Boston College Environmental Affairs Law Review

Volume 4 | Issue 4 Article 5

1-1-1975

Controlling Oxidants in Los Angeles

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CONTROLLING OXIDANTS IN LOS ANGELES

*by Paul B. Downing**

Professional students of environmental affairs decry their seeming lack of influence on environmental policy decisions. In spite of their best efforts decisions are continually made primarily on political grounds. It is my hypothesis that at least part of the reason for this is that the output of technical and economic analysis is so confusing that it provides no guidance to decision makers. A case in point is the very detailed analysis conducted within the U.S. Environmental Protection Agency (EPA) in the first half of 1973 on alternative policies for controlling photochemical oxidants (smog) in the Los Angeles Air Quality Control Region (LAAQCR).

On January 15, 1973 William Ruckelshaus, then Administrator of EPA, proposed a most unbelievable plan for the control of photochemical oxidants in Los Angeles.[1] This plan called for a massive program for the control of emissions from used cars and various stationary sources. The most striking component of the plan was the requirement that travel by motor vehicle be curtailed by 82 percent during the summer months (May-October). The primary method of accomplishing this reduction was to be gasoline rationing.

There was immediate reaction to the announcement of this plan. Neither politicians, pollution control officials, nor the general public took the plan seriously. It was generally agreed that an 82 percent reduction in the driving of cars was so far beyond the achievable as to be ludicrous; a 20 percent reduction, maybe, but not 82 percent. Furthermore, various experts argued that an 82 percent reduction in vehicle miles traveled (VMT) was not even necessary. For example, Los Angeles Air Pollution Control District (LAAPCD) officials claimed that the oxidant standard will be met by 1980 without any gas rationing and with only a modest retrofit program. Rand Corporation studies indicated that it may be possible to meet the standard by 1977 without gas rationing. Others argued that if Detroit would clean up the car the problem would be solved.

How did EPA find itself in the position of proposing a plan which even they admitted was beyond reasonable bounds? As we shall see, it was a combination of physical facts and legal/political constraints. The physical characteristics of the basin make control very expensive. The inversion layer is very low and air movement constricted. At the same time Los Angeles is extremely dependent on the automobile for transportation. This combination results in a control requirement beyond EPA's estimate of the capability of purely technological (device installation) solutions; hence, 82 percent gas rationing. Legally EPA had to propose such a plan. The Clean Air Act does not allow for delays beyond 1977 in meeting the oxidant standard, and EPA was under court order to comply with the Act. Even EPA acknowledges that 82 percent gas rationing is too high a price to pay for clean air. Some lesser level of control will ultimately be instituted.

How much control? When? By what means? The people of Los Angeles must ultimately decide. The purpose of this article is to review EPA's role in this debate, present the technical considerations and uncertainties, and suggest a method of proceeding toward the ultimate decision.

I. Background

The Clean Air Amendments of 1970[2] require that states submit for approval to the Environmental Protection Agency *detailed* plans for implementing the national ambient air quality standards.[3] California's initial plan for Los Angeles indicated that the oxidant standard would not be met in 1975 or 1977 (in fact not even in 1985). Consequently, on May 31, 1972, EPA disapproved the transportation control portion of California's Los Angeles plan.[4] A deadline of February 15, 1973 was set for the submission by California of a new transportation plan. On November 16, 1972 the U.S. District Court ordered EPA to prepare a proposed plan for the Los Angeles AQCR by January 15, 1973.[5]

The task of preparing the proposed plan was given primarily to two analysts in the San Francisco Regional Office. By mid-December they had consulted with many experts and had produced a plan which was presented to and approved by EPA Administrator Ruckselshaus. This proposed plan was published in the Federal Register on January 22, 1973.[6] This is the now famous "gas rationing" plan.

The plan was grossly misinterpreted by the press. Headlines warned of 82 percent gas rationing. Only by careful reading of articles written by the few informed reporters could the public determine the full extent of the plan. Basically the plan consisted of three major components. First, several additional controls would be placed upon stationary sources of hydrocarbons (HC). Second, a very extensive retrofit program would be initiated consisting of the installation of catalytic reactors and evaporation controls on a large percentage of the used car population. Also to be required was the implementation of a loaded annual emission inspection for all light and heavy duty motor vehicles and the conversion of fleet vehicles to gaseous fuels. Third, vehicle miles traveled would be reduced by as much as 82 percent, but only during the most smog-prone period of the year. The required reduction in VMT would be obtained by rationing gasoline during the months of May through October.

On January 19, 1973 Robert Fri, Deputy Administrator of EPA, appointed the "Los Angeles Task Force."[7] The Task Force had two primary responsibilities: to conduct the public hearings required by law, and to provide a complete technical evaluation of all aspects of oxidant control in the Los Angeles AQCR.

The public hearings were held at various locations in the region over a three week period. The stated purposes of the hearings were to obtain public comment on the plan and various alternatives suggested in the Federal Register notice and to obtain technical assessments and data. In fact, the public hearings were not a very effective method of accomplishing either of these tasks.[8]

The general public reaction can be summarized as follows. The gas rationing part of the plan was not taken seriously by any except the most avid conservationists. Even the Sierra Club argued for a milder form of VMT reduction, while recognizing that lower VMT reductions meant not meeting the federal oxidant standard in 1977. Many individuals and local public officials blamed the automobile manufacturers for not developing a clean car. It became obvious at the hearings, and during subsequent attempts by members of the EPA staff to obtain information, that no significant support or cooperation would be forthcoming from state or local pollution control agencies. Their attitude was that the Clean Air Act was excessively stringent and that it was not desirable (economically or politically) to meet the federal oxidant standard in 1977.[9] The most the public appeared willing to accept was a strong stationary source control program, a fairly strong auto retrofit program, and a VMT reduction of 20-30 percent. People would prefer obtaining the VMT reduction by building bus lanes, taxing gasoline, and restricting parking. Gas rationing would be accepted to obtain 20-30 percent VMT reduction only as a last resort. Any further reductions would be unacceptable. Since the participants in the public hearings were generally more pro-control than the population as a whole, this probably represented a high estimate of what the public would accept.

II. Technical Analysis

The principal component of photochemical oxidants is ozone (O_3) which is a very rapid oxidizer of materials such as rubber and paint. A second component is nitrogen dioxide (NO_2), a brown poisonous gas which produces the characteristic brownish color found in Los Angeles air. Aerosols (microscopic liquid droplets) which substantially reduce visibility are also produced. Finally, there are small quantities of other chemicals such as peroxyacetyl nitrate (PAN) which are powerful eye irritants. All of these materials are referred to in the popular literature as "smog."

Photochemical oxidants are formed by the chemical reaction between certain hydrocarbons (HC) and nitrogen oxides (NO_X) in the presence of sunlight. Reactivity is the concept employed to indicate which HC compounds (designated as RHC) will react with (NO_X) to produce oxidants. This reaction takes place over time, being very fast for some HC compounds (highly reactive) or very slow for others. As is further discussed below, however, even this fairly simple notion has been the subject of considerable confusion.

A control strategy for photochemical oxidants must concentrate upon the sources of HC and NO_X. These emission sources may be divided into two categories — stationary sources and mobile sources. Stationary sources include power plants, oil refineries, dry cleaners, etc. In California primary responsibility for the control of emissions from stationary sources is granted to the Air Pollution Control District for the county in which the stationary source is located. Mobile sources include automobiles, trucks, buses, motorcycles and aircraft. The California Air Resources Board (CARB), a statewide organization, has primary responsibility for the control of these sources. Since each mobile and stationary source has different emission characteristics and presents different control problems, an effective control program must be very detailed and complex. Furthermore, control of one source may affect the emissions of other sources. For example, a tax on gasoline may increase the use of buses and, consequently, their emissions. An effective plan must take these interactive effects into consideration.

In the process of developing the preliminary plan, and in subsequent public and scientific community reactions, many technical issues were raised. One of the assignments given by the Administrator to the Los Angeles Task Force was to assess and reconcile uncertainties in these technical areas. Five study groups were formed to carry out this assessment. One group addressed the health effects of oxidants and the experimental justification for the national primary standard for oxidants which had previously been set at 0.08 parts per million (ppm).[10] Another group examined the air quality model which was used in the preliminary plan in order to develop a more accurate relationship between emissions of HC and NO_X and expected levels of photochemical oxidants. A third group concentrated upon the current emissions from stationary sources and the control technologies available for their reduction. A fourth group performed a similar inventory and study of available controls for mobile source emissions. The final group concentrated upon the methods of reduction of VMT. The following sections will present a summary of the principal findings of these groups.

