Studies such as these take into account factors such as socioeconomic status and age differences.) Similarly, research in Amsterdam showed a higher risk of dying from lung or heart disease for adults living within 300 feet of a freeway.

In the United States, a study in Hunts Point, New York, a small area impacted by up to 20,000 diesel trucks per week, found not only increased rates of infectious and chronic diseases but also that the death rates from pneumonia, flu and stroke were twice that of New York City as a whole. Moreover, the asthma rate at Hunts Point was reported to be the second highest in the U.S. In another New York study, in Erie County, children living within 650 feet of heavily traveled roads were almost twice as likely to be hospitalized for asthma as children living 1600 feet, or more, away from busy roads.

In 1998 diesel exhaust particulate (DEP) was declared a toxic air contaminant by the California Air Resources Board, again based on wide range of clinical and epidemiological studies from throughout the world. For example a Finnish study showed that a group of healthy volunteers who exercised intermittently and breathed diesel exhaust for one hour showed well defined pulmonary inflammatory response. Similarly, respiratory fluids drawn from traffic officers in Rome contained ten times more particles, and larger numbers of macrophages and inflammatory cells, than samples from residents living in a relatively unpolluted town. Both a German study of infants and a Dutch study of 4,000 children concluded that children living near major roadways with heavy diesel traffic experience a higher prevalence of respiratory symptoms.

Here in the U.S., a study of subjects exposed to diesel exhaust demonstrated that even modest concentrations had clear inflammatory effects on both asthmatics and non-asthmatics. A California study of more than 2,000 children at 12 schools found a definite link between levels of black smoke, a marker for diesel trucks and buses, and both declines in lung function and increased respiratory symptoms. Investigators for this study concluded that truck traffic leads to significant health impacts to children living near major roadways.

Today we are concerned about not only fine particles, but also the very smallest-or ultrafine-particles, which are so small they are capable of penetrating cell walls and the blood-brain barrier. Ultrafine particles are much less well understood but initial data show their highest concentrations occur on major roadways, and reports are accumulating about the health impacts of such particles as a function of proximity to traffic. For example, British researchers examined the respiratory fluids of 22 children from 3 months to 16 years of age scheduled to undergo elective surgery. Ultrafine particles were found in all children, but the levels in children living on busy roads were triple that of those youngsters living on quiet streets. (For an overview of additional traffic-related health effects studies see www.healthandcleanair.org/spring2004, from which some of the studies cited above were taken.)

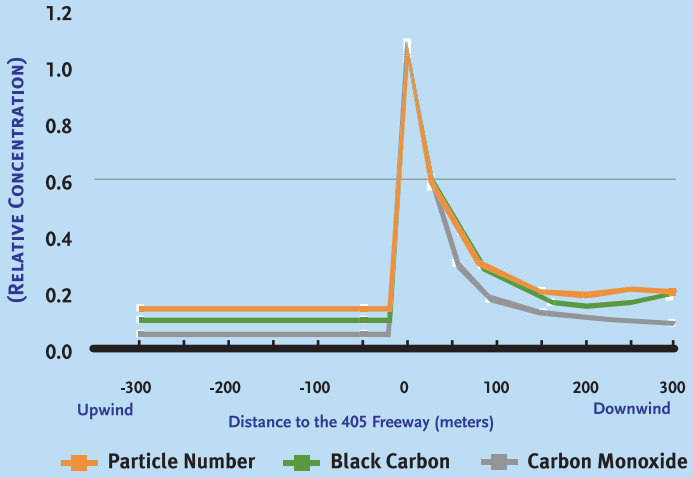
QUANTIFYING THE SPATIAL DIMENSION AND ITS IMPLICATIONS

Particularly over the past five years, UCLA, USC and UC Irvine researchers have moved to the forefront of research concerning highly localized impacts of vehicle emissions, for example by providing new physical evidence that vehicle-related pollutant concentrations spike at such roadways but then fall off fairly rapidly with downwind distance (under conditions of steady, moderate winds). Figure 2 shows data for black carbon, carbon monoxide and particle number obtained in 2002 by UCLA researchers for the I-405 freeway. Pollutant concentrations were low on the upwind side of the freeway, spiked upward dramatically at the freeway, and then fell to near background (or upwind) levels within about 650 feet or so of the freeway, on the downwind side. Similar results were found for the I-710 freeway. These results show clearly that locating homes, schools or other facilities within about 650 feet of major arterials can lead to elevated exposures to deleterious particles and gases for "downwind" occupants. Thus, these physical measurements of vehicle-related pollutants help explain the health effects observed in subjects living, working or attending school very close to major roadways vs those spending their time well away from major arterials.

