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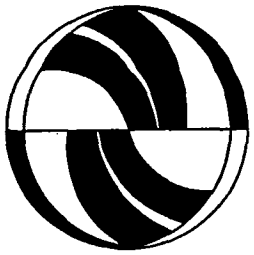

Transportation and Air Quality in California: A Policy Analysis

Elizabeth Deakin

Working Paper
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The University of California
Transportation Center

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1 INTRODUCTION

Significant accomplishments in air pollution emissions control have occurred over the past twenty years. Emissions have been substantially reduced by both industrial and transportation sources; over the ten year period 1977-86, the U.S. Environmental Protection Agency (EPA) reports improvements in each of the six air pollutants for which health-based national ambient air quality standards (NAAQS) exist -- lead, sulfur dioxide, ozone, carbon monoxide, nitrogen dioxide, and particulates. Yet major problems remain:

o Some 100 million Americans live in the 75 or more urban areas that still violate the air quality standards for ozone (O3) or carbon monoxide (CO). Transportation emissions are in large part responsible for these continued violations; EPA reports that mobile sources make up one-half or more of the volatile organic compounds (VOC) and nitrogen oxide (NOX) emissions in many cities, and that the CO nonattainment problem is almost entirely the result of mobile sources.

o Acid rain is increasingly recognized as a national and international problem, and while industrial emissions are the main culprit, transportation emissions of VOC and NOX also have been implicated.

o Growth effects are likely to erode the transportation sector's air quality gains of the last two decades unless additional control measures are implemented. In particular, increases in both the number of vehicles in use and the total vehicle-miles of travel will more than offset the reductions expected from vehicle emissions controls and inspection/maintenance programs, if emission controls remain at current levels. In especially fast growing areas this may already be occurring; data recently released by EPA indicates that the number of metropolitan areas exceeding the allowable one-hour ozone level of 0.12 part per million increased from 62 to 68 over the last year, and while the trend in CO levels is still downward, a reversal is projected to occur starting about the year 2000.

Given this situation, transportation control measures (TCMs) are again being put forward as a way to reduce emissions. At the time of this writing, TCMs appear in draft Clean Air Act renewal legislation in both the Senate and the House, in proposed acid rain provisions, and in proposed EPA policy. While it is too early to tell what the final legislation and regulations will contain, it does seem likely that TCMs will be prominently included.

State- and regional-level interest in TCMs is also on the rise. California, where O3, CO, and NO2 problems are the worst in the nation, in September 1988 passed its own Clean Air Act (AB 2595, the Sher bill) calling for transportation controls in all nonattainment areas, with increasingly specific requirements depending on the severity of the area's pollution problem. Legislation including transportation control requirements also is under consideration in several other states. Thus, another round of TCM planning and implementation can be expected in the next few years.

Transportation control planning is not, of course, a new undertaking. Major TCM planning efforts were carried out in the early and mid-'70s under the 1970 Clean Air Act Amendments. TCM plans were updated and elaborated upon under the 1977 Amendments. Parallel work was carried out in the '70s as a major element of energy conservation and energy contingency planning, as well as under the transportation systems management (TSM) regulations promulgated by the Federal Highway Administration and the Urban Mass Transportation Administration in 1975. Recent initiatives in

traffic mitigation provide additional experience and evidence. This body of earlier work deserves examination for lessons it may offer for future transportation management endeavors.

This paper presents a review of transportation-air quality planning, assessing both past performance and future prospects. The next section of the paper reviews experiences with transportation-air quality planning efforts conducted under the 1970 and 1977 Clean Air Act Amendments, and briefly reviews current proposals for the Act's renewal. Section 3 then examines the effectiveness of transportation control measures, taking a closer look at experiences with several of them. The final section of the paper looks at future directions for transportation-air quality planning and identifies areas where additional research is needed.

2 TRANSPORTATION-AIR QUALITY PLANNING UNDER THE CLEAN AIR ACT: EXPERIENCES UNDER THE 1970 AND 1977 AMENDMENTS

Since 1970, the Clean Air Act has called for the planning and implementation of transportation measures which would contribute to the attainment of ambient air quality standards. Early transportation control plans (TCPs)[1] were among the first to propose widespread ridesharing, priority treatment of high occupancy vehicles, and parking management measures that subsequently have received much wider attention and interest. The early TCPs, however, were highly controversial, as much because of the style in which they were developed as their content. When in 1977 Congress again amended the Clean Air Act, it added several provisions designed to overcome problems which occurred under the 1970 amendments and to further specify requirements for transportation control. Since then, two more planning efforts which include transportation measures, in 1979 and 1982, have been undertaken in most non-attainment areas.

These early experiences provide an important opportunity to examine both technical and institutional issues in the development of transportation-air quality plans, and to identify issues that will need to be addressed in future efforts. In this section, a brief history and critique of transportation control planning is presented.

The 1970 Amendments

Transportation controls initially were not a central feature of the Clean Air Act Amendments of 1970. That legislation mandated the establishment of health-based ambient air quality standards, set nationwide deadlines for the standards' attainment, and required the implementation of new car emissions controls. Within that framework, states (acting through their air pollution control agencies) were required to prepare State Implementation Plans (SIPs) that would demonstrate attainment of the air quality standards, but were given flexibility to select such additional measures as they deemed necessary and appropriate to meet the standards by the deadlines. The focus of the Act, and its legislative history, make clear that technological changes were expected to reduce both industrial and vehicular emissions to levels necessary for attainment of the standards. 'Transportation and land use' controls were mentioned as an option that could be included if necessary, but the Act did not discuss the nature of such controls.

By 1973, it had become clear that political, economic, and technical constraints would make achievement of stationary and mobile source emissions reductions a slow process, and that most metropolitan areas would be unable to meet the Act's 1975 attainment deadline. This gave the

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1. A glossary of abbreviations is provided in the Appendix.

'transportation and land use controls' phrase in the 1970 Act new importance. At first, however, EPA took the position that transportation control measures were too new for them to be feasibly implemented within the deadlines; EPA consequently exercised its statutory authority to extend the attainment deadline by two years, to 1977, for all areas needing transportation controls. However, environmental groups successfully challenged in court the use of automatic, blanket extensions (rather than ones based on case-by-case reviews of SIPs), and EPA was required to mandate transportation control plan development aimed at least initially at the 1975 attainment date. Operating under a tight deadline and with limited input from transportation agencies, state air quality agencies (and sometimes EPA in cases where air agency actions were insufficient) produced highly controversial plans that included a range of transit incentives and auto disincentives. Gasoline rationing was mandated when that was the only way 1975 attainment could be demonstrated (on paper). Based on the obvious problems with implementing these plans, EPA then granted the extensions to 1977 that it initially had proposed.

In most areas, the extensions provided the opportunity to modify the SIPs, remove the most controversial transportation control measures, and refine other plan elements. Implementation of some TCMs proceeded, while others underwent further study. Progress was made as new emissions controls were introduced on automobiles and industrial sources. Despite these gains, however, it soon was apparent that the ambient standards could not be attained by 1977 even with transportation controls.

The 1977 Amendments

Congress addressed this problem in the 1977 Clean Air Act Amendments, modifying the deadlines for attainment and inserting much greater detail on transportation controls into the text of the law. In effect, urban transportation controls became another key element of the Clean Air Act strategy, by providing the 'safety valve' required to sustain rigorous performance criteria in the face of political and technical realities.

Some took a cynical view of this development, assuming that transportation control was less a serious pollution control strategy than a way for Congress to avoid reopening arguments over the regulatory theory of the Clean Air Act (interviews, 1977-78 and 1982-83.) But others believed that urban transportation afforded opportunities for emissions reductions. This view was consistent with the drift of federal transportation policy in the mid-1970's, which envisioned an increasingly structured regional transportation planning and implementation process, with greater federal involvement in specifying the conditions of project approval. It appeared to many that air quality considerations could be introduced in a straightforward way into the kind of rational planning and decision-making process reflected in federal transportation regulations. Accordingly, based on language in the Clean Air Act Amendments of 1977, formal requirements for transportation control planning were grafted onto the urban transportation planning process.