Health Effects of Oxidants

The Clean Air Act requires that the EPA Administrator set "national primary ambient air quality standards, . . . the attainment and maintenance of which, in the judgment of the Administrator, based on such criteria and allowing an adequate margin of safety, are requisite to protect the public health."[11] Pursuant to this requirement, EPA had surveyed the reported health effects caused by oxidant exposures of various levels and set the national standard at 0.08 ppm. Due to the severity of controls required for Los Angeles to achieve this level, however, many, including EPA personnel, questioned the necessity of such a low standard. A complete review of the literature used in setting the oxidant standard[12] was undertaken and subsequent studies reviewed for pertinent data. It was found that the study of a sensitive group of asthmatics,[13] which was used as primary justification for setting the standard at 0.08 ppm oxidant, had been incorrectly interpreted. Instead of observing effects in this group at 0.10 ppm oxidant as the Criteria Document states, the study showed these effects only at 0.25 ppm oxidant. Other epidemiological studies have shown effects in the 0.20-0.25 ppm range in man and animals. Effects have been shown in animals, but not in man, at lower concentrations. The results of these and other health effects studies are summarized in the Appendix.

Other studies have shown radiomimetic (radiation-like) effects on animals at 0.20 ppm oxidant.[14] These effects are thought to be similar to those found for exposures to radiation of many times the levels considered safe for man by the Atomic Energy Commission. Furthermore, epidemiologists do not feel that there is any level of radiation exposure which does not cause some damage to man. This raises the possibility that there is *no* threshold (the maximum exposure level which causes no adverse health effects in man) for photochemical oxidants. The premise of the Clean Air Act is that there is such a threshold.

The interpretation of the results of this assessment is somewhat ambiguous. If the radiomimetic studies are ignored, no effects are found in man below 0.20 ppm. Adding a "reasonable margin of safety" to this observation may yield a primary standard of 0.15-0.18 ppm. On the other hand, if there are truly radiomimetic effects, a standard of 0.00 ppm can be justified within the context of the Act. This is clearly unattainable any where in the world, since background levels range from 0.02 ppm to 0.06 ppm.

Thus EPA is left with an unworkable definition of clean air. How clean should it be? This question can only be answered after an open public debate in which the benefits of various levels of cleaner air are weighed against their costs. The answer most certainly will vary from place to place. What level is best for Los Angeles? Nobody knows, but the most desirable peak oxidant level for the LAAQCR in 1977 is just as likely to be above the 0.20 ppm level as below it.[15]

Air Quality Model

In producing the preliminary control plan which had drawn all the public criticism, a very simplistic model of oxidant formation had been used. Basically it assumed a direct linear relationship between reactive hydrocarbon (RHC) emissions and observed peak oxidant levels. Since the peak oxidant level in 1970 was 0.62 ppm and the national standard was 0.08 ppm, an 87 percent reduction in RHC emissions would be required.

Several technical objections were raised to the use of this procedure. First, it uncritically accepted estimated 1970 emissions of RHC. Since this estimate determines the allowable RHC emissions in 1977, errors in estimating the 1970 emissions can have a very substantial effect on the amount of control required. This issue will be further discussed below. Second, many studies have indicated that oxidant formation involves both RHC and NO_X emissions. This relationship depends both on the level and relative mix of the two emissions and is therefore non-linear. Finally, because of prevailing ocean winds, it is necessary to relate upwind emissions to downwind observations of peak oxidants.

A more sophisticated model of oxidant formation in the LAAQCR was devised by EPA analysts to take into account these non-linearities and wind effects.[16] This model required an even stricter 91 percent reduction from the estimated 1970 RHC emissions and a corresponding reduction in NO_X emissions in order to meet the federal oxidant standard.

It should be noted that the EPA interpretation of air quality in Los Angeles is highly controversial. Many scientists, including representatives of the LAAPCD, argue that the most effective way to control oxidants is by reducing NO_X by large amounts relative to RHC. They argue that the high relative NO_X emissions resulting from the control of RHC and CO without control of NO_X emissions in new 1966-1970 model year cars has caused a lower reaction rate but a higher potential peak oxidant reading. Other scientists argue that almost exclusive attention should be paid to the control of RHC. A lack of resolution of such fundamental disputes has been one reason for the inability to gain either public or scientific acceptance for various control proposals.

Stationary Sources

This group concerned itself with two related questions. First, what were the emissions of pollutants from stationary sources in 1970?[17] Second, what additional controls can be placed on stationary sources and with what effect?

The California Air Resources Board (CARB) presented a baseline inventory of emissions of total and reactive HC and NO_X as well as other pollutants for the LAAQCR in 1970. In order to proceed with stationary source controls it was necessary to critically evaluate this inventory.[18] Reports are first received by the LAAPCD from various sources detailing fuel usage, solvent usage and their chemcial properties. These are then multiplied by emission factors to yield estimated emissions. The emission factors are derived from engineering studies and from the results of tests run when controls were installed for the individual source. The group found three primary problems with this estimation technique.

First, there is no reason to believe the usage data presented by the source. Sources know how much they can use without being in violation of current LAAPCD rules and may adjust their data accordingly. However, this was not thought to be a serious problem compared to the others listed below.

Second, the estimation technique assumes that all control devices never break down or are turned off, that they always work at the removal rate found during the certification testing procedure, and that required fuel and solvent switching is done correctly and on time. However, devices do break down and may not be operated when required. The effect of this on actual emissions is unknown, but it is clear that the current inventory represents a lower bound estimate. The level of maintenance can also materially affect both the rate of degradation and the probability of a breakdown. The correct emission factors would take non-compliance and degradation into account. Based on work done by Downing and Watson,[19] a rough guess would be that emissions range from 3 to 10 times the reported levels.

Third, the estimated emission level of RHC depends upon the definition used for reactivity. Since the region has a long retention time for emissions, especially during the summer, many compounds which would be considered non-reactive in other air basins should be considered reactive in this basin. The 1970 inventory for RHC was calculated using LAAPCD's legal definition of reactivity which counts as non-reactive many compounds that most scientists feel are highly reactive.[20] The EPA definition, on the other hand, counts almost all hydrocarbon compounds as reactive because of the long retention time in the Los Angeles basin. Since the inventory uses the LAAPCD definition, it again underestimates true emissions of RHC. EPA attempted to obtain the data required to estimate stationary source emissions of RHC using its definition from the LAAPCD, but was not granted access to their files.[21] As with the estimates of total HC emissions, any estimate of RHC emissions made on this very limited set of data is subject to great error.

There are a number of additional control methods which may be employed to reduce stationary source emissions of RHC.[22] These include the use of activated carbon adsorption for dry cleaning establishments, substitution of nonreactive 1, 1, 1-trichloroethane for compounds now used in degreasing operations, expanded use of high solids and water based coatings and control of evaporative emissions from gasoline marketing operations. Some feel that such controls are now available, or could easily be made available, for all but very small operators using the applicable process. Others feel that many of these controls are highly speculative and unproven. Thus, the policy maker is faced with yet another uncertainty. Clearly, more control than was employed in 1970 is available, but no one can say how much more with any great confidence.

Mobile Sources

The primary mobile source and presumably the largest single contributor to the photochemical oxidant level is the automobile. Estimates of its contribution range from 60 to 90 percent of the problem.[23] Even without additional controls, however, the automobile's contribution is expected to decline both in absolute and relative terms through 1980. But if the air quality standard is to be met by 1977 additional controls on *used* cars will be needed. The same two basic questions must be asked for automobile emissions as were asked for stationary sources. First, what were the emissions from automobiles in 1970? Second, what can be done to reduce these emissions? Again the answers to both of these questions are highly uncertain and controversial.

There are several methods of measuring the emissions of automobiles. The car to be tested is run through one of the several alternative driving patterns and the emissions are measured. For any given driving pattern emission measurement in terms of grams per mile will differ for cars of different model years. Furthermore, the number of miles the average car in each model year is driven differs. Combining these various factors, a total automotive emission estimate may be calculated for any driving pattern. Even within this simple framework, however, there have arisen several disputes.

First there has been disagreement over what constitutes a typical driving pattern.[24] EPA's CVS-1 test, employing only a cold start, and CVS-2 test, employing both a cold and a warm start, have been the major candidates. Interestingly, the CVS-1 test makes older cars dirtier relative to newer cars. Since older cars were heavily represented in the 1970 car population but will be relatively scarce in the 1977 car population, more emission reductions would result from the normal process of attrition using CVS-1 rather than CVS-2 emission estimates. Consequently, fewer additional controls would be needed.

Second, as with the stationary source inventory, the issue of reactivity has to be addressed. For some reason the reactivity assumption for automobile emissions used by California and by EPA counts more compounds as reactive than does the assumption for stationary sources. Thus, the assumptions are inconsistent and make stationary sources appear cleaner relative to the automobile.

Finally, while the emission estimates do take into considerations the average degradation that occurs over the life of a car, they assume all cars have their control devices installed and in good working order. In the presence of virtually no enforcement to insure that this is the case, it is almost certain that emissions were substantially higher in 1970 than the estimates. In fact several news reports have been published indicating that many people have been tampering with these controls in order to prevent stalling, balky starting, poor performance, and poor gas mileage associated with controls.[25] In summary, the emission inventory for automobiles is a highly uncertain lower bound estimate of true emissions in 1970.