The implications of both these recent physical measurements of pollutants levels and the accumulating health effect studies are gaining the attention of regulators and legislators. Partly in response to these new findings, the California Legislature passed regulations preventing the siting of new schools in California any closer than 500 feet of a freeway. However pre-school facilities have not yet received the same attention concerning their proximity to major roadways. The proposition passed by California voters to fund the "First Five California" Initiative, an unprecedented statewide effort to ensure that all young children enter school properly prepared, is likely to lead to a rapid expansion in "pre-school" training of children ages 1-5.

Figure 2

Relative Concentrations of Black Carbon, Carbon Monoxide, and Particle Counts Upwind and Downwind of the I-405 Freeway in West Los Angeles



Source: Zhu, Hinds, Kim and Siotas (2002)

It is critical to ensure that such new facilities are not built in close proximity to major roadways, and to conduct research concerning the prevalence of existing pre-school facilities close to major arterials.

The ARB recently sponsored a study session on the relationship between the location of sensitive receptors and air pollution sources. Although focused primarily on stationary source emissions and their implication for land-use, smart growth and environmental justice policies, this study session can be seen as a forerunner to similar workshops on the potential for using "distance criteria" with regard to siting new development near major roadways. The sooner such meetings bring together air quality, planning, and zoning agency representatives with developers and community advocates, to focus on mobile source emission impacts, the better.

ENVIRONMENTAL JUSTICE

Agency officials and academic researchers are growing increasingly interested in the broader societal implications of the health and measurement studies cited above, in part because they raise serious local health disparity concerns that may be overlooked by the existing regional-scale air quality standards (AQS) "conformity" process. For instance, even though Southern California has met federal AQS for carbon monoxide and nitrogen dioxide on a regional basis, concentrations will be more elevated along heavily-traveled roadways leading to disproportionate exposure along such corridors.

Concerns that areas with high traffic densities are primarily minority and low-income have been raised by a recent California Dept. of Health Services study of traffic distribution in California that found non-white children were about three-to-four times more likely to live in areas with high traffic density than white children. Researchers at UCLA and elsewhere are attempting to quantify environmental justice aspects of the health effects findings related to proximity to traffic, in particular identifying whether the search by low-income families for affordable housing in Los Angeles, and imposition of higher roadway densities in less affluent neighborhoods, lead to disproportionate vehicle pollution impacts on minority populations. Initial analyses show that while not necessarily benefiting from freeways, due to low vehicle ownership, minority and high poverty neighborhoods in Los Angeles bear over two times the traffic density of the rest of the southern California region.

This relatively new environmental justice concern about highly localized vehicle emission impacts adds to the more traditional concerns about disproportionate impacts of stationary sources (e.g. toxic release facilities) in minority communities. Although the SCAQMD and SCAG conduct sub-regional and socioeconomic assessments of air pollution, our growing understanding of the health risks for populations near major roadways emphasizes the critical need for transportation and air quality planners to address the highly *localized* impacts of vehicle-related pollutants, particularly in the context of the environmental justice issues discussed here.

IN-VEHICLE EXPOSURE

The demonstration of highly elevated vehicle-related pollutant concentrations on or near major roadways has profound implications not only for occupants of near-roadway homes and schools, but also for the exposure of passengers in vehicles traveling in congested conditions. Over the past 15 years research has shown that in-vehicle concentrations of exhaust pollutants are several times higher than those measured at nearby fixed site monitors and in many cases higher than measured along roadways. Recent studies in southern California with real-time instruments and "chase-car" techniques have served to quantify current in-vehicle exposures associated with Los Angeles freeways and surface streets, especially when following diesel vehicles. One of these chase car studies, using an electric vehicle to avoid any contamination by the vehicle's own exhaust, has shown up to ten times higher concentrations of ultrafine particles within the cabin of the chase car while driving on congested freeways compared to urban background concentrations.