Diagnoses of the pre-1977 attempts at transportation control planning revealed a number of problems and thus set the course for corrective legislation and guidance. Reviews of early plans found that many transportation provisions were narrowly conceived, partially specified, and poorly analyzed. In part, this appeared to be the result of short deadlines and limited resources for producing the initial control plans; there simply wasn't time or money to consider all the possibilities or to develop concepts fully. In part, there was little direct experience with many of the measures, nor was there data and know-how on which to base forecasts. Early plans also had been developed largely by agencies which lacked funding control or implementation authority for the transportation measures they suggested. In any event, many of the early plans included measures such as high occupancy vehicle lanes without stating exactly where such lanes might be located or how they would be financed; proposed major increases in transit service without having consulted with the operating

agencies; or incorporated parking fee increases without having contacted local governments. The net result too often was a plan that at once was controversial, vague, of questionable effectiveness, and not demonstrably feasible.

The 1977 amendments and the guidelines that followed addressed these concerns in some detail. Deadlines for preparing transportation control strategies (and for attaining the ambient standards) were extended. A list of measures presumed to be "reasonably available" was included in the legislation. EPA was directed to produce information documents on the measures and on analysis and forecasting methods. Planning procedures that encouraged greater responsibility and action on the part of funding and implementing agencies were spelled out.

Key to the process was the requirement that a SIP revision be produced which demonstrated that the air standards would be attained, and that "reasonable progress" toward that objective would occur. Failure to produce an approvable plan could be dealt with by the withdrawal or restriction of federal transportation funds. Some $75 million in special funds were authorized to pay for transportation control planning and analysis.

The result was a highly structured process for transportation control plan development, with a dedicated (if short-term) funding source. The central activity in this process was the analysis and evaluation of the full range of reasonably available measures, with detailed development of those that appeared to be feasible (technically and politically) in each local area. Planning was to begin with a broad look both at the listed measures and at other components of ongoing planning activities; the preliminary evaluation was to consider a full range of impacts, including transportation and air quality effects, changes in fuel consumption, and social and economic consequences. Political, institutional, and financial feasibility also were to be analyzed. Measures which survived this initial screening were to undergo detailed design and further evaluation, then be integrated into an overall strategy for air standards attainment. Finally, the best options were to be moved forward to implementation through timely inclusion in work programs and budgets.

Responsibility for carrying out this process generally was assigned to a lead agency or consortium of agencies at the metropolitan level, usually the metropolitan planning organization (MPO).[2] Funds were allocated to the designated agency to pay for plan development. State, regional and local agencies with project approval and implementation authority were to participate throughout the effort, and were expected to assure consistency between air quality planning and other planning activities. Part of the adopted plan was to be a clear statement of implementation responsibility, along with a demonstration of capability to fulfill implementation commitments.

Public involvement was to be a key component of the transportation-air quality planning process. The role of the public was seen as two-fold: first, citizen input and the response of elected officials was to provide an assessment of the acceptability of various proposals; and second, people concerned about the environment were to be given greater access to decision-making, so that programs and projects beneficial to air quality would stand a better chance of being adopted. Guidelines on broadening representation on transportation advisory committees, and on methods for increasing the involvement of citizens and interest groups, were issued.

In short, the 1977 Amendments spelled out a rational-model planning process with strong pragmatic elements. Alternatives were to be identified, evaluated in increasingly detail, selected on

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2. Curiously, the MPO had not appeared in statutory language prior to the 1977 Amendments. It was a regulatory creation of DOT intended carry out the '3-C' (continuing, comprehensive, and coordinated) planning process in each metropolitan area.

merit, and put into effect. The model was normative in that it stated what should occur, but it also was positivist in its attempt to tie transportation-air quality planning to existing institutions and procedures, assigning duties to those organizations whose ordinary responsibilities appeared to correspond to the information, resources, and authorizations needed for TCM implementation. The planning process emphasized analysis and forecasting. It used public involvement as a means of balancing conflicting objectives and desires. And it assumed that the results of this process (backed up by the potential for sanctions) would be a program of projects achieving the maximum feasible clean air benefits.

How well did this model work? A review of experience in a variety of urban areas indicates that results were mixed. Significant problems resulted from 1) the legacy of previous transportation-air quality planning efforts, 2) continued difficulties in integrating air quality planning and transportation planning, 3) the relatively low priority given to air quality attainment by most transportation agencies, and 4) the lack of earmarked funds for the effort. On the positive side, Clean Air Act funds 1) supported the first systematic analyses of transportation management and control strategies; and 2) led to the implementation of certain beneficial transportation measures that otherwise might have been disregarded, and accelerated the implementation of others.

These points are considered in more detail in the following paragraphs.

Problems Encountered

Legacy of Earlier TCM Planning Efforts: In the early period of transportation control planning, air quality agencies, working against tight deadlines and under court orders, often proposed measures which were seen widely as unrealistic and even punitive -- areawide parking surcharges, one-day-a-week driving restrictions, gasoline rationing. While such proposals served primarily to justify the need for extensions of the attainment dates and were quickly withdrawn, they left many transportation planners, local officials, and private-sector actors with the opinion that air quality agency staff had an unrealistic view of the significance of air pollution as a public issue, and that TCM planning was an activity likely to be controversial and unpleasant.

Problems also arose because clean air advocates initially were not knowledgeable about the planning or funding of transportation projects, and lacked experience with which to judge the feasibility or potential effectiveness of the proposals they were making. For example, air agency staff and environmental lobbyists advocated major expansions of bus service in suburban areas as a way of reducing auto use, proposed that the MPO impose region-wide surcharges on commuter parking fees, recommended development bans in areas not served by transit, and proposed to spend funds designated for a freeway expansion on ridesharing programs instead. Moreover these suggestions sometimes were made in what was perceived as a confrontational way, i.e., in terms that implied transportation agencies had "caused" the air quality problem, and were remiss for not having taken steps to correct it already.

It proved difficult for air agencies to overcome the mistrust and antagonisms engendered by these early experiences. Indeed, transportation agency staff, business representatives, and local officials continued to bring up these early experiences more than a dozen years later, in discussing why they preferred not to be too closely identified with transportation-air quality planning. Even though air agency staffers grew more sophisticated and no longer treated transportation agencies as "the enemy", bad feelings lingered as at least a partial barrier to increased cooperation. The early efforts at transportation control thus left a residue of doubt about TCM planning.

Difficulties Integrating Air Quality and Transportation Planning: The fit between transportation-air quality planning as described in the 1977 Amendments and implementing regulations and the ongoing activities of the agencies responsible for the delivery of transportation facilities and services was far from perfect. Most of the lead transportation-air quality planning agencies did carry out detailed studies of transportation control measures, and in so doing developed enhanced skills in air quality analysis and a better understanding of what might be accomplished. However, translating these detailed studies into implemented programs and projects proved to be another matter.

In most cases, transportation-air quality planning was carried out by the lead agencies (usually the MPOs) with relatively little involvement of other organizations. The funds available for TCM planning were not sufficient to allow for substantial pass-throughs to implementing agencies; most lead agencies spent the funds meeting paperwork requirements, i.e., carrying out the required analyses of the candidate measures and putting together the required planning documents. However, the MPOs themselves have few implementation responsibilities; these rest with state highway agencies, regional and local transit operators, and local planning and public works departments (as well as private businesses and individuals.) Thus, while the analysis process increased MPO staff's knowledge of TCMs, it had much less impact on the organizations whose action was needed to proceed with implementation.

Not surprisingly, TCM planning done by MPOs was oriented almost exclusively toward the projects and programs included in their areawide plans. Often, this meant conducting a detailed air quality analysis of the area's formal transportation planning documents, including (in the late '70s and early '80s)[3]:

- o the long-range element of the regional transportation plan, stating a general long-term strategy for capital investment in the regional transportation systems.
- o the transportation systems management element of the regional transportation plan, listing short-term operational strategies for improving the utilization of the existing capital stock.
- o the transportation improvement program (TIP), an annual compilation of projects budgeted for implementation in the coming year or formally scheduled for implementation within five years.