Presumably, federal new car standards will eventually lead to a reduction in the emissions of new automobiles even if the 1975-76 standards are deferred as President Ford has requested.[26] Most concern therefore has been directed to the subject of retrofit devices for older cars. Currently there are four principal devices being considered for installation in some or all of the used car population: vacuum spark advance disconnector (VSAD), exhaust gas recycler (EGR), catalytic converter, and evaporation controls.[27] Each of these devices has been subject to considerable criticism and uncertainty. Questions have been raised about their effectiveness as well as their interaction with the other automotive systems. Because technology is evolving, other questions have revolved around the dates by which the devices will be required and the potential costs to the car owner. Concern has been expressed over the health effects of massive retrofitting of catalytic reactors. Recent research has indicated that large volumes of platinum oxides in the form of fine particulates are emitted from catalytic reactors.[28] Since it is well known that fine particulates and metal oxides can be significant health hazards, there is the possibility that the cure may be worse than the disease in this case. Even more recently, additional concern has been voiced over sulfur oxide emissions from catalytic reactors.[29]

The CARB provides us with an example of the type of difficulties control agencies can get into when mandating controls.[30] In an effort to reduce NO_x emissions from the 1966-69 model year cars (NO_x emissions had increased due to efforts to control HC and CO emissions from these cars) the CARB passed a regulation requiring every car in this group to have an approved control device installed. They approved five devices, three of which were based on VSAD and two of which were based on EGR. Evidence gathered after the approvals were granted indicated that the VSAD devices caused a rapid increase in valve wear which led to substantial increases in emissions of all pollutants and large repair bills. The EGR devices did not have this problem. The CARB considered this new evidence and decided to suspend all approvals until more information could be gathered. The five companies which had "approved" devices were left with stocks of these device kits which had been produced in anticipation of the July 1, 1973 implementation date. In the meantime cars remained uncontrolled until 1974 when the program was reinstituted due to additional evidence that the problems were not as serious as originally thought. Similar problems could occur with any mandated device which has not been tested on large numbers of different cars.

Adding to the above difficulties were internal inconsistencies over the availability of lead-free gasoline which was required for the proper functioning of catalytic reactor retrofits. The official position adopted by EPA was that only 75 percent of the 1971-74 model cars, 20 percent of the 1966-70 cars and none of the older cars could be retrofitted. This position was based on automobile manufacturers' estimates that not more than the above cited percentages of automobiles could be made to function "properly" on 91 octane lead-free gasoline. At the same time someone within EPA (it is not clear who) decided that 94 octane lead-free gasoline would not be available (or would not be required to be made available) in the LAAQCR by 1977. If higher octane gasoline were made available, this could increase the applicability percentages substantially.

At the same time this applicability decision was announced internally, it was also stated that, contrary to then current EPA policy, evaporative control retrofit kits would not be available by 1977. The argument used was that since no such kit existed or had been tested up until that time, EPA could not *guarantee* that such a kit could be produced by 1977. Yet this was no different from what had been done with all new 1970 model domestic and foreign cars sold in California. The fact is it *could* be done, but would be expensive (about $150 per car). This decision appeared to be based on economics rather than technical infeasibility.

Vehicle Mile Travel Reductions

Since emissions per vehicle mile could not be reduced below a certain level, it was obvious that substantial reductions in automobile vehicle miles traveled (VMT) would be required if the oxidant standard was to be met. Proposed strategies generally revolve around making the automobile less attractive relative to alternative methods of transporation. There are two general ways this can be done. One is to increase the price of automobile travel relative to mass transportation. The other is to change the relative time of travel.

Unfortunately, automobile price elasticity studies indicate that a very large increase in the cost of driving would be needed in order to obtain a small decrease in VMT.[31] This is, of course, more true for necessary trips such as to and from work and less true of other trip types such as vacations or shopping. It also appears that even large price decreases for public transportation, including free transit, have very little effect on demand. Generally, greater elasticity has been found for changes in travel time than was found for price changes. Studies indicate that demand can be substantially affected by changes in the time it takes to travel by car and find parking. This appears to be true also for changes in the frequency of trips and time of travel of public transportation.

The required VMT reduction in Los Angeles indicates price increases of at least 200 percent. However, existing studies are not valid for extrapolating that far. With increases in price and/or travel time increases of this magnitude, people may move to locations nearer their work or they may just move out of the air basin. They also will give up many trips they otherwise would have taken. They will suffer higher costs and massive inconvenience. But how this will affect VMT and the demand for public transportation cannot be reliably determined from existing studies.

III. Integrated Control Model

The major job faced by the Task Force was the assimilation of all of the control option information produced by the various technical analyses outlined above. The great variety of control policy options available made it impossible to determine by ordinary means an optimum or preferred policy, because many of the options interact with one another. It was also difficult to decide at what level a particular category of sources should be controlled relative to other sources. To resolve this problem adequately it was necessary to consider all of the important interactions among control policies as well as the costs.

Formulating, developing, and operating a model which would do this was an exceptionally difficult and time consuming task beyond the time and resource constraints of the Task Force. Fortunately, the Rand Corporation had been working on such a model for about one year when the Task Force was formed. The model was calibrated for San Diego but with recalibration and modification it was made to address the relevant quesions for Los Angeles.[32] The principal goal of this study was to determine an optimum set of control strategies for each of several peak oxidant goals for 1977 (ranging from 0.25 to 0.08 ppm) and then to investigate the sensitivity of the determined strategy to differing estimates of the input parameters. The model's objective function was to obtain the level of control of RHC and NO_X necessary to reach the specified air quality goal at least cost. Interactions among sectors were accommodated through an iterative solution algorithm.

The results of this analysis shed substantial light on the policy choices available to EPA and the people of the basin.[33] Using both the EPA assumptions and a somewhat more optimistic set of technical assumptions it was found that obtaining peak oxidant levels of about 0.25 ppm in 1977, while representing a major control effort, would not be prohibitively expensive (about $200 per family per year). Oxidant levels would continue to decline for dates beyond 1977 as a result of this strategy. As the desired oxidant level to be reached in 1977 is lowered to 0.08 ppm the cost rises sharply to between $2,000 and $3,500 per family per year (and this is probably an underestimate). As the level of control was increased, an ordering of control strategies was found. Stationary source controls were added first, followed by retrofits for used cars. Only at high levels of control was it desirable (cost-effective) to institute bus service. At the very high levels of control necessary to meet the oxidant standard the model indicated that it would be necessary to reduce *both* trips by private automobile and bus trips.

The above results followed from one set of technical assumptions. In order to determine the sensitivity of the indicated strategy to alternative estimates of the technical input parameters, alternative assumptions were made and the model was rerun. The key input assumptions to the model which were varied were the required reduction in oxidant level (the air quality model), reactivity, effectiveness of catalytic reactors, applicablity of retrofits, and applicability of stationary source controls. It was found that the model was highly sensitive to variations in all input parameters in the sense that a more pessimistic assumption for any one parameter dictated much higher levels of control activity for all sources than in the base case.

Formulation of the Final Plan

The information briefly discussed above represented that available to the Task Force for the preparation of its final plan. It was clear that estimates of all the critical technical parameters varied widely among analysts. Furthermore, these differences in opinion appeared to derive directly from a lack of empirical observations which could be used to resolve differences. There were no studies available which would show definitively how people, atmospheres, and machines would react to these controls. The Task Force was left with only a very crude approximation of the effects of alternative policies. And, to make the job of policy formation even more difficult, the estimates kept changing almost from day to day as new and/or different information became available.

The result was the proposal of a second preliminary plan.[34] The important aspects of the plan were 1) the admission that the use of all "reasonable" measures would not meet the standards, 2) an explicit requirement for state implementation of the plan, 3) an explicit time phasing of the implementation process commencing October 1, 1973, 4) a statement that gas rationing, even though impractical, will be used to the extent necessary to meet the standard in 1977, and 5) a statement that "the Agency will utilize every means available to avoid the need to impose impractical measures (such as gas rationing) to reach the goal by 1977."[35]

After an opportunity for interested parties to comment, the "final" plan was published.[36] It differed in detail from the previous proposed plan but basically reached the same conclusion: "However, the EPA does not believe that massive gasoline rationing is either socially acceptable or enforceable, and will work toward alleviating the neccessity for such drastic control in 1977."[37] The main addition to this plan was the use of economic disincentives, primarily parking surcharges. These provisions were subsequently rescinded, on January 15, 1974, because the Energy Emergency Act (which was then being considered, but was not passed by Congress) contained provisions which required that any disincentives such as parking taxes must be approved by Congress before they are included in transportation control plans.[38] In addition, several minor revisions have also been made which have pushed back dates for required implementation of various provisions of the plan.