A recent analysis by a UCLA doctoral student of the experimental data from another chase car study indicates that although the average person in California spends only about 1.5 hours (or 6% of a day) driving, this time spent in vehicles will typically be the most important factor in their overall daily exposure to diesel exhaust particulate, accounting for one-third to one-half of their 24 hour exposure to DEP. Table 1 shows the average concentrations of black carbon, a marker of diesel exhaust particulate matter, experienced by a passenger car occupant following various vehicles and exhaust configurations. The clear message is that traffic congestion which forces cars to follow diesel vehicles closely, especially diesel trucks and buses with low exhaust, leads to highly elevated exposures of the passenger car occupants (and that drivers should do their best to avoid driving directly behind such vehicles, particularly those emitting black smoke).

Table 1
Black carbon concentrations measured inside a passenger car while following various vehicles in Los Angeles. (Fruin, Winer and Rodes, 2004)

Vehicle Followed	Black Carbon Concentration Inside Vehicle ($\mu g/m^3$)
Gasoline Passenger Car	~5
Diesel Truck with High Exhaust	13
Diesel Truck with Low Exhaust	21
Transit Bus with Low Exhaust	90

Source: Fruin, Winer and Rodes, 2004

In the past five years, scientists have also conducted two studies of children's exposure in diesel school buses in southern California. The most recent and comprehensive of these studies, conducted by UCLA/UC Riverside researchers, investigated not only the school bus microenvironment but also bus stops and a school loading/unloading zone. These scientists measured a wide range of particle and gaseous pollutants using real-time instruments to capture the dynamic behavior of the exhaust from nearby vehicles, as well as of the moving bus platform itself. For example, spikes in black carbon concentrations aboard the school buses, due to emissions from other school buses and from diesel trucks traveling nearby, exceeded 40 to 50 ug/m^3, far higher than ambient concentrations of black carbon in Los Angeles away from traffic (typically in the range of 1 or 2 $\mu g/m^3$).

This research also demonstrated for the first time that all of the buses studied experienced "self pollution." That is, a portion of the exhaust from the school bus itself entered the cabin, a phenomenon generally not observed in vehicles such as passenger cars. How to minimize or eliminate self-pollution is the subject of on-going research.

Clearly, reducing children's pollutant exposure during bus commutes is an effective way to protect their health, and cost-effective measures for achieving such reductions have been communicated to all 1700 school districts in California by the ARB, based on the recommendations from the UCLA/UCR study.

REDUCING VEHICLE-RELATED EMISSIONS: A TRIPLE WIN

We have seen that vehicle emissions not only dominate the regional problem of photochemical smog, but also threaten the health of those living, working or schooling in close proximity to roadways, as well as all of us who spend time on congested arterials. All three of these impacts call for renewed efforts to both reduce vehicle emissions, especially diesel vehicle emissions, and the number of vehicles on roadways. Immediate and practical measures are needed. Programs to phase out the dirtiest diesel school buses must be accelerated and school bus operators should be forced to maintain bus engines to eliminate visible smoke.

The current exposures of the longest-commuting children on diesel school buses in Southern California are unacceptable. Incentives should be found to encourage more rapid turnover or retro-fitting of the dirtiest diesel trucks, especially once cleaner diesel fuels and emission control technologies become available in the next few years. Similarly, we should continue to strongly encourage conversion of commercial fleets from diesel or gasoline to natural gas, hybrid, or all electric vehicles.

Particular focus is needed on eliminating "super emitting" passenger vehicles which constitute only about 10% of the vehicle fleet but represent almost half of the emissions of carbon monoxide and VOC's and about 90% of the particulate emissions from passenger cars.

To date the Smog Check program has failed to adequately address the problem of super-emitters (e.g. by not including the oldest vehicles), but making the Smog Check program more effective by further reducing fraud and tampering, for example, could pay big dividends. Other measures to minimize the number of high-emitting vehicles include requiring longer warranties for emission control systems, and implementing "buy and crush" programs for older vehicles. Remote-sensing technologies which can identify high-emitting vehicles are already in use in other states. California needs to seriously consider adoption of such technologies in support of Smog Check and "buy and crush" strategies. The recent decision by the legislature and governor to include the oldest

vehicles in the Smog Check program is a step in the right direction, since these vehicles are prime candidates for becoming super-emitters.