Sometimes, different scenarios regarding funding levels and project priorities were tested; in other cases the adopted five year and long range plans simply were assumed to be given. Under either approach, the measures emphasized were, or could be, included in the regional plans and programs: large or areawide projects such as high occupancy vehicle lanes on freeways, new rail transit facilities, regional carpool and vanpool programs. Most plans did include local projects funded with federal or state dollars (since they had to appear in the TIP), but locally-financed TCMs received little attention.

But for many TCMs, the regionally-oriented planning approach was problematic. Measures such as parking management, most bike and pedestrian projects, and the majority of traffic engineering and traffic flow projects rarely appear in regional plans and programs; for the most part they are developed and implemented by local agencies with little or no federal or state assistance. In some areas, the lead agency performed a general assessment of the feasibility and effectiveness of locally

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3. Federally mandated planning requirements were reduced considerably by the Reagan Administration. However, many states retain planning regulations that resemble the old federal guidelines.

funded TCMs and stopped there; in other areas local projects were considered only if the local agencies (especially those from the larger cities) themselves had developed and analyzed them. If local agencies reported a parking management program or a traffic signal retiming project, for example, the analysis might be incorporated into the air quality plan; but absent such reports, it often was assumed that no action would be taken at the local level.

The tendency to downplay local action may well have been justified under the circumstances facing most lead agencies. The effort necessary to work with local agencies to develop suitable TCMs, analyze them, and include them in a SIP revision was out of line with available resources. But without funds for either planning or implementation, local agencies were unable to pursue TCMs even when there was an interest in doing so. As a consequence, the regionally-oriented planning approach undoubtedly missed many opportunities for TCM action which individually might not have looked substantial but which collectively might have had significant impact.

Secondary Priority Given to Air Quality: Another problem TCM planning faced was the relatively low priority accorded to air quality issues by transportation professionals and local decision-makers. In most non-attainment areas, air pollution was (and remains) a continuing concern that regularly appears on the list of problems identified in public surveys; but it rarely has been assigned a high priority for action. Moreover, apparent conflicts with other important public goals (air pollution reduction vs. free-flowing traffic, e.g.) have continually complicated the issues.

Transportation agencies clearly have had difficulties in resolving air quality goals with their own missions to improve mobility. In several areas, air agencies and transportation agencies disputed whether major highway projects were consistent with clean air goals, with air agencies arguing that continued highway building would encourage additional auto use and delay attainment, while transportation agencies argued that without the highway projects, congestion would exacerbate air pollution. Impasses frequently developed, and transportation agencies retreated to the position that any project not clearly in conflict with the SIP should be acceptable. Air agencies have continued to insist that a more affirmative responsibility exists, but this view has not prevailed in most places.

There are other reasons for the low priority given TCM planning and implementation. One is a widely-held belief that, until automotive technology changes substantially, there is little that can be done to relieve the auto emissions burden, short of drastically (unacceptably) restricting auto use. In interviews, numerous transportation professionals argued that alternatives to the auto were already in place and that those who conveniently could use them were for the most part doing so. They saw the gains from additional incentives and expenditures as potentially very costly, and not likely to make much difference. Furthermore, many reported a decided reluctance to limit personal transportation choices through government policy, and several were concerned that auto disincentives might hurt the local economy by reducing locational attractiveness.

In addition, a range of other groups expressed doubts that further auto emissions reductions were as important as control of industrial emissions and related problems such as acid rain. Elected officials worried that further transportation interventions would be politically unpopular. Environmental groups noted that fashioning an effective acid rain policy was of greater interest to them than transportation control. All told, there was little public pressure to "do something" about transportation-related emissions, even from air quality advocates. Several transportation professionals commented that air quality agencies themselves showed relatively less concern about transportation than about stationary sources of pollution; they saw this as confirmation that active pursuit of emissions-reducing transportation measures was not a high priority.

Reluctance to take stern action to control auto emissions also resulted from ambiguities in the scientific basis for air pollution regulation. Uncertainties about the long-term health effects of

exposure to air pollutants, questions about the quality of data on emissions and concentrations, uncertainties about the atmospheric processes of ozone formation and dispersion, and difficulties in forecasting future emissions, concentrations, and exposure levels all raised doubts about what should be done. Among transportation professionals, a common view was that onerous steps should be taken only if there is a clear danger, and they were not convinced that a case for air pollution as a clear danger had yet been established.

For all of these reasons, air quality concerns were not given noticeably higher priority in transportation planning despite the provisions of the 1977 Clean Air Act Amendments. As noted earlier, much of the planning effort consisted of gathering together measures already slated for implementation for reasons in keeping with traditional transportation planning objectives (such as increasing mobility or relieving congestion). Special funding for transportation-air quality planning generally was used to develop detailed estimates of the emissions reduction potential of these measures, as required by SIP regulations, rather than to search out and refine proposals for additional TCMs. The anticipated public pressures for stronger initiatives in transportation generally failed to materialize, and air quality thus was treated as another requirement to be dealt with, but hardly an imperative for action.

Funding Problems: A fourth problem that tended to limit the impact of the planning done under the '77 Amendments was the lack of clear funding source for TCM implementation.

First, as noted earlier, Clean Air Act planning money made it possible to evaluate TCMs, but funds were not sufficient to pay for implementation as well. This restricted both what was considered and the priority given to the candidate programs and projects.

The lack of clear funding for TCMs was exacerbated by the shortfalls in transportation funds which had begun to appear in the early '70s. In many areas, lack of funds was making it difficult to implement even strongly supported projects: competition for the available money was fierce. There was almost no interest in funding TCMs by cancelling or substantially postponing other projects (although the topic was a source of arguments between air and transportation agencies.) Operating under the politics of 'fair-share' and 'wait-your-turn', even the most desirable TCMs thus ended up far down on the funding list; the time frame for implementation was more likely to be 6-15 years rather than the five years or less available before the Clean Air Act's deadline 1982-1987.

Furthermore, a number of TCMs are not eligible for funding under most federal and state programs; they have no established source of financing except for local general funds. Such TCMs had to compete not only with other transportation projects but with the full range of demands on local general funds, including economic development, housing, welfare, and public safety.

Together, these funding problems reinforced lead agencies' tendency to evaluate only projects that already were under consideration at the regional level.

Benefits Produced

Systematic Analyses of TCMs: The transportation-air quality planning effort provided many areas with their first opportunity to systematically evaluate the full range of transportation system management measures, to consider the potential of a package of TSM measures in addressing the problems of a subarea or travel corridor, and to do a thorough impact analysis. In many areas, transportation-air quality planning also led to the establishment of criteria for the expansion of transit and ridesharing and the development of guidelines for measures such as park-and-ride lots and facilities for high-occupancy vehicles. By creating pressures for agencies either to implement TCMs or

demonstrate their infeasibility, the requirements induced better matching of measures to markets, detailed consideration of cost-effectiveness, and reassessment of budgets. The result has been a more realistic understanding of what various transportation measures could, and could not, accomplish, as well as a better sense of implementation potential.

Benefits also have resulted from the strengthening of procedures and the development of better information necessitated by TCM planning requirements. For example, air quality funds necessitated the review and updating of data bases,the consideration of more cost-effective ways of gathering information on travel choices and system performance, helped support the development of lower-cost, faster, and more policy-sensitive analysis techniques; and led to the establishment of procedures for monitoring projects' effectiveness.

It also is worth noting that air quality planning provided crucial support for metropolitan planning staff at a time when traditional funding sources (especially comprehensive planning funds from the U.S. Department of Housing and Urban Development [HUD]) had been severely reduced.

Early Implementation of TCMs: The implementation of a number of TSM and transit measures can be attributed to the transportation-air quality planning process. In several urban areas measures such as carpooling, vanpooling, and preferential treatment of high occupancy vehicles were implemented largely because of the air quality requirements. A number of TCMs were first considered at the urging of EPA and other air agencies, and implementation probably occurred more quickly and extensively than would have been the case absent such a push. Other measures, especially parking management plans and trip reduction ordinances, were put together explicitly because of Clean Air Act requirements, often with funds for transportation-air quality planning. These measures probably would not be in place but for the transportation-air quality planning efforts.