Some progress is being made on the implementation of some parts of the plan.[39] The Southern California Association of Governments (SCAG) produced a transportation control plan which includes provisions for bus lanes and preferential treatment of buses very similar to the EPA plan. This transportation control plan is now being implemented. A parking management plan is in negotiation as well. A retrofit program for used cars is now being implemented. This program, which is less ambitious than required by the EPA plan, requires 1) the installation of vacuum spark advance disconnect (VSAD) devices on all 1955 to 1965 model year automobiles if there is a change in ownership, 2) the installation of either a VSAD or an exhaust gas recycle (EGR) system on all 1966 to 1970 model year automobiles upon renewal of registration (hence all cars in this group will be retrofitted by the end of 1975), 3) the *voluntary* installation of a catalytic converter on any automobile, and 4) the implementation of a required annual emission inspection and maintenance program for all automobiles while retaining the random side-of-the-road inspection system now being used in the LAAQCR. EPA's estimate of the effect of this program is that it will reduce peak hourly oxidant readings from 0.62 ppm (observed in 1970 in Riverside and 1974 in Uplands) to approximately 0.42 ppm.

IV. Alternatives for Oxidant Control in the LAAQCR

The observation that the peak oxidant level in the LAAQCR was as bad in 1974 as it was in 1970 highlights the range of uncertainties faced by policy makers. There are a number of alternative explanations for this fact. It might have been an extraordinarily bad year meteorologically. Or, growth in population and VMT might have offset emission reductions achieved (at least on paper) between 1970 and 1974, or emission reductions in practice might not have been as great as they were expected to be prior to implementation.[40] Or there may have been an entirely different reason—the causes have not yet been sorted out. Faced with massive uncertainty about all technical aspects of control, policy makers must search for a policy which will reduce these uncertainties while making progress in control. The Administrator is faced with a political strategy game as well. He must decide where he wants to go (what level of control) and how he is going to get there politically. In this section three alternative technical plans are set forth. A general scheme for implementing and enforcing these plans is presented. Finally some judgments are made about the benefits and costs of each alternative. Discussion of how the Administrator might obtain adoption of the preferred option will be left for the last section.

Technical Control Alternatives

The three technical control alternatives presented here range from a modest effort (the minimal strategy) which does not go beyond the efforts the CARB has already committed itself to, through an intermediate strategy, to the most stringent control strategy which the author feels could have a chance of being accepted by the people of Southern California.[41] While not coinciding exactly with the results of the Rand study, these alternatives generally follow the pattern it suggests. *All of these controls are in addition to those included in the State of California's plan for the LAAQCR.* Strategies for the three proposed alternatives are summarized in Table I.

Control options for stationary sources concentrate primarily on gasoline marketing and users of organic solvents. It is proposed that in all three strategies vapor recovery will be practiced for all phases of gasoline marketing, including the filling of individual cars. This system is presently being instituted in San Diego. The main obstacle appears to be retrofitting automobiles to allow for vapor recovery, although several gasoline filling nozzles have been designed which may make this unnecessary. Large users of organic solvents and surface coatings have previously been regulated by the LAAPCD's Rule 66. Carefully defining what constitutes a source and extending coverage of the rule to small operations would significantly improve the situation. Currently any operation which releases less than 140 pounds per day of RHC is exempt from control, even if several such operations are carried out at one site. The emissions from the aggregate of all operations at the site may exceed the 140 pound minimum, but they remain uncontrolled if no one operation emits more than 140 pounds per day. Sources thus have an incentive to break up operations in order to avoid control. For the minimal strategy it is suggested that Rule 66 be applied to all sources regardless of size or location. In addition, in the intermediate and stringent strategies it is proposed that Rule 66 be modified to require substantially greater use of high solids and water based coatings as well as water based printing ink. In all three strategies it is suggested that activated carbon adsorbers be installed on all dry cleaning operations and again, it is recommended that the small source exemption be removed. Also, in all three strategies 1, 1, 1-trichloroethane would be substituted for current solvents in all degreasing operations.

Some level of control of aircraft will occur without additional action. The modification of the JT-8D engines on 727 jets to reduce smoke also reduces RHC emissions. By 1977 there is expected to be a substantial replacement of 707's and DC-8's with the new wide body jets. These also have substantially lower emissions. In the stringent strategy the addition of towing and other ground controls at major airports (including military) is proposed.

The control of mobile sources is complex. For heavy duty vehicles, the minimal strategy adds an inspection and maintenance scheme to the Federal and State new truck controls which are already being implemented. Also, PCV is to be installed on all trucks and buses

TABLE I

SUMMARY OF CONTROL STRATEGIES FOR OXIDANTS

SOURCE	MINIMAL STRATEGY	INTERMEDIATE STRATEGY	STRINGENT STRATEGY
Stationary Sources			
Petroleum			
Production	Maximum control is already being exercised		
Refining	Maximum control is already being exercised		
Marketing	Vapor recovery	As per minimal	As per minimal
Organic Solvents			
Surface coatings	Strengthen and expand Rule 66	As per minimal More extensive use of water based and high solids coatings	As per intermediate
Dry Cleaning	Activated carbon adsorbers Expand to small operators	As per minimal	As per minimal
Degreasing	1, 1, 1- trichloroethane to replace other solvents Expand to small operators	As per minimal	As per minimal
Mobile Sources			
Aircraft	Modification of JT-8D engines, expanded use of wide-body jets	As per minimal	As per minimal Towing and other ground controls
Heavy duty vehicles	Federal and state new truck controls Inspection and maintenance	As per minimal Catalytic reactors on 75% of all 1966-74 trucks PVC on all 1966-74 trucks	As per intermediate Evaporation controls catalytic reactors on 1955-64 trucks
Motorcycles	Ban 2 strike Reduce rapid growth	As per minimal Restrict registrations	As per intermediate
Light Duty vehicles	Blowby, No control on 75% of 1955-70 cars Maintenance and side of road inspection	As per minimal Catalytic reactors on 75% of 1966-74 cars	As per intermediate Catalytic reactors on 75% of 1955-65 cars Evaporative control on all 1955-69 cars
Travel and Bus strategy	Bus and car pool lanes on primary freeways, Bus system expanded to 2200 vehicles with free rides	Bus ramp lanes and ramp metering, Bus system expanded to 4000 vehicles. Parking restrictions Gasoline surcharge of $0.20/gallon	Bus lanes on major streets Bus system expanded to 7000 vehicles Parking surcharge of $3.00 day Gasoline surcharge of $1.00/gallon

not so equipped. The intermediate strategy calls for the use of catalytic reactors on at least 75 percent of the 1966-74 gasoline-powered heavy duty vehicles. The stringent strategy extends this measure to 1955-65 heavy duty vehicles as well. In addition, evaporative controls would be installed on at least 75 percent of all heavy duty vehicles. In all three strategies concentrated effort should be placed on the control of gasoline powered vehicles since these are greater emitters than diesel engines.

Motorcycle control takes a different tack from other motor vehicle controls. This is because virtually no work has been done on technologies for the control of their emissions. Consequently the various strategies rely heavily on restricting ownership. Two stroke engines are much greater emitters than four stroke engines. Two stroke motorcycles were only one-third of the 1970 motorcycle population yet they accounted for over 60 percent of estimated emissions. Consequently two stroke motorcycles are banned from use in the basin in all three strategies. In addition, registrations of all motorcycles are limited to the 1973 level in both the intermediate and stringent strategies. This is necessary because controls on automobiles and gasoline taxes will make motorcycles more attractive. Since four stroke motorcycles emit approximately as much RHC and NO_x per mile as a 1970 automobile, unrestricted growth would cause substantial increases in emissions.

In the minimal strategy the only control for light duty motor vehicles is NO_x reduction by the use of VSAD or EGR retrofit on 75 percent of the 1955-70 model year cars. In addition a side-of-the-road inspection and maintenance system is employed to help insure that controls on all cars are installed and operative. This strategy is basically a variant of the one now being used in parts of the Los Angeles basin. Catalytic reactor retrofits for 75 percent of the 1966-74 cars and a loaded annual inspection are added in the intermediate strategy. The stringent strategy adds catalytic reactor retrofits for 75 percent of the pre-1966 cars. Finally, evaporation control systems are installed on all 1955-69 cars (1970 and newer cars have them as original equipment).

In addition to these technical controls each strategy includes some efforts to attract people away from cars and into public buses and/or car pools. In the minimal strategy primary freeways would have one of the existing lanes dedicated to the exclusive use of buses and car pools (3 or more people per car). This has two effects. One is to make mass travel faster and the other is to restrict the mobility of the single occupant car. The bus system would be expanded from

1500 to 2200 buses with a corresponding increase in route miles and improvement in service characteristics. Bus service would be free. The intermediate strategy replaces bus lanes with ramp metering such as the system being installed on the Santa Monica freeway. The advantage of ramp metering is that all lanes are free flowing, not just the bus lane. Buses (and perhaps car pools as well) would have preferential access to the freeways. Cars will have to wait in line or drive through city streets. Restrictions will be placed on the supply of parking spaces in the major trip attraction centers with preference given to car pools. In the stringent strategy, bus lanes are added to major city streets as well. A gasoline tax of up to $1 per gallon is also called for in this strategy.