Adopting more stringent fuel economy standards, or even just enforcing the existing federal standards would be helpful. On the other hand, we should be cautious about allowing widespread introduction in Southern California of diesel engine automobiles, as is happening in Europe. We must be absolutely confident such vehicles cannot turn into high emitters of NOx and particulates as they age and/or are poorly maintained. Light-duty diesel "super-emitters" would be even more of a serious problem than gasoline super-emitters with respect to the direct health impacts of mobile sources. Finally, electrification of truck transfer stations and cargo ship docks could materially reduce emissions from these important sources.

THE LIMITS OF TECHNICAL FIXES

Although the measures suggested in the preceding section offer practical approaches to reducing vehicle emissions, there remains a striking paucity of other technological solutions for dramatically reducing overall emissions in the region over the next 10-15 years. For example, a major criticism of the current 2003 Air Quality Management Plan, is that more than half of the emissions reductions shown to be needed to eventually meet the federal AQS for ozone and fine particles are included in a "black box" of undefined control measures. In fact, SCAQMD officials have publicly stated they have run out of viable options for further reductions in stationary source emissions, and that essentially the entire burden for further improvements in ambient air quality must fall to the ARB and mobile source controls.

But while the ARB remains the most progressive air agency in the world, it too may be running out of "silver bullets." The ARB's zero emissions policy foundered for lack of sufficient advancements in battery technology, and most of today's new passenger cars are already ultra-low emitting (ULEVs) or even super ultra-low emitting (SULEVs), with little prospect for further meaningful reductions in tailpipe emissions.

Although hybrid vehicles are a welcome addition with respect to fuel economy, and may represent a bridging strategy through the "peak oil" era, in most cases (especially for "mild" hybrids) they do not offer dramatic improvements in emissions over conventional gasoline SULEVs. Moreover, market penetration of hybrids is unlikely to be more than 25% of total sales even a decade from now. The development of commercial, cost-effective and energy-saving hydrogen vehicles with significant market penetration lies even further into the future, notwithstanding current publicity about hydrogen highways.

Heavy-duty (HD) diesels, both on and off-road, as well as marine traffic and aircraft, remain among the most problematic emission sources in the basin. While gasoline vehicles and many stationary sources became much cleaner, diesel truck, marine and aircraft emissions have been much less regulated. As a result, these three types of emission sources have emerged as major contributors to regional particulate matter, as well as oxides of nitrogen (NOx) and a range of air toxics. As noted earlier, the ARB was finally able to overcome the opposition of the diesel trucking and engine manufacturing industries and declare diesel exhaust

particulates a toxic air contaminant in 1998, augmenting the federal emission control program for heavy-duty diesels commencing in 2007. However, because of the very slow turn-over of HD-diesel trucks, compared with gasoline vehicles, these dirty sources are likely to be with us for a long time, unless cleaner diesel fuel and retrofit control technologies are widely adopted and prove to be exceptionally effective. Adopting these strategies aggressively is essential given the explosive growth in freight movement in the region resulting from the role of the Long Beach and Los Angeles Ports as gateways to Asian trade (as discussed later).

Given SCAG's population projections for the region – which account for recent declines in birth rate but still project robust growth – and the corresponding increase expected in vehicle numbers, it is clear we need to augment the remaining technical fixes with significant reductions in vehicle miles traveled (VMT). Thus, while the air quality agencies will find their efforts to reduce *emissions per VMT* increasingly difficult, it is transportation, smart growth and land-use strategies designed to reduce *VMT itself* that will become increasingly critical to the region's air quality program.

TRANSPORTATION POLICIES

With respect to transportation policies to reduce motor vehicle use and their emissions, the question remains will the region reach a point at which high fuel costs, near-gridlock congestion, and the health-effects evidence cited above begin to encourage meaningful alternatives to the automobile culture that has dominated southern California for the past sixty years? To date, of course, this has not happened. Despite three decades of transportation control measures by SCAG and other agencies, the average occupancy of passenger cars in southern California has not significantly varied from about 1.2 occupants per vehicle during that entire time. Moreover, the move to ever larger, heavier, less fuel efficient and higher-emitting SUV's and light trucks over the past decade suggests that both the public and the vehicle manufacturers still are not ready to consider a major shift in mobility options in regions like southern California. It seems likely that only sharply higher fuel costs associated with "peak oil" and the continued trend toward intolerable congestion will bring about a public demand and political will for alternatives.