It is important to note that some measures generated such controversy in early transportation control plans that air agencies omitted them from subsequent plans. In the interim, local transportation problems stemming from congestion and inadequate funding created a grass roots movement toward transportation controls quite apart from air quality benefits. Yet if the history of a specific measure is traced, its introduction to the political dialogue often appears to coincide with the early air quality plans, and analyses conducted during the air quality planning process have sometimes played an instrumental role in a much later decision to implement. This hints at a significant (if subtle) role for transportation control planning in helping to define the long-term policy agenda.

Summary

In summary, transportation-air quality planning did not completely fulfill the expectations of those who drafted the 1977 Clean Air Act Amendments. Transportation-air quality planning did help develop better data and better transportation analysis and evaluation skills, and can be credited for the implementation of a number of TSM measures which otherwise might have been passed over or delayed. It did not make major changes in the way transportation agencies consider air quality, nor did it substantially alter transportation priorities. Skepticism and distrust that had built up due to previous air quality planning failures left a residue of concern that was not removed by the '77 Amendments' procedural reforms. Perhaps the greatest shortcomings of the process were its inability to create a way to pursue TSM measures falling under local jurisdiction, and its focus on refining analyses rather than dealing with funding and implementation issues.

Table 3. Land Use-Transportation Strategies

1) matching land development to transportation capacity
*exactions and fees for on- and off-site transportation facilities and services
*transportation/land use consistency (General Plan)
*transportation/land use consistency (zoning, transportation improvement program)
*adequate public facilities requirements
*transportation conditions of approval for new developments
*conditional zoning tied to traffic mitigation
*annexations tied to infrastructure and service availability
*restrictions on traffic-intensive uses

2) directing development to areas with adequate transportation capacity, services
*urban limit lines
*infill policies
*transfer of development rights

3) developing land use patterns which offer opportunities to engage in activities without having to travel far
*clustering of buildings
*on-site/near-site services (convenience stores, banking facilities, child care centers)
*jobs-housing balance
*mixed use development

4) creating environments which support the provision of and encourage use of commute alternatives
*density increases/bonuses in areas served by transit
*compact development, cluster development
*subdivision/zoning/site design requirements for transit
*pull-outs, transit shelters, park-and-ride, preferential parking, etc.
*annual development quotas, caps

5) encouraging land uses and designs that permit trips to be eliminated
*offices in the home
*"smart buildings"

o whether suburbanization of employment will, over time, help reduce trip lengths, or increase them

o whether/how much policies encouraging additional housing development in parallel with job growth will help reduce commute trip lengths, congestion, and related problems

o whether growth management strategies such as urban limit lines, infill incentives, growth-pacing controls, aid in traffic management

o what other benefits and costs, direct and indirect, are associated with these strategies.

Currently, researchers disagree on these matters. For example, some argue for strong policies to encourage housing development in closer proximity to jobs, and vice versa; others assert that proximity is less important than clustering (so that transit and ridesharing is facilitated), and argue that jobs-housing balance absent such clustering might even lead to more auto use and more sprawl (since trips in the 2-10 mile range are in general too short for pooling and too long for walking and cycling.) Studies to date have suggested positive results (up to 10 percent in reduction in emissions for jobs/housing balance, e.g.) but have been based on very simple assumptions (e.g., that a certain

3 THE EFFECTIVENESS OF TRANSPORTATION CONTROL MEASURES

As the next round of TCM planning gets underway, it will be important to understand the degree to which various transportation measures can improve air quality. While caution must be exercised in generalizing about TCMs from a limited number of specific cases, there fortunately is a sufficient body of analysis and experience to permit an examination of the emissions reduction potential for the most important measures.

Transportation control measures can be grouped into several categories, according to their primary objective or effect:

- o Improvements to alternative modes: These measures increase the attractiveness of transit, carpools and vanpools, bicycling and walking in comparison to the single-occupant auto.

- o Disincentives to auto use: These TCMs are designed to discourage travel by single-occupant vehicle (SOV), usually by restricting SOV movements at certain times or in certain places, or by removing subsidies, increasing costs, or decreasing convenience.

- o Operational improvements for emissions reduction: These measures are intended to directly reduce vehicular emissions without necessarily changing the amount of auto use.

- o Technological changes to reduce emissions: Fuel, engine, or other equipment changes reduce emissions per mile.

- o Reducing the need for travel: These measures allow individuals to engage in desired activities with less travel, e.g., by substituting communications technologies or arranging land uses so that trips can be consolidated or shortened.

A more detailed listing of TCMs is presented in Table 2.

The categories in Table 2 help to illustrate that TCM effectiveness depends on a number of factors, including the percent and type of trips affected. The first three categories are intended to reduce emissions without significantly changing travel behavior or reducing VMT. The strategies are supply- and operations-oriented and would require traffic engineering skills for implementation.

Categories 4-6, in contrast, are intended to reduce emissions by reducing VMT. They explicitly intend to alter travel behavior, through incentives in some cases and disincentives in others. are demand- and market-oriented and their implementation would require skills in planning and economics as well as more traditional engineering.

The final two categories emphasize control of emissions without necessarily altering either transportation facilities or travel demand. Category 7 includes technology options of the sort that have been responsible for much of the emissions reduction to date. Their effectiveness is dependent on neither transportation system changes nor travel demand alterations, but they raise questions of technological readiness and cost. The final category includes vehicle-oriented items which which can be implemented via regulation of the sort air pollution control agencies work with.

Table 2. Transportation-Air Quality Strategies

1) improving traffic flow conditions through road improvements and better utilization of existing capacity
*new roads; added lanes
*intersection widenings; over- or underpasses
*provision of left- and right-turn lanes
*peak period on-street parking bans
*efficient signal timing
*freeway ramp metering and flow metering
*timely accident removal

2) shifting trips to less congested routes
*route guidance
*route restrictions
*corridor management

3) shifting trips to less congested times of day/days of week
*flextime programs
*staggered work hours
*staggered work weeks
*congestion pricing
*peak period restrictions on travel, deliveries

4) shifting travel to less polluting modes
a) provision of/improvements to commute alternatives:
*better transit: denser networks, increased frequency, direct service, express service, timed transfers
*specialized services (shuttles, club buses, shared taxis)
*programs to market, promote, and assist carpooling, vanpooling,
bicycling, walking

b) provision of related facilities:
*HOV lanes, bypasses on freeways and local streets
*HOV signal preemption on on-ramps, major intersections
*improved transit stops, shelters, stations
*park-and-ride lots
*parking facilities for carpools, vanpools
*bike paths and parking
*walking paths and sidewalks

c) subsidies/other incentives:
*transit passes, employer provided or subsidized vehicles for pooling, mileage payments for bike, walk use
*preferential parking allocation, location, and price for HOVs
*guaranteed rides home; midday transportation; short-term auto rentals

5) reducing auto use and removing auto subsidies:
*promotion of voluntary no-drive days
*vehicle-free zones, transit malls
*area entry licenses
*parking by permit only
*congestion tolls, entry tolls
*parking pricing
*control of parking supply, location, use, rates
*no free employee parking for solo commuters

6) eliminating some trips altogether
*telecommuting
*teleconferencing
*delivery services
*automatic payroll deposits

7) technology substitutions
*new emissions control devices
*clean fuels
*clean engines

8) other restrictions on idling

How much any one measure actually accomplishes emissions reduction objectives depends on several factors. The share of travel the measure affects, the type of trips affected, how widely the measure is implemented, sensitivity to exogenous changes, and whether there is full or only partial compliance are among the factors to be considered.

For example, many of the measures included in transportation-air quality plans, and particularly the demand-oriented ones, apply only to peak period work travel: ridesharing programs, flextime, and to a large extent transit services and incentives, are aimed at commuters. The trip to work is a

natural target, both because it is the most susceptible to shifts to alternatative modes and because it is most likely to occur in congested conditions. But work trips account for only a third of the vehicle miles travelled and 20-25 percent of the trips in most cities. Suppose that 70 percent of the workers in a community drive alone. Shifting fully half of these commuters to alternative modes would affect only about 11 percent of the VMT and less than 8 percent of the trips. Since a more likely shift is less than 10-15 percent of the drive-alone trips (Horowitz, 1982), net benefits per work trip-oriented measure probably will not exceed a few percentage points in overall air pollution reduction.