A rough approximation of the effect of these three alternative strategies is presented in Table II. It can be seen that increasing stringency of controls has a marked effect on predicted peak oxidant using the EPA air quality model discussed above. But peak oxidant is not the only relevant measure of air quality improvement. Another measure is the number of days which have oxidant readings above the federal standard of 0.08 ppm. In 1970, 250 days had peak oxidant readings above 0.08 ppm. Using the estimated emission reductions and the results of the EPA air quality model it is estimated that the minimal strategy would reduce this to 150 days while the stringent strategy would reduce it to 37. Thus, it can be seen that small reductions in observed peaks yield large reductions in the number of days above the standard. This occurs because controls shift the frequency distribution of observed peaks so that many fewer are above the standard. The same phenomenon occurs when hours above the standard are calculated, but the effect is even more rapid. A 76 percent reduction in the peak represents a 85 percent reduction in days above the primary standard and a 97 percent reduction in hours above the primary standard. Surely the total exposure to oxidant is important in assessing damage reductions. In fact many health studies recognize this by using average exposure rather than peak exposure as their measure of pollution. This being the case, the number of hours above 0.08 ppm may be a better measure of control and, by implication, damage reduction, than is the peak oxidant.

Before moving on to the discussion of implementation and enforcement, there is another control option which merits brief discussion. This is the control of interior air. If there is a portion of the population which is more seriously affected by oxidants and which must remain in the basin when ambient oxidant concentrations are

TABLE II

RHC EMISSIONS INVENTORY (TON/DAY)

SOURCE	1970	MINIMAL STRATEGY	INTERMEDIATE STRATEGY	STRINGENT STRATEGY
Stationary	349	130	85	85
Petroleum	143	26	26	26
Production	—	—	—	—
Refining	5	6	6	6
Marketing	138	20	20	20
Organic Solvents	193	90	45	45
Surface Coatings	98	54	27	27
Dry Cleaning	6	—	—	—
Degreasing	23	—	—	—
Other	66	36	18	18
Other Stationary	13	14	14	14
Aircraft	38	25	25	15
Heavy Duty Vehicles	111	51	41	20
Motorcycles	27	22	14	14
Light Duty Vehicles	1088	418	209	177
VMT Reduction Effects	0	-29	-21	-60
Total Emissions	1613	617	353	251
Peak Oxidant (ppm)	0.62	0.28	0.19	0.15
Days Over Standard	250	150	90	37
Dosage Reduction (% reduction from 1970 level)	—	60%	92%	97%

high, then this group may still markedly reduce their exposure to harmful levels of oxidant. A study conducted by Professors Sabersky, Sinema, and Shair indicates that interior photochemical oxidant concentrations lag exterior concentrations by only a slight amount.[42] Thus, the usual recommendation to remain inside on bad days does not appear to be very helpful. However, a simple activated charcoal filtering device can be used to reduce the oxidant level to well below the standard. The seriously affected person could install such a device and avoid much of the potential harm. The main problems with this technique is that it restricts mobility and may require the installation of central air conditioning to make the indoor air bearable on hot smoggy days. This means that it will be less accessible to the lower economic groups. However there is no obvious reason why such filters could not be installed in public buildings and perhaps automobiles as well. If exposure is important, this might be a cost-effective short-run alternative to major reductions in VMT.

Implementation Alternatives

Having decided upon the level of control, the Administrator must decide how the plan will be implemented and enforced. There are two basic options available: regulation and economic incentives. The regulatory approach requires a given act such as the installation of a device. It has strong advocates and some advantages. A primary advantage is that it is more certain to achieve the desired effect. But it has disadvantages as well. For example, there are some 1966 model year cars which can be effectively retrofitted with a catalytic reactor and some that cannot. Regulations would have to specify the cars to be excluded. This makes the regulation complicated and difficult for citizens to understand. Furthermore, it is likely to offend the public's sense of equity since some people must install the device at substantial cost while others, who happen to own a similar but excluded car, would not bear similar costs. Another problem with regulation is that it provides no incentive to install more effective devices. For example, suppose that there are two devices which control emissions by at least the amount required by a regulation: one costs $20 and controls 20 percent, while the other costs $30 and controls 40 percent. The car owner would have no incentive to install the more expensive device even though it is more effective. Furthermore, with this form of regulation, firms are given an incentive to find the cheapest way to control emissions just to the required level, but no incentive to find more effective controls at the same or higher cost.

Economic incentive systems may solve these problems. They restore equity between those similarly situated. They cause people, and consequently firms, to search for more effective as well as less expensive devices. The major problem with economic incentives is that they do not provide the certainty sought by control agencies. In the following proposal, the advantages of both systems are used while their major disadvantages are at least reduced, if not completely avoided.

Finally, it is obvious that some adjustment in the current institutional arrangement of air pollution control is necessary. Part of the problem of ineffectual control agencies is due to a fragmentation of authority. Movement should be toward a single regional air pollution control agency which has broadly based powers over both mobile and stationary sources. This agency should also have a significant input into the policy actions of a new regional transportation authority, which will have strong control over local transportation agencies. In order for the regional control agency to exercise this control, I propose that it be the source of a major portion of funding for mass transit and highways. Another part of the problem has been the dependence of state and local control agencies upon political bodies for the financing of their control activities. I suggest a financing scheme, such as the pollution permit fee discussed below, which will reduce this dependence, thus allowing the agency a freer hand to control without fear of political reprisals.

Economic Incentives For Control

The economic incentives proposed here have two basic goals. They provide polluters an inducement to decrease emissions. They also provide automobile drivers (and stationary sources, if we can think of a practical way to do it) an incentive to emit less during the crucial morning hours. The chief mechanism for achieving these goals is a pollution permit fee aimed at all polluters. In addition I propose several incentives directed particularly at the reduction of vehicle miles travelled.

For automobiles the current registration fee would be replaced with a fee based upon the estimated emissions of the car. The control agency would first estimate, on the basis of annual samples, an average annual mileage and average emission per mile for each model year in order to obtain an estimated annual emission of RHC, CO and NOx (in pounds per year). These emissions would then be multiplied by a fee per pound to determine the pollution permit fee. The car would not be registrable until the fee was paid.

A hypothetical fee schedule for pollutants might set a charge of \$.60 a pound for RHC, \$.02 a pound for CO and \$.50 a pound for NO_X.[43] Approximate registration fees for typical cars would then be about \$57 a year for 1974 cars, \$75 a year for 1970 cars, \$104 a year for 1966 cars and \$132 a year for 1962 cars. The system would have a retrofit rebate provision, which would reduce the fee by the amount of emissions prevented. Thus, if the owner of a 1964 car installed a VSAD device, he would save approximately \$94 on the pollution permit fee. Since the annual device cost is approximately \$52, it would pay for him to install the device. The fee schedule could, of course, be set at any desired level.[44] In order to accomplish its purpose, however, the charge per pound of pollutant should be set high enough to act as an incentive to install control devices.

For motorcycles and aircraft the same system would be employed. Aircraft owners could reduce the fee through control efforts, including the towing of aircraft at airports to reduce on-the-ground emissions. Since two-cycle motorcycles are especially heavy polluters they would pay high fees for on-road use (if such use is not banned). However, if they are used for off-road activities exclusively and thus are not registered, they would not pay the pollution permit fee. But this may be acceptable since this type of use is generally at the edges or outside of the air basin. All stationary sources regardless of size would be included in the pollution permit system and would pay a fee. The same fee schedule as used for mobile sources would be employed. Thus a solvent user who is just at the lower limit of current (1973) control and is emitting 140 lbs. of RHC per day, 6 days a week, would pay an annual fee of $26,208.00 (140 lbs. x 312 days x $0.60) in our hypothetical fee case. This would obviously give the firm an incentive for additional control, even if it already met the current standard. It could lead to the development of new technology. In addition, it would reduce the problems caused by firms which break up their operations so that individual sources within a plant are below the control threshhold. Thus, a firm would pay the same fee whether it had one operation emitting 140 lbs/day or ten operations, each emitting 14 lbs/day.

The polluter permit fee system suggested here gives polluters a substantial incentive to control today. But it has an additional, and perhaps more important, advantage. The control cost per pound for stationary sources at currently available technology is much less than for mobile sources. It is very likely that further research into control alternatives would uncover many effective controls. The current legal enforcement system places the burden for this research on EPA. The permit fee system would give the polluters an incentive to do this research. It would also provide a market for other firms to do this research and sell the resultant devices or process changes to polluting firms. Thus, the permit fee system is likely to lead to greater control and/or less expensive control over time due to its research-stimulating feature.

To encourage multiple occupancy and reduce automobile VMT, this proposal would prohibit the use of any car on major corridor freeways with less than three occupants between 6 and 9 AM and between 4 and 6 PM, unless a special tag is prominently displayed. This special tag would be obtained from the regional pollution control agency. A sizable monthly fee would be charged for this tag unless the driver could demonstrate an exceptional need to drive alone during these times and an annual income below a level set by policy makers. The multiple occupancy rule is necessary because the pollution permit fee provides an incentive to control emissions per mile but does not affect travel during the crucial periods for peak oxidant production. This system would impinge mostly on trips to work and would provide people with an incentive to car-pool or to use public transportation.