In the meantime, we should pursue available transportation strategies that have the potential to reduce VMT and emissions now, including increased carpooling and vanpooling, "congestion pricing," use of smart shuttles at the community level, and introduction of so-called "intelligent transportation systems." Light rail projects offer the advantage of reduced health impacts from both regional and local air pollution, and such projects should be encouraged where present or future densities make subsidized rail transit reasonable.

For most of the region, however, given relatively low population densities and the enormous geographical extent of Southern California, bus service utilizing CNG buses remains the most cost-effective and air quality-beneficial alternative to automobiles. But such service needs to be enhanced if is to be more widely used, including coordinating services across various local providers, wider adoption of express lanes, and continuing to modernize and expand the bus fleet. More effective leadership and successful models are needed in pursuing these air quality/transportation strategies and such models can be found in many European cities. Closer to home, much can be learned from Portland's effective use of a sophisticated mix of integrated transportation and land-use strategies. Which brings us to the intersection of air quality and smart growth/land use policies here in Southern California.

SMART GROWTH IMPLICATIONS

Any strategy that meaningfully reduces VMT should be supported and encouraged. Key features of the smart growth movement – creating housing next to jobs and services, using mass transit hubs as foci for residential housing, and otherwise reducing dependence on the automobile – have the potential to reduce trips, especially the all-important "cold starts" which account for most of a gasoline vehicle's emissions for a typical city trip. However, an important implication of the health effects and measurement research cited above is the tradeoffs that must be weighed in proceeding with smart growth strategies such as mixed-used and infill development. For example, we must be careful to avoid promoting higher housing densities in immediate proximity to freeways and other heavily traveled arterials or we risk offsetting the gains from fewer trips with greater exposure to vehicle exhaust.

Smart growth strategies must also take into account that mixed-use patterns that place housing above or immediately adjacent to commercial, industrial, or retail businesses run the risk of impacting residents with toxic air emissions. Obvious examples are dry cleaners still using perchloroethylene, restaurants that are sources of fine and ultrafine particles (especially fast food restaurants relying heavily on frying), gasoline stations, and small industrial sources of VOC, heavy metals or other air toxics. Fortunately both the ARB and SCAQMD are beginning to interact with planners, zoning agencies, developers and community advocates to address these concerns.

LAND-USE IMPLICATIONS: BUILDING BUFFERS

Our new understanding of the near-proximity health impacts of vehicle exhaust also has implications for land-use policies in the region's transportation corridors, namely the need for buffers along major roadways, especially freeways, to prevent housing, schools and child-care facilities from locating within about 650 feet. Of course this can only complicate transportation strategies based on widening freeways, or creating entirely new roadways, and can also impact the critical need for affordable housing by the less affluent. A key policy question is what alternatives can be found if – based on public health concerns – the comparatively affordable housing immediately adjacent to freeways were to be eventually eliminated, and what would be the overall trade-offs in terms of the health and welfare of affected populations? In large portions of the Inland Empire and Orange County, for example, it is middle class housing that is likely to be affected, as well as less affluent housing. More research is needed on who lives along the major roadways of the region, and on the social and economic implications of restricting future housing development within buffers of about 650 feet of such arterials. All of this pre-supposes that regulatory mechanisms can be found – in the face of private property and local community control issues – that would permit future land-use policies to restrict development within appropriate buffers along major arterials. The issues of compensation and the legality of removing land from development in these buffers, or even eventually removing existing, loom large and require attention.

REDUCING PHOTOCHEMICAL SMOG

It is important to emphasize that the strategies discussed above to reduce VMT and per vehicle emissions, thereby reducing *near-proximity* exposures to vehicle exhaust, will also benefit the *regional* photochemical smog problem. Vehicles remain the dominant source of most of the criteria pollutants and reducing such emissions is ultimately critical to bringing the entire region into conformity with the new and more stringent federal air quality standards for ozone and $PM_{2.5}$. However, more can be done, beyond the measures cited above for reducing motor vehicle emissions.