Many traffic engineering oriented measures also tend to be most beneficial during peak periods (and some, e.g., ramp metering, may operate only during peaks.) Added capacity, for example, may not be particularly needed at other times of the day.

Another factor is the geographic scope of implementation of the TCM, and the percent of trips affected. For example, auto restricted zones can reduce VMT, emissions, and exposure levels. However, they are suited to central business districts and other concentrated areas of activity. Only trips that would otherwise have entered such areas would be affected. Similarly, freeway traffic flow improvements have an effect only on those trips using the freeway and perhaps using parallel routes (where the effect could be positive if trips switch to the better-flowing freeway, or negative if trips are stored on arterials in order to keep the freeway moving.)

The size of the market also is important. Substitution of a bicycle trip for an auto trip is extremely effective in eliminating emissions, but is realistic and attractive for relatively few people. As another example, a city-wide tax on parking would affect the travel choices of only those commuters for whom the tax raised the cost. If employers or businesses pay for the parking, reductions in travel would be highly unlikely. In many areas the affected market segment would be very small; only 10-20 percent of all employees, and virtually no customers or clients, pay for parking.

Finally, implementation experience may differ from forecasts for reasons beyond the direct control of planners and engineers. Unanticipated changes in social and economic factors can undermine measures' effectiveness; cheap fuel has had this effect in recent years. Or those affected may resist or find ways to circumvent TCMs. Examples include parking in nearby residental neighborhoods to avoid parking fees and restrictions, successfully lobbying for discount tolls for regular commuters, and purchasing a vehicle just before a new engine or emissions control technology is introduced to avoid having to use the new equipment for some years.

To develop a better understanding of these issues it is instructive to look at several in more detail. Commute alternatives (transit and ridesharing), traffic flow improvements (especially signal timing), and parking management will be considered here.

Commute Alternatives

Transit improvements

Transit improvements include a wide variety of actions designed to attract riders by providing fast, safe, convenient, comfortable, financially attractive services. Transit improvements may be made by providers of conventional public transit services, by public agencies in charge of highways and streets, by private transportation companies, or by employers, businesses, and/or neighborhood organizations. Common actions include:

- o new routes and services
- o increased frequency of service

- o reduced in-vehicle times, accomplished by providing non-stop or limited-stop service and/or reducing route circuity
- o direct service (no transfers) or speedier, "timed" transfers
- o reductions in access time, accomplished by route restructuring, provision of door-to-door collector and distributor services linked to line-haul services, development of park-and-ride lots, etc.
- o transit-only streets, lanes and ramps, signal preemption, and similar infrastructure and operations designed to increase transit's speed and reduce delays due to traffic conditions
- o transit information centers, ticket sales, etc. at convenient locations
- o adequate lighting, security, and protection from the elements at stations and stops
- o fare discounts and /or subsidies, especially for regular users (provided by government, employers, retailers, or others)
- o special services (subscription buses, shuttles, luxury buses, etc.) designed for specific market segments
- o joint development at transit stations, both to build a market for transit and to help cover the cost of providing it.

Experiments are regularly are being carried out to test new strategies for encouraging transit use. For example, several areas are offering free taxi rides to the transit user who unexpectedly must work late or leave work midday for a family emergency, and a few are testing the effectiveness of providing services such as child care, dry cleaners, banking facilities, and convenience food shops at transit stations and park-and-ride lots.

Literally hundreds of examples of transit improvements have been documented, thanks in large part to the Urban Mass Transportation Administration's Services and Methods Demonstration Program. A few illustrative examples are provided below.

Improvements in Routes and Frequencies of Conventional Transit Services: Portland, OR has implemented an extensive timed-transfer system for its suburban areas, wherein buses converge at well-designed transfer centers, allowing passengers to change vehicles with a minimum of delay or difficulty. The suburban services also are well coordinated with the new light rail system. In the downtown, a transit mall emphasizes the city's commitment to public transportation while reducing traffic delays for transit users.

Fare Subsidies and Other Incentives: In the San Francisco Bay Area, numerous programs are in place to provide additional financial incentives for transit use. For example, the City of San Francisco requires on-site transit pass sales at most major developments built in the last five years. Berkeley, CA's commute alternatives program sells transit tickets and passes at its downtown Transportation Store, encourages employers to subsidize transit users, and works with state and regional agencies to identify and develop park and ride sites.

Special Services for Targeted Markets: Large developers and employers in such diverse suburban areas as Woodland Hills, TX, Montgomery County, MD, and San Ramon, CA have assisted in the establishment of subscription buses, shuttles to transit stations, and luxury van services.

The success of such programs varies widely and often is subject to debate. Between 1970 and 1980, almost all major metropolitan areas experienced a decline in transit's share of travel, and some systems also experienced a net loss of ridership. The losses occurred despite massive expenditures on operating subsidies, rolling stock, and in some areas fixed guideways. They were largely due to a combination of increasing auto ownership and use, decentralization of housing and workplaces, and rising household incomes; they also reflected federal, state, and local funding cutbacks that in many

areas necessitated fare hikes and service reductions. Declines in transit's share of urban trips have continued through the '80s, a time of low gas prices but ever-worsening traffic congestion.

Yet individual improvements such as those listed above often have had significant impacts in the markets they influence. Some argue that overall, investments in transit have stemmed its decline from what it might otherwise have been, and have reduced the need for additional highway capacity as well. In general, however, the high cost of providing transit, and questions about its effectiveness, mean that improvements will be scrutinized closely and will increasingly have to demonstrate strong benefit-cost ratios.

Many transit agencies and regional planning organizations continue to forecast increased transit mode shares in their long term plans. The forecasts often are based on projections of increased transit capacity, continued low, heavily subsidized fares, and (in a number of cases) significantly increased auto operating costs and travel times. The transit agencies admit that their ridership projections reflect hopes for the future rather than trend projections; many find themselves developing cutback strategies. However, in earlier air quality plans the transit forecasts generally were taken at face value and adopted as a TCM. Based on the forecasts and projections, air quality improvements of 3-5 percent often were estimated. Such benefits clearly cannot occur unless both secular trends and funding difficulties are reversed.

Transit improvements will reduce emissions to the extent that they 1) attract riders away from automobiles, or 2) result in more efficient operation of the transit vehicle itself, and therefore reduce transit vehicle emissions. Some transit measures may do both--preferential treatment through reserved lanes, signal preemption, etc. is an example--but other measures risk less efficient operations in hopes of attracting riders. In such cases a careful assessment is imperative. For example, if the frequency of diesel bus services is increased in hopes of attracting more riders, diesel emissions will increase proportionately; ridership increases obtained from former auto users will be needed to offset the emissions increases.

Analysts also should be aware that various kinds of transit services can and do compete with one another (and with walking, biking, etc. in some environments), not just with single occupant autos. Examples of express buses and vans attracting a substantial portion of their ridership from competing rail service have been documented in the New York and San Francisco metro areas.

Finally, attention should be given to cold-start emissions. On a seven-mile trip, about 90 percent of the emissions occur in the first mile. Thus, express buses from park-and-ride lots may attract more riders than comparatively circuitous, slow neighborhood services, but there may not be a net improvement in emissions.

Transit services have other benefits and costs that should be noted. Well-designed transit improvements can reduce operating costs for the transit provider, and/or help attract other sources of income, e.g., from joint development. This sometimes is as important to the operator as ridership increases. Transit improvements also provide much needed mobility and access to those who lack an auto, cannot drive, or choose not to do so. And in some cases, transit improvements can help shape a denser, more pedestrian-oriented, more urban (and urbane) built environment.

Transit services are costly, however. Rarely can services be provided for less than $25/hour, and costs frequently are twice that, or even more. In some cases where ridership is very low, it would be cheaper to simply buy each rider a new automobile! Furthermore, since transit vehicles get only 3-5 miles per gallon of fuel and usually travel on circuitous routes with underutilized "backhaul" trips, they must carry some 7-15 passengers to compete with autos on a per-passenger fuel efficiency basis. In addition, transit vehicles tend to be noisy, and maneuver poorly in heavy traffic or narrow streets;

these characteristics may generate complaints from residents and even from business owners, particularly if the vehicles are carrying few passengers.