In addition to the permit system and multiple occupancy permit, a gasoline tax, which would vary with the season, is also proposed. Since the multiple occupancy rule would be applied only to freeways, it would provide no disincentive to driving on regular streets. One possible schedule might be a charge of $.20 per gallon in winter and $1.00 per gallon during summer months. The proceeds from this tax could be used to help finance the proposed free bus system.

The above set of incentives would do little good unless a cheap and effective alternative mode of travel were available. It is fairly clear that highly subsidized, and preferably free, bus service should be instituted on a massive scale by 1977 if substantial VMT reductions are to be achieved. This system would be the responsibility of a regional transportation authority. Financing would be from diversion of the current federal and state gasoline taxes as well as from the proceeds of the other proposed taxes and fees. Priority bus lanes could also be provided on city streets, as well as freeways, as a part of this system (depending upon the stringency of the plan adopted).

This entire incentive structure can be used in combination with a system of regulation. The regulations would follow one of the three strategies discussed above (or some other alternative). A regulation would *require* that a particular action be taken. This requirement would be open ended in the sense that any action which reduces emissions by more than that required would be allowed. No penalty for non-compliance need be specified since those who are unable or unwilling to comply will be paying a higher pollution permit fee.

In our automotive example discussed earlier,[45] the owner of a typical 1964 car would find that non-compliance with a regulation requiring a reduction in NO_x emissions of at least 40% would cost him $94 per year while compliance would only cost him $52 per year. Only if he owned a 1964 car which was extremely expensive to retrofit (*i.e.*, over $94) would it pay not to comply with the regulation. Even then, however, the pollution permit fee provides him with an incentive to search for a retrofit system to control NO_x emissions. It will pay him to install any device which costs less than his savings on the pollution permit fee, even if it does not meet the regulation. The advantage of the combined system is that it maintains the incentive structure and at the same time provides assurances that at least the minimum controls specified by the regulations will be implemented in most cases. Only in cases where control is much more expensive than the average or expected cost, would individuals or firms violate the regulations. These cases may be more than offset by cases where the incentive system induces control measures greater than those regulated. The important point is that under the current system of standards, delay can reduce cost; but in the incentive system, delay is more costly than control.

Enforcement and Monitoring

It has become increasingly clear that enforcement of air pollution controls is a major problem. Slack enforcement will lead to substantial increases in actual emissions. Current enforcement efforts in the Los Angeles AQCR, while better than in most air basins, could be vastly improved.[46]

The enforcement program I propose includes several components. Primary among them is a major increase in the personnel and resources devoted to enforcement of controls. Coupled with this would be the development and implementation of an effective emission monitoring system. To the extent possible this system would consist of on-site continuous monitoring devices for stationary sources. Where this is not possible, proxies, such as down-wind ambient air monitors and/or random inspections by control personnel, would be used. For mobile sources, I propose a substantial increase in the number of side-of-the-road emission inspection stations. The current average frequency of inspection for stationary sources is about once every year. The average frequency for mobile sources is approximately once every year and one half. Both of these frequencies should be increased to something like once every three months for sources which cannot be continuously monitored. These inspections should be unannounced.

In order to insure that these proposals are truly effective in controlling emissions, an information feedback system should be instituted to check on the progress and effectiveness of the plan. With this information the enforcement, monitoring and fee schedules can be adjusted as necessary.

Costs, Benefits, and Air Quality

As pointed out previously, emission control estimates are highly uncertain in terms of both cost and effectiveness. For example, the cost of producing a retrofit device is usually estimated by engineers by assuming fixed input prices and some unspecified volume and rate of production. However, if more devices are required in a shorter period of time, costs may be several times the estimate. In addition, recent inflation has more or less destroyed the assumption of fixed input prices.

An even more difficult cost to measure is the welfare loss to the people of the basin due to the required shifts in transportation modal choices and the reduced drivability of retrofitted and new automobiles. One way to estimate this cost is to measure the value people place on the transportation foregone when the price is increased. There is a problem in obtaining such an estimate because only the very roughest of estimates of the demand curve for transportation is available.

Nevertheless some sort of cost estimates would seem necessary, if only to place the preceding proposals in perspective. A rough approximation of the costs of the three strategies which have been discussed is presented in Table III. They are based on 1973 estimates of control costs from EPA internal studies, from the studies conducted by the Rand Corporation, and from my own studies.[47]

TABLE III

APPROXIMATE COSTS OF ALTERNATIVE STRATEGIES (Millions of Dollars)[a]

STRATEGY COMPONENT	MINIMAL	INTERMEDIATE	STRINGENT
Stationary source controls	20	60	60
Motor vehicle retrofits	100	400	540
Bus system expansion	80	500	780
Parking, Transportation controls	70	200	300
Welfare loss	0	250	2000
Total annual cost	270	1410	3680
Approximate cost (dollars per family per year)[b]	90	500	1250

[a] These are only rough approximations and should be taken as no more. They are derived from various sources as cited in the text.

[b] This assumes that *all* control costs are passed on to Los Angeles residents, which certainly overestimates the impact on them by some unknown amount.

There is not sufficient information currently to estimate the dollar value of the benefits of controlling oxidants. All that can be done is to cite observed effects at various exposures. This has been done in the Appendix for health effects. In addition, there are damages to plants caused by ozone. Visible plant damages have been shown to occur at levels as low as 0.1 ppm peak hourly oxidant. The most common symptoms are yellow or white blotches on leaves, excessive dropping of leaves and fruit, and dried brown edges on flowers. In addition, yields of agricultural crops such as citrus fruit and grapes are substantially reduced by exposure to oxidant. Visibility (a highly valued characteristic in Southern California) is substantially reduced by the products of photochemical smog (primarily aerosols and NO_2). At approximately 0.08 ppm oxidant Mount Baldy is clearly visible from Riverside. At approximately 0.2 ppm it is no longer visible and the Box Springs Mountains (only 2-3 miles away) become hazy. At approximately 0.4 ppm even the Box Springs Mountains disappear and everything becomes hazy.

A very rough and admittedly judgmental comparison of the benefits and costs of the three alternatives studied are presented in Table IV.[48] This comparison indicates that the implementation of the minimal plan can result in a substantial reduction in health effects and a substantial improvement in aesthetics at a seemingly small cost. The intermediate plan could substantially eliminate observed health effects in man, with the exception of eye irritation, as well as attain even greater improvements in aesthetics. The cost of this plan may be too high for these benefits, however, especially for low income families. A financing method which would reduce the payments for control by lower income groups may be warranted in order to obtain general acceptance of this plan. The stringent plan reduces eye irritation and provides additional insurance against possible radiomimetic effects. The cost both in monetary terms and reduced mobility are very high. One wonders if the insurance is worth this cost (it appears as if the people of Los Angeles have decided that it is not).

TABLE IV

ROUGH BENEFIT/COST COMPARISON FOR ALTERNATIVE PLANS

PLAN	PEAK OXIDANT (ppm)	ANNUAL COST $/FAMILY	HEALTH AND AESTHETIC BENEFITS
Minimal	0.28 (0.15-0.40)[a]	90.00 Some reduction in ease of movement but no trips foregone	Virtual elimination of lung constriction & throat irritation Elimination of decreased pulmonary function effects Reduced possible radiomimetic effects Substantial increase in number of clear days and virtual elimination of days with very poor visibility

			Substantial reduction in visible damage to pine trees, ornamental plants, etc.
Intermediate	0.19 (0.10-0.30)	500.00 Greater reduction in mobility & a relatively minor number of trips foregone Possible increases in platinum oxide particles which are a health hazard	Substantially reduce (if not eliminate) increased aging of red blood cells, structural damage to heart muscles, increased chromosomal abnormalities, decreased visual activity, asthmatic attacks, coughing, chest discomfort Further reduce chances of radiomimetic effects Even greater increases in visibility Even greater improvement in conditions of plants
Stringent	0.15 (0.08-0.25)	1,250.00 Substantial reduction in mobility and at least a 20% reduction in number of trips taken Even greater levels of platinum oxide particles	Substantially reduce but not eliminate susceptibility to infections, eye irritation, neonatal mortality Further reduce chances of radiomimetic effects Still greater improvements in visibility but some unclear days remain Still greater improvements in the condition of plants but some visible damage and crop loss will remain

[a] This represents the author's very judgmental assessment of the possible range of outcomes of each plan. By comparison, it should be noted that 0.27 ppm is the first alert stage for oxidant in Riverside County. At readings above this level school children cannot go outside to play at recess or participate in physical education classes.

V. Political Strategy and Bargaining

On Friday, June 15, 1973 the Acting Administrator of EPA reproposed a control plan for the LAAQCR.[49] Two days previously he had announced to the Los Angeles press that he would go to Congress to seek a change in the Clean Air Act to exempt Los Angeles from meeting the ambient air quality standard for oxidant by 1977. His stated reason for seeking a delay was that the level of vehicle mile travel restrictions needed to reach the standard is far beyond any-thing reasonable. This conclusion is consistent with the technical analysis presented here under any reasonable set of assumptions. The state and local authorities have responded to this plan, and to the November 12, 1973 final plan (which is roughly equivalent to my intermediate strategy), with a control program substantially weaker than the EPA proposal, although somewhat more stringent than their original proposed plan which EPA had rejected.