Greater cooperation and coordination is needed between the SCAQMD and Los Angeles/Long Beach port officials. The current tensions between these agencies needs to be replaced by a much closer scrutiny of the regional air quality impacts of the proposed dramatic expansion of the ports – especially given that the ports are now the single largest stationary source in the basin for several key pollutants. Both the ARB and the SCAQMD must continue to press the EPA for greater regulatory control of aircraft and marine emissions, and

quantify more accurately the cumulative emissions from all airport activities within the South Coast Air Basin.

Other strategies not involved with exhaust emissions but which might make meaningful contributions to reducing regional smog include addressing more effectively faulty vapor recovery systems at gas stations, mandating portable gasoline containers that trap evaporative emissions, and continuing efforts to educate consumers not to top off their tanks during refueling or to spill gasoline accidentally.

BENEFITS

A number of modeling studies have shown that meeting the federal AQS would be a net benefit economically, in terms of reduced mortality, fewer lost work days, less hospital admissions, and lower overall medical costs for respiratory illnesses. However, demonstrating experimentally the *direct* health benefits of reducing VMT and vehicle emissions is more difficult since most emission control programs phase in over long periods of time. Fortunately, we now have data from the 1996 Olympic Games in Atlanta that quantify and support anecdotal evidence from the Los Angeles Olympics. Analysis of data from the 1984 Olympics in LA suggested that even with only a 10% reduction in daily trips, traffic flowed more freely and air quality improved significantly in southern California.

During the 17 days of the Atlanta Olympic games, residents responded strongly to pleas that they leave their cars at home and take the bus. As a result traffic congestion all but disappeared on the major roadways (away from Olympic venues) and concentrations of traffic-related pollutants fell by up to 50% from levels predicted by air quality models for normal traffic densities. An immediate effect was seen in emergency rooms where during the 17 days of reduced traffic, acute care visits for asthma fell by more than 40%. A drop of about 10% was seen in visits for acute asthma attacks in emergency pediatric departments. This "inadvertent" experiment in Atlanta, and earlier in southern California, shows clearly the immediate health benefits of reducing vehicle trips and the corresponding vehicle-related pollutant emissions, and bolsters the traffic-related health effects studies cited earlier.

Beyond the direct improvements in the health of millions of children and adults, many other social, environmental and economic benefits accrue from reducing VMT and vehicle emissions, as well as from improving fuel economy. Examples include lower fuel expenditures, less dependence on foreign energy sources, reductions in greenhouse gas emissions, and less congestion and lost productivity.

CONCLUSION

This essay has documented that the air pollution problems of Southern California manifest themselves at two distinct spatial scales: the well recognized regional photochemical smog problem, and the currently less-well understood highly localized impacts of vehicle emissions (especially from diesel vehicles) immediately adjacent to and on major roadways. Addressing both types of air quality impacts raises new challenges for government, the private sector and the public.

Unless a new arsenal of effective emission control programs can be developed, including for the first time addressing marine and aircraft emissions in a meaningful way, growth in the region may prevent us from ever reaching the more stringent health-based ambient air quality standards for ozone and particulate matter promulgated by EPA in 1997. At the other spatial scale, the challenge over time is to develop buffers along major roadways in order to minimize direct exposure to vehicle exhaust. Both challenges argue for pursuing strategies that offer viable alternatives to the automobile, encourage more rapid transition to cleaner diesel vehicles of all kinds, and provide greater collaboration between policy-making agencies in the region.

Once again the Southern California region has an opportunity to provide leadership to the rest of the nation and to be a model for other mega-cities around the world, most of which are struggling with serious air quality problems and many of the same infrastructure and planning impediments as found here. The decisions made over the next ten years will determine whether southern California continues to be a world leader in responding to the full range of air pollution issues identified in this essay, or a symbol of the failure of regional policies to address the critical interconnection of air quality, transportation and land-use policies at the mega-city level.

Nothing less than a paradigm shift is required, in which urban planners, transportation experts and air quality specialists, as well as the private sector and those concerned with environmental justice at the community level, come together to develop integrated approaches that can be effectively implemented to protect public health. As emphasized repeatedly in this essay, these approaches must address the problem at both spatial scales: the regional smog problem, and the immediate impacts of vehicle exhaust on commuters and those living, working or schooling in close proximity to major roadways. The time to begin this paradigm shift is now.

Arthur M. Winer is Professor of Environmental Health Sciences, and a core faculty member in the Environmental Science and Engineering Program, in UCLA's School of Public Health.