Emissions changes due to transit improvements cannot be estimated very meaningfully in the abstract. Earlier modelling efforts are often hard to interpret because they assumed parking surcharges and/or gas price increases would accompany the transit measures (see, e.g., Horowitz, p.249.) Actual experiences must be interpreted in light of the significant drop in automotive fuel prices of rcent years. Very roughly, however, emissions reductions of less than 1 percent to as much as 20 percent have been estimated for particular corridors. Areawide effects on the order of 5 percent might be possible at the upper end of the spectrum of changes.

Transit benefits of any sort will not be ralized unless some means of implementing transit improvements is found. This will require careful and realistic planning, reflecting what has been learned about traveller behavior and mode choice. Transit is not likely to be successful in reducing auto use unless it can offer travel times, costs, and comfort levels at least comparable and probably better than the auto. Today, with funding for transit a major concern, wishful thinking about transit can be destructive, since "disasters" may undermine public confidence and reduce willingness to support transit.

Funding considerations suggest another aspect of effective implementation: joint public-private approaches are becoming increasingly important. Private sector involvement in transit improvements may offer cost-saving ways of providing facilities and services, new sources of funding for publicly-provided transit, mechanisms for encouraging increased transit use, and/or market-making opportunities through land development projects. Private firms' willingness to get involved in the transit arena is by no means assured, however, nor are benefits from involvement automatic.

Probably the most important point is that transit needs to be tailored to meet the needs of the markets it wishes to serve. Today, in many of these markets, an auto is always available, out-of-pocket costs of travel are not a concern, time is short, and flexibility is needed. Serving such markets will require a broader conception of transit, encompassing subscription services, taxis and dial-a-rides, vans and shuttles as well as conventional buses and trains.

Ridesharing

Ridesharing programs promote, assist, and provide incentives for sharing rides to and from work. Increasingly, transit is considered a form of ridesharing, along with carpools and vanpools; but most ridesharing programs still focus on the latter two, as will we here.

Ridesharing programs have placed thousands of commuters in carpools and vanpools in urban areas across the country. Ridesharing is relatively inexpensive compared to transit, since it is largely a self-service mode with public costs limited to matching and coordination assistance. It can work in low-density areas that are not efficiently served by transit, especially when the other trip end is a considerable distance away, in a congested area where parking also may be scarce and expensive. Ridesharing has been considerably less successful when congestion is absent, parking is inexpensive to provide or obtain, or trips are short. The major market for rideshare programs thus has been among suburban commuters who make relatively long trips along congested routes into major employment centers with costly or limited parking. Whether ridesharing can be made to work in suburban job centers with little congestion and plentiful parking is still an open question, although a number of attempts to do so are underway.

Ridesharing has been implemented in a variety of ways. Early programs, established to reduce VMT and hence improve air quality and conserve energy, operated through special-purpose region-

wide agencies. At first, freeway signs, radio announcements, and other areawide marketing strategies were used to reach potential customers. Experience soon taught that efforts were more effective when programs were offered with employer endorsement, assistance and incentives. Today, most programs work with major employers to encourage their employees to join pools, and areawide promotions play a secondary role.

Transportation agencies often support ridesharing as an alternative for congestion relief because it is cheaper than capital-intensive highway expansions or capital- and operations-subsidized transit. Their efforts include provision of complementary facilities and services, such as priority high-occupancy vehicle lanes and mass transit. Nevertheless, few states provide significant levels of funding for ridesharing programs.

Employers participate in ridesharing programs for a variety of reasons. Some, worried about traffic congestion and its adverse effects on community relations, consider ridesharing programs a "good neighbor" policy. Some also view ridesharing as an employee benefit, although others question how important it is as such. Increasingly, however, employer participation in ridesharing is a matter of government incentives and requirements. Some communities offer density bonuses or reductions in parking requirements to employers (and/or developers) that agree to aggressive commute alternatives programs. Other areas require ridesharing as a traffic mitigation strategy. Federal, state, and local tax incentives also have been provided to employers who assist employee ridesharing.

Ridesharing programs' impacts are generally too small to be reflected in areawide auto occupancy data or vehicle counts. For example, in a typical urban area, the number of vanpools operating is counted by the hundreds, and agency- or employer-formed carpools (those above the natural or "base case" level that occurs without special efforts) typically amount to a few thousand. The impacts can be notable at the level of a particular travel corridor, a single employer, or a small downtown, however. For example, pooling over the San Francisco Bay Bridge has permitted peak-period passenger counts to increase while vehicle counts have remained stable.

Some researchers question whether existing ridesharing programs might not have already saturated their primary markets, so that future growth would require much higher levels of effort. For example, it might be increasingly necessary to offer large financial incentives for ridesharing, such as subsidized use of a vehicle; to work with employers that have so far been considered too small to have much ridesharing potential; or to implement substantial disincentives to driving alone. Efforts to do these very things are underway in some areas, especially where traffic congestion is severe. Transportation management associations have been formed to provide ridesharing services and incentives to all employers, large and small, in an area; trip reduction ordinances have been enacted to require employers to offer commute alternatives and sufficient incentives for their use to achieve specified mode shares or participation rates.

Nevertheless, ridesharing is likely to remain primarily of interest to employees who live a long way from work -- 15 miles or more for carpools, and 25 miles or more for vanpools. For shorter trips, the added time to pick up and drop off passengers and the inconvenience of conforming to a fixed travel schedule will probably outweigh any cost savings or other incentives. In addition, in many areas large numbers of employees use their cars for work-related trips, or make child care, shopping, and personal business trips on the way to and from work and at lunch. On-site facilities and services and compensatory transportation (such as shuttles, taxi vouchers, and short-term car rentals) may remove some of the need for the car, but are still in the experimental stages.

How effective ridesharing can be in reducing emissions depends on several factors. An important issue is whether trips are eliminated or merely shortened. In the latter case (for example, when the pool meets at a park-and-ride lot) cold start emissions offset a part of the gain from pooling, and the

overall effect will depend on trip length and congestion levels. If some of the poolers were former transit users, effectiveness may be further reduced.

Many transportation-air quality plans produced in past years projected major areawide increases in auto occupancy due to ridesharing programs. In areas with established programs, the calculations in support of these estimates often were based on an assumption that pool formation rates would be maintained at the same or higher levels than obtained when the programs were started. In areas with little ridesharing activity, the assumption often was that new programs would be established and would prove to be as successful as those in other cities, even though conditions might be substantially less promising. As in the case of transit, the assumptions made about future utilization of ridesharing are large ones.

Surveys of operating ridesharing programs offer more concrete evidence on effectiveness. An early study of 38 metropolitan areas (Wagner, 1980) found that work VMT had been reduced .03 percent to 3.6 percent. This would translate into lesser emissions reductions, however, because of cold starts. More recent work, reflecting today's low fuel prices, suburban travel orientation, and free parking, indicates areawide emissions reductions on the order of 0.8 percent might be expected. (CSI, 1989)

Traffic Flow Improvements

Traffic flow improvements are measures, usually relatively low-cost and small-scale, which increase roadway capacity, increase or smooth out speeds, and/or reduce delays and stops. Traffic flow improvements can be accomplished in a variety of ways. Retiming traffic signals as a system can improve efficiency of operations significantly; retiming is especially effective when signal timings have not been reviewed in a number of years, but has proven successful for new signal systems as well. Streets' traffic-carrying capacity also can be enhanced by restriping for additional lanes, adding turning bays, restricting turning movements and/or cross-traffic, and eliminating pedestrian crossings at critical locations; removing parking or restricting its use to off-peak periods; removing unwarranted stop signs, improving sight distances, and eliminating roadside hazards or distractions; relocating bus stops and loading zones to remove bottlenecks; limiting curb cuts and restricting peak period use of those which create excessive "friction"; and using one-way street couplets. Metering access to roadways, use of shoulders and medians for additional travel lanes during periods of heavy flow, provision of motorist advisory systems to even out traffic loadings and direct travellers away from tie-ups, establishment of programs to quickly remove disabled vehicles from the traffic stream, and even peak period pricing strategies are other means of improving traffic flow.