The EPA position appears to recognize that the final control effort in the LAAQCR will be the result of extensive bargaining. The strategy they use in this bargaining could be very important in determining which plan is eventually adopted for Los Angeles. There seem to have been two strategies available to EPA in 1973. One was to declare any more stringent plan than that proposed by EPA to be too costly relative to the benefits. The Administrator would hope that this decision would be seen by both pro-control and anti-control political factions as a very rational compromise. In this way he would gain acceptance from both sides and the plan would be adopted. This appears to be the strategy which EPA followed, but it does not seem to have worked.

The alternative strategy grows out of the realization that political decisions are by nature elaborate bargaining systems. A compromise is reached through offers and counter-offers by the interested parties. If EPA is supposed to be the political representative of the pro-control faction, then this alternative strategy called for it to bid for *more* control than the Administrator actually expected to attain, in order to leave room for compromise to the level he prefers. The State of California offered a very weak control plan. The Administrator's statement and the final plan represent a counter-offer which is also relatively weak. This leaves little room for bargaining. If the final plan is EPA's preferred position (that is, if they are following the first strategy) and the state does not agree to the plan (which it has not), then a level of control below that desired by EPA will result. The pro-control political faction might feel that EPA has chosen the less preferred alternative.

VI. Conclusion

The people of Los Angeles are faced with a most confusing situation. Public officials and private analysts have widely differing views of the problem and its solution. On the one hand they are told by the Los Angeles APCD that if EPA would just leave them alone the problem will be solved by 1980. Even more incredibly they were told in 1970 by Governor Reagan that the problem was already solved. Others tell them that it is impossible to solve the problem without killing the local economy. At the same time they are told that their children should not play outside a substantial number of days per year. They blame Detroit, the oil refineries, the steel mills, and the other guy for causing the problem. They seek an easy solution and are offered a kaleidoscope of options to choose from—everything from hydrogen-powered cars to fans in the sanitary sewers. In reality there are no easy solutions. The problem is caused by them, by the firms they work for, and by the government they control. They must make the hard choices about how much to control and how clean their air should be.

It is reasonably clear that some level of control beyond that already in existence in 1974 is socially desirable. But how much more? This question cannot be answered with the available facts. The studies summarized here indicated that we only have the very crudest of guesses as to the emissions of pollutants in 1970, as to the effectiveness and applicability of control options, or as to the savings in human suffering and property damage which might result from control. Politicians, faced with total disagreement on many aspects of the technical analysis understandably turn to political rather than technical criteria in their decisions. In the face of these uncertainties the politically expedient thing to do is to go slow while making a show of going fast.

What are the chances that a plan such as that suggested here will be adopted and implemented in the near future? In my opinion, there is virtually none. Even if EPA wanted to, and it is not clear that it does, it has no real power to force local officials to comply, short of calling in Federal Marshals to stop traffic, which would be politically unacceptable. Only the local electorate can do it and they have shown little inclination to do so yet. If the population in general favors improved control, they will get it. If not, I submit that Congress and EPA are political realists, and they will fold in the face of local resistance to control.

In the meantime, do not be fooled by calls for more study *before* implementing any additional controls. More studies are needed but by their very nature thay cannot provide the certainty anti-control groups call for. This can only be done by experimenting with policies in the real world. Time-phased implementation of a control program is one way to make progress *and* collect needed information. The longer the delay in implementation, the less desirable will be the retrofit portions of a control program. This seems like a saving because these control expenses can be avoided. However, the higher oxidant levels which result from delay cause increased health and aesthetic damages. Delay is not costless. Moving ahead can reduce the political influences on environmental policy by providing the information needed to produce reliable technical and economic analyses of policy options.

The lesson to be learned from the Los Angeles experience is that any attempt at air pollution control will have to deal with a highly complex and grossly uncertain world. Simple solutions just do not work. What is needed is a set of institutions which explicitly take these complexities and uncertainties into account. These institutions must be flexible in order to adjust to new information. They must also provide incentives to move ahead and to collect information which allows control agencies (and the people in the air basin) to determine how successful controls are. The set of institutions suggested here is a first attempt at designing such a system. Obviously, much more work on these issues is needed.

APPENDIX

Summary of Selected Health Effects on Exposure To Photochemical Oxidant

Extent and Duration of Exposure	Observed Effects
A. Demonstrated Adverse Effects	
0.08 ppm for 3 hours	Increased susceptibility to streptococcal bacteria infection in mice.[50]
0.1 ppm and above	Eye irritation in man.[51]
0.1 and 0.2 ppm for 7 hours per day for 3 weeks	Increased neonatal mortality in offspring of exposed mice.[52]
0.2 ppm for 1 or 2 hours	Increased aging of red blood cells in mice.[53]
0.2 ppm for 5 hours per day for 3 weeks	Reversible structural changes in cells of heart muscle fibers of mice.[54]
0.2 ppm for 5 hours	Increased chromosomal abnormalities in hamsters.[55]
0.2 ppm for 3 hours	Decreased visual activity for dark adaptation and middle vision ranges in man.[56]
0.25 ppm daily maximum hourly exposure	Increased frequency of asthmatic attacks in man.[57]
0.25-0.30 ppm daily maximum hourly exposure	"Threshold" for increased coughing and chest discomfort[58] in man.
0.3 to 0.8 ppm average for 8 hour workday	Complaints of chest discomfort and throat irritation by workers.[59]
0.37 ppm for 2 hours	Decreased pulmonary function after moderate exercise in man.[60]
B. No Demonstrated Adverse Effects	
0.13 ppm daily maximum hourly exposure	No significant increase in asthmatic attacks in man.[61]
0.05-0.28 ppm daily average exposure	No effect on ventilatory performance of school children.[62]
0.2-0.25 ppm average for 8 hour work day	No complaints of chest discomfort and throat irritation of workers.[63]
Ambient concentrations in Los Angeles	No significant effects on mortality due to occurrance of smog-alert days in man.[64]

FOOTNOTES

* Associate Professor of Economics, Virginia Polytechnic Institute and State University.

[1] Press Conference of William Ruckelshaus, Los Angeles, California, January 15, 1973.

[2] 42 U.S.C. §§ 1857 *et seq.* (1970).

[3] 42 U.S.C. § 1857c-5 (1970); *see also* 40 C.F.R. §§ 51.10-51.22 (1973).

[4] 37 Fed. Reg. 10851-55 (1972).

[5] Riverside v. Ruckelshaus, 4 E.R.C. 1728 (C.D. Cal. 1972).

[6] 38 Fed. Reg. 2194 (1973).

[7] The Los Angeles Task Force consisted of three people from within EPA: Mr. Alan G. Kirk II, Deputy General Counsel; Dr. Joel Horowitz, Systems Analyst, Office of Air and Water Programs; and Dr. Paul Downing, Economist, Office of Reasearch and Development.

[8] During the entire set of hearings no new technical information was obtained, nor were any new workable alternatives proposed. The only surprise at the hearings was the position of the Sierra Club. It offered a plan similar in character to those discussed below. It stated that it would be satisfied with substantial progress rather than strict adherence to the federal oxidant standard. The hearings did serve to demonstrate EPA's concern for public opinion as well as provide a method of formalizing positions.

[9] *See* testimony of Mr. Robert Chass, Director of the Los Angeles Air Pollution Control District, March 5, 1973 (a transcript is available at the EPA offices in Washington, D.C.). Note also that the California Air Resources Board which had the responsibility to produce a plan to meet the federal oxidant standard refused to do so citing the severe undesirable economic and social effects which such a plan would cause if implemented. The state plan, which EPA rejected, is also available at EPA's Washington, D.C. offices.

[10] 40 C.F.R. § 50.9 (1973).

[11] 42 U.S.C. § 1857c-4(b)(1) (1970).

[12] National Air Pollution Control Administration, Public Health Service, U.S. Department of Health, Education and Welfare, AIR QUALITY CRITERIA FOR PHOTOCHEMICAL OXIDANTS (March 1970).

[13] E.C. Schoettlin & E. Landau, *Air Pollution and Asthmatic Attacks in the Los Angeles Area*, PUBLIC HEALTH REPORTS, 76:545-48 (June 1961).

[14] R. Brinkman, H.B. Lambert & T.S. Venings, *Radiomimetic Toxicity of Ozoned Air*, LANCET, 1 (7325):133-36 (January 1964); R.E. Zelac, *et al.*, *Inhaled Ozone as a Mutagen I and II*, ENVIRONMENTAL RESEARCH, 4:262-82, 325-42 (1971).