The objective of these traffic flow improvements is to maximize the carrying capacity of the roadways rather than to reduce overall travel, shorten trips, or otherwise affect the pattern of demand. Thus while measures which lead to shifts in the frequency, mode, time, or destination of travel also may improve traffic flow, they will not be considered here.

Examples of traffic flow improvement projects are plentiful; traffic engineers have a long record of accomplishment. Most urban areas can identify numerous examples of low-cost projects which were implemented under FHWA's TOPICS program in the 1960s. Typical projects included channelization, installation of turning bays, and use of medians to reduce cross-traffic and/or parking lane "friction".

On-street parking management also has been widely implemented, and is reported to have proven extremely beneficial in Washington, DC, San Francisco, Boston, and other major cities (Ellis, 1982). Measures range from curb-lane parking bans during peak periods, to selective removal of parking spaces to improve intersection capacity, to better enforcement of existing parking regulations.

Computer-assisted traffic signal timing has been emphasized in recent years. Probably the most prominent example is California's Fuel-Efficient Traffic Signal Timing Program, a multi-year, multi-million dollar effort which to date has retimed nearly 4000 signals in urban areas across the state. The FETSIM projects, on average, have produced reductions in stops of 16 percent, delay reductions of 15 percent, travel time reductions of 7.2 percent, and fuel use reductions of 8.6 percent for the affected travel (Deakin and Skabardonis, 1986). Recent software additions permit emissions estimates, and show reductions of up to 8 percent in both CO and HC in the affected traffic streams. (Skabardonis and Deakin, 1986.)

There also has been considerable analysis of other strategies for improving traffic operations. Deakin and Skabardonis (1985) present an analysis of improvements which include the addition of turning lanes and lane restriping in a dense downtown network; Schwartz and Home (1983) discuss metering strategies being used in Manhattan. The effects of such programs are extremely site-specific, and it is somewhat risky to attempt generalizations. Reported improvements in speeds, delays and stops--presumably for the corridor rather than areawide-- have ranged from 2-10 percent.

Effectiveness at reducing emissions depends in large part on context. Traffic flow improvements reduce emissions by reducing stops and starts, speed changes, and idling. The amount of emissions reduction will depend both on the design of the measure being implemented and on the specific characteristics of the implementation environment. Computer programs and hand calculation procedures are available for a wide range of measures and conditions, although most methods require substantial amounts of data for accuracy.

Extensive modelling and some direct emissions measurements have been carried out for signal retiming; this work suggests that emissions reductions on the order of 4-5 percent could be obtained within a typical range of affected networks. In California, about 40 percent of urban travel occurs on signalized networks, suggesting that ubiquitous signal retiming might reduce areawide emissions by up to 2 percent. (The numbers would vary considerably among communities.)

For other traffic flow improvement measures, fewer reliable studies of effectiveness are available. Few SIPs included detailed analyses of these measures; in any event, a case-specific analysis would be in order. A very rough estimate, accounting for the fact that traffic would be affected on only a subset of an area's network, is that emissions reductions of 1-2 percent might be attainable from aggressive, widely implemented programs to improve traffic flow.

Other benefits accrue. Traffic flow improvements tend to reduce fuel consumption, noise, and vehicle wear and tear. First year savings from reduced fuel consumption alone often exceed project costs. Most traffic flow improvements also improve safety, and indeed, a number of these projects are funded under federal and state highway safety programs.

However, some traffic flow improvements have drawbacks that require careful consideration. Removal of on-street parking in areas where the spaces are relied upon by abutting retail shops or residents will, at minimum, cause inconvenience; in some cases more drastic adverse economic impacts could result. Similarly, restrictions on turning movements may improve traffic flow but reduce accessibility and force travellers to make circuitous trips to reach businesses and residences. Improvements in vehicle flow can sometimes degrade the pedestrian environment, for example by increasing traffic speeds to uncomfortable levels or cutting short pedestrian crossing times at intersections. The potential for such negative effects underscores the need for context-specific evaluation. Measures can sometimes be devised to minimize adverse impacts or to compensate for them.

Concerns are sometimes voiced that traffic flow improvements may induce additional trips and/or affect mode choice by producing better operating conditions for motorists. For the types of measures considered here, the travel time improvements for any one trip are usually less than a minute in total. Such improvements are likely to be important for short trips (under 10 min., e.g.) but not for long trips (over 30 min.)

The effectiveness of traffic flow improvements thus requires case-specific analysis, since their effects depend very strongly on the implementation context. At the same time, traffic flow improvements need to be considered from a system perspective rather than on an intersection-by-intersection or street-by-street basis. Counterproductive results can be obtained otherwise. For example, some cities have retimed their signals to give preference to through traffic, basing their studies on main street travel times only. Subsequent analysis of the street system as a whole has often found that operation is suboptimal; excessive delays for side streets and turning movements more than offset the benefits to the main street travellers. Similar counterproductive results may be produced if ramp metering or other strategies to protect freeway capacity divert motorists to longer, slower, more congested routes; the benefits to the protected route must be weighed against such disbenefits.

In addition, most traffic flow improvements should be reviewed on a regular basis. Many traffic flow improvements are sensitive to changes in traffic patterns or volumes; it has been estimated that signal retiming improvements are effective for only two to three years in the typical city, for example (Wagner, 1980). Even moderate traffic growth usually results in a need for signal retiming in 3-5 years. Introduction of a major new traffic generator or other changes that alter spatial or temporal patterns of travel may require modifications to the traffic control system on a much shorter time frame. (Deakin and Skabardonis, 1985).

Ironically, this traditional transportation improvement strategy has no programmatic source of funding in most areas (except for such streets as happen to be on a federal or state "system"), so that a major barrier to implementation is paying for the improvements. An exception in California is traffic signal retiming for systems of 10 or more interconnected signals, which are eligible for state grants from the Fuel-Efficient Traffic Signal Timing (FETSIM) Program.

Parking Management

Parkng management is a good example of a measure which analyses indicate to be highly effective at congestion relief, energy conservation, emissions reduction, but which has been implemented in only a few areas. While parking management includes many strategies, such as preferential locations for HOVs and resident permit programs, here we will consider the supply and price of parking provided for employee (commuter) use and its impact on travel choices.

Parking is provided by many cities in municipal lots and garages. Because local governments do not pay taxes themselves and most have access to relatively inexpensive money (tax revenues, on-street parking fees and fines, low-interest or interest-free bonds), they can provide parking at less than what it would ordinarily cost the private sector. When costs are low -- or revenues from other sources are commingled with parking revenues -- cities often appear make money on their parking supply activities while charging low rates (at least, not considering alternative uses of the land.) Even if municipal parking loses money, however, many localities justify it on the grounds that a convenient supply of parking supports economic development and business retention.

Parking also is provided voluntarily by the private sector. Depending on land prices, parking demand patterns, and prevailing parking rates, some companies apparently generate a profit by providing parking as a principal use. More often, parking serves as an important interim use during

land assembly and building design and approval, bringing in at least enough revenue to cover land holding costs.

With few exceptions, most employment centers provide 3-5 parking spaces per thousand square feet of building floor area. There are several reasons this parking is provided:

o City zoning usually requires it. Most cities, concerned about the problems which might result from inadequate off-site parking, have established requirements which would protect them from maximum demand at an assumed zero price.

o Banks often require parking even if zoning doesn't. While this in not an iron-clad rule, developers report that proposals lacking plentiful parking are seen as riskier, require justification, and may raise the cost of the loan.

o Plentiful parking is seen as an important competitive factor in the marketing of buildings and retention of tenants.

o Parking is seen as necessary from a public relations perspective, to avoid problems from spillover into others' parking facilities or to the on-street spaces in residential neighborhoods.

o Finally, parking can occasionally be a good money-maker, although profit does not appear to be common.

In some cases, tradition is probably the best explanation of why developers provide so much parking-- they haven't really considered why.