[15] While a peak level of 0.20 ppm may seem quite far from the current standard, it is very clean compared to the 0.62 ppm peak observed in Riverside (part of the LAAQCR) in 1970. A peak of 0.20 ppm would imply a reduction of 90 percent in the number of hours above 0.08 ppm. If it is total exposure rather than peaks which cause long term health damages as many health scientists contend, this represents a very substantial improvement. Note also that plans which reach 0.20 ppm in 1977 generate even cleaner air in 1978, 1980, etc., thus further increasing benefits.

[16] This model was developed by a group headed by Dr. Edward Schuck of EPA's Office of Research and Development, and is the model now used by EPA for official peak oxidant estimates in the LAAQCR.

[17] The 1970 emission inventory is used to calculate the allowable emissions in 1977. Allowable emissions in 1977 equal 9 percent of the estimated 1970 emissions. If the 1970 emission inventory is biased downward, then the allowable emissions in 1977 will be lower than are necessary to reach the oxidant standard. The result could be a plan which is more stringent than necessary.

[18] This evaluation is based largely on work done by Ronald Mueller and David Souten of EPA's Region IX office and Dr. James DeHaven and Barbara Woodfill of the Rand Corporation.

[19] P.B. Downing & W.D. Watson, Jr., *Enforcement Economics in Air Pollution Control*, Washington Environment Research Center, U.S. Environmental Protection Agency (December 1973).

[20] For a discussion of the reactivity issue see J.C. DeHaven & B.M. Woodfill, COST AND EFFECTIVENESS OF STRATEGIES FOR REDUCING EMISSIONS FROM FIXED SOURCES: THE SAN DIEGO AIR BASIN, 1975, Appendix H (Santa Monica: The Rand Corporation, December 1973).

[21] Personal communication with Dr. Joel Horowitz of EPA, November 5, 1974. Dr. Horowitz indicated that while access to the files by EPA personnel was still denied, the LAAPCD was producing an estimated inventory using EPA's definition of reactivity.

[22] For a general discussion of available controls and problems in implementing them see J.C. DeHaven & B.M. Woodfill, FIXED SOURCES: COST AND EFFECTIVENESS OF ALTERNATIVE CONTROL STRATEGIES (Santa Monica: The Rand Corporation, June 1973).

[23] *See, e.g.*, Environmental Quality Laboratory, California Institute of Technology, SMOG: A REPORT TO THE PEOPLE OF THE SOUTH COAST AIR BASIN (January 1972); Los Angeles County Air Pollution Control District, PROFILE OF AIR POLLUTION CONTROL (1971).

[24] *See* M. Smith & D.M. Weston, *A Technique for Generating Representative Chassis Dynamometer Test Cycles* (Paper presented at the 65th Annual Meeting of the Air Pollution Control Association, Miami Beach, Florida, June 18-22, 1972). Of course, exact duplication of a driving cycle does not imply that the cycle is truly representative of the typical driving pattern in the LAAQCR.

[25] *See, e.g., The Cost of Cleanliness*, NEWSWEEK, 80:99 (December 4, 1972); B. Schorr, *State's Tests Indicate Car Pollution Controls Don't Work Very Well*, WALL STREET JOURNAL, December 12, 1972.

[26] What may happen politically in this regard seems to change from day to day. For a general discussion of the delay of new car emission standards see C. Holder, *Auto Emissions: EPA Decision Due on Another Clean-Up Date*, SCIENCE, 187:818-22 (March 7, 1975).

[27] For a general discussion of control devices and their costs see P.B. Downing & L.W. Stoddard, *The Economics of Air Pollution Control for Used Cars*, in J.N. Pitts, Jr. & R.L. Metcalf (eds.), ADVANCES IN ENVIRONMENTAL SCIENCE, Vol. 3, at 203-382 (New York: John Wiley & Sons, 1974).

[28] W.D. Balgord, *Fine Particle Emissions from Automobile Emissions Control Catalysts*, Technical Paper No. 23, Environmental Quality Research and Development Unit, New York Department of Environmental Conservation (September 1972).

[29] *See* C. Holder, *supra* note 26.

[30] *See Vehicle Smog Program Nears New Showdown*, LOS ANGELES TIMES, April 14, 1973.

[31] The results in this area are derived from a literature search and assessment done by Dr. Scott Atkinson, Office of Research and Development, EPA.

[32] B.F. Goeller, *et al.*, STRATEGY ALTERNATIVES FOR OXIDANT CONTROL IN THE LOS ANGELES AIR QUALITY CONTROL REGION (Santa Monica: The Rand Corporation, December 1973).

[33] As with any model of this sort that is developed over a short period of time, there are certain problems with the lack of data. Policy makers and analysts are, and should be, skeptical about the specifics of its results. However, the study does provide some important clues as to the correct set of policies for the LAAQCR.

[34] 38 Fed. Reg. 17683 (1973).

[35] *Id.*

[36] 38 Fed. Reg. 31232 (1973).

[37] *Id.* at 31237.

[38] 39 Fed. Reg. 1848 (1974).

[39] This discussion is based upon a telephone conversation with Mr. Ronald Mueller, Analyst, EPA Region IX Office, November 26, 1974.

[40] Recent evidence that this is the case for 1972 and 73 model years cars can be found in California Air Resources Board, SURVEILLANCE OF MOTOR VEHICLE EMISSIONS IN CALIFORNIA, QUARTERLY PROGRESS REPORT (April-June 1974).

[41] The data and discussion which follows is the result of the author's analysis. Sources include all of the data discussed above and various discussions with other analysts both within EPA and elsewhere.

[42] R.H. Sabersky, D.A. Sinema & F.H. Shair, *Concentrations, Decay Rates, and Removal of Ozone and Their Relation to Establishing Clean Indoor Air*, ENVIRONMENTAL SCIENCE AND TECHNOLOGY, 7:347-53 (April 1973).

[43] Note the word "hypothetical." If such an incentive system were implemented a complex set of calculations would be used to determine the exact charge to be used.

[44] *See* Downing & Stoddard, *supra* note 27.

[45] See text, *supra* at note 43.

[46] This point was made repeatedly by representatives of the League of Women Voters in the March 1973 hearings in the Los Angeles area.

[47] *See* Goeller, *supra* note 32; Downing & Stoddard, *supra* note 27.

[48] The peak oxidant effects are drawn from the estimates in Table II. The estimated range of effects results from the author's judgment of the uncertainties involved in the air quality model and the emission reduction effects of the strategies. The cost estimates are drawn from Table III. However, it is felt that the dollar cost estimates might not adequately quantify all of the costs of control. A verbal description of some of the effects on mobility and secondary pollutant possibilities is included to provide a greater understanding of the full impact of each strategy. The health effects (benefits) are drawn from the Appendix. The aesthetic benefits are derived from the author's experiences while living in Riverside, California and from conversations with Dr. O. Clifton Taylor (a specialist in the study of oxidant damage to plants) and Dr. Joseph Behar (an atmospheric chemist), both of the Statewide Air Pollution Research

Center, University of California, Riverside, between 1970 and 1974.

[49] 38 Fed. Reg. 17683 (1973).

[50] D.L. Coffin, *et al.*, *Effect of Air Pollution on Alteration of Susceptibility to Pulmonary Infection* (Paper presented at the Third Annual Conference on Atmospheric Contamination in Confined Spaces, Dayton, Ohio, May 1967).

[51] N.A. Richardson & W.C. Middleton, *Evaluation of Filters for Removing Irritants from Polluted Air*, HEATING, PIPING, AND AIR CONDITIONING, 30:147-54 (November 1958).

[52] Brinkman, Lambert & Venings, *supra* note 14.

[53] *Id.*

[54] *Id.*

[55] Zelac, *supra* note 14.

[56] J.M. Lagerwerff, *Prolonged Ozone Inhalation and Its Effects on Visual Parameters*, AEROSPACE MEDICINE, 34:479-86 (June 1963).

[57] Schoettlin & Landau, *supra* note 13.

[58] D.I. Hammer, *et al.*, *Photochemical Oxidants and Symptom Reporting Among Student Nurses in Los Angeles*, In-house Technical Report, Human Studies Laboratory, U.S. Environmental Protection Agency (1973).

[59] M. Kleinfeld, C. Giel & I.R. Tabershaw, *Health Hazards Associated with Inert-Gas-Shielded Metal Arc Welding*, ARCH. IND. HEALTH, 15:27-31 (January 1957).

[60] M.D. Hazucha, D.V. Bates, S. Field, C. Parent & F. Silverman, *Short Term Effects of Ozone on the Human Lung* (Paper presented at the American Medical Association's Air Pollution Medical Research Conference, Chicago, October 2-3, 1972).

[61] Schoettlin & Landau, *supra* note 13.

[62] R.S. McMillan, *et al.*, *Effects of Oxidant Air Pollution on Peak Expiratory Flow Rates in Los Angeles School Children*, ARCH. ENVIRONMENTAL HEALTH, 18:94-99 (1969).

[63] Kleinfeld, Giel & Tabershaw, *supra* note 59.

[64] California Department of Public Health, CLEAN AIR FOR CALIFORNIA, Initial Report, March 1955; Second Report, March 1956; Third Report, 1957.