There is another question, however: why is parking provided to employees free of charge? Here, too, there are several explanations, including most of those listed above. Some of the particulars reported by developers and employers are as follows:

o In some areas, parking can be provided at little cost in surface lots. Collecting fees and the responsibilities it entails (hiring and supervising employees, monitoring and controlling cash, providing security, etc.) can be more effort than it seems worth.

o Zoning restrictions such as setbacks, maximum lot coverage regulations, etc. may prevent alternative profitable use for the land. Providing surface parking may be cheaper than landscaping if a manicured, irrigated landscape would be the alternative.

o For garage spaces within the building, separate cost accounting may not have been done. Allocation of costs of shared foundations, etc. may appear unduly complicated to the developer. Even if costs are known, however, they are not necessarily presented to the lessee as a separate cost item.

Perhaps more importantly, free parking is widely viewed as an important tenant amenity and employee benefit. Parking costs thus are embedded in lease terms and absorbed as a (tax-deductible) operating expense rather than charged to employees. It is estimated that nationwide, about ninety percent of all employers receive free parking, and still more pay only a portion of the cost.

Free parking is not, however, free in any real sense of the word. A 320 sq. ft. space in a surface lot, financed over a 30 year period at a 10 percent interest rate, (or alternatively, assessed an annual land rent), would cost $20-25/mo. (including costs of pavement, striping, maintenance, etc.) at land prices of only $5/ sq. ft. $20/sq. ft. land prices would push the monthly parking cost up to $60-$70.

A space in a garage would cost much more: in most markets, $10,000-15,000 if the structure is above-ground, and $20,000 or even more if below-grade spaces are considered. Such spaces, considering amortization and operating expenses, would need to rent at $120-250 per month to cover costs.

Analyses and a few experiences indicate the size of the effect that charging for parking would have. Modeling results suggest price cross-elasticities (how many would shift modes) are low, in the .1 - .3 range for most commuters, so that a doubling of (the perceived) costs of drive alone travel would reduce traffic by 10-30 percent. But even a moderate parking charge could double drive alone commute costs. Commuters behave as though their trips cost them 6-9 cents a mile excluding parking (fuel at 3-5 cents plus a little for oil, maintenance, etc.). At the median US commute trip length of 10 miles one way, operating costs are some $1.20 -1.80 a day. Thus, parking at $30 -35 per twenty day working month would more than double the cost of the drive-alone commute -- which should in turn cut drive-alone commuting by 10- 30 percent. (It should be noted that extrapolation of observed elasticities to the higher ranges of parking charges might not be warranted. Also, lower response would be expected among higher income workers and vice versa; and less response than predicted might occur if people see themselves as having no reasonable alternatives, need the car at work or to pick a child up on the way home, etc.)

Studies in Los Angeles have reported that a 30 percent decline in drive alone did, indeed, occur under fairly similar conditions to those discussed above. (Shoup) Some analysts have suggested that parking pricing may be a second-best approach to rationalizing transport costs. (Direct road pricing reflecting miles driven, amount of congestion and air pollution caused, etc. is clearly preferable from an economist's point of view.) However, there are several barriers to change, and caution is in order.

First, the federal tax code is not supportive of a change in policy. Free parking is classified as a working-condition fringe benefit to employees, much as would be a sofa in the office. As such, parking is a tax-deductible expense for employers. Furthermore, the value of these tax benefits has no ceiling, and as indicated above can exceed $200/mo. per employee in some areas.

On the other hand, vanpool, carpool, and transit pass subsidies are deductible only up to $15.00. Any subsidy above that amount results in the **entire** subsidy being treated as taxable income, costing the employee some 28 percent (the marginal tax rate for most) and requiring that the employer undertake additional record-keeping and reporting. Alternate treatments, such as a commute allowance rather than a direct subsidy of any mode of commuting, also would result in taxable income.

Attempts to redress this disparate treatment have so far failed. Given the federal budget deficit, any change would probably have to be tax-neutral. Thus, proposals simply to raise the permissible subsidy to commute alternatives have so far been rejected. UMTA has suggested that an alternative revenue-neutral approach would be to exempt all commute subsidies up to $60 and to tax all over that amount; but they note that the taxes would fall principally on core areas of major cities and hardly at all on suburbs.

It has been argued that the vanpool/carpool taxable benefit is unenforceable in any practical sense because of the trail of audits that would be needed, as well as difficulties in determining "market value" of the subsidized trips under many common circumstances. Market value of parking spaces also could be hard to establish given current cost accounting and leasing practices. Nevertheles, in the current situation some employers are undoubtedly dissuaded from providing rideshare financial assistance; and the sizeable benefit to those who drive and park undermines spending for commute alternatvies.

Another reason for caution in adressing this inequity is that commuters may find any of several ways to circumvent a parking surcharge. Many will make use of off-site free parking if it's within

walking distance--and sometimes if it's not. For example, in the central areas of Berkeley, where free employer-provided parking is rare and off-street spaces cost $35-$65/mo., a severe problem with spillover into residential neighborhoods has developed. Resident permit parking programs are being instituted to cope with the problem. In a number of other cities, commuters reportedly park in residential districts near transit stops and take the bus or train the last few blocks to avoid paying for parking; in suburban areas, shopping center parking lots reputedly are used as rendezvous for formation of "carpools" to take advantage of preferential parking.

Being among the first developers, employers, or cities to forego free parking could be uncomfortable. For developers or building owners/managers, competition from other buildings would be a concern, and banks might be reluctant to lend if the competition would have better parking. For employers, taking away a benefit is usually nigh-on impossible; also, parking could become a labor negotiation issue. Not providing parking in the first place (new employers, or employers at a new site) may be somewhat easier, but could be problematic in a tight labor market. For cities, the threat that a developer would merely "go next door", taking away desired tax base (and possibly, major employers as well) is frightening. Overall, then, getting started could be difficult.

Summary

The typical TCMs such as ridesharing, transit, and traffic flow improvements have been found to produce emissions reductions, in favorable implementation environments, on the order of 1-3 percent each, with higher percent reductions feasible in particularly salutary circumstances. The effects of all of the measures are heavily context-specific and over-broad generalizations from specific examples is risky.

A program of such measures could produce total emission reduction benefits of some 5-10 percent. The results are not strictly additive because of interactions among TCMs. Particular measures may serve several objectives: restriction of on-street parking may simultaneously act as a disincentive to auto use and lower emissions from those cars still on the road by reducing stops and delays. Measures also can be combined so that they complement each other -- an increase in parking fees can be used to fund rideshare matching services, and HOV lanes can provide a time savings incentive. Occasionally, however, TCMs compete with one another. For example, in some areas, carpool and vanpool programs find that substantial numbers of their members are former transit users.

Since the SIP regulatory approach requires specific estimates of percent reduction in emissions overall and on an annual basis, detailed analyses will be needed. Nevertheless, the lesson of the earlier TCM efforts should be kept clearly in mind: to clean the air it is necessary to implement TCMs, not just study them.

4 FUTURE DIRECTIONS

Overall, transportation control measures have been found to be useful in reducing emissions. While individually, measures produce modest results, integrated packages of measures can be more effective than most stationary source controls. Especially with the longer-term orientation that appears to be emerging in discussions of air quality planning and management, a more rigorous, systematic implementation of TCMs seems possible. In addition, a wider range of options, including land use strategies and new technologies, may be available.

Nevertheless, prospects for further reductions of transportation emissions remain clouded, for several reasons:

o If measures such as ridesharing, traffic flow improvements, and improved public transit are indeed already widely deployed in their "easy" (low cost/voluntary/incentive) forms and in their most obvious markets, additional benefits from these measures will likely depend on finding new ways to increase their effectiveness. This might include packaging them together to capture synergistic effects, and widening their reach, e.g., applying them in smaller, thinner markets. The new organizational approaches to implementation and enforcement--employer based and publicly mandated--are being counted on to help accomplish that, but how well they'll do remains to be seen. Many transportation planners are concluding that a broader range of strategies, including land use strategies, will be needed in order to have a substantial effect on problems such as air quality.

o Land use-transportation strategies can make sense if a longer-run perspective is adopted. (In the five- to ten-year frameworks of earlier TCM planning, they were rarely considered useful.) Judging from actions being pursued for congestion relief, greater emphasis on transit-oriented site design, cluster development and density bonuses, traffic management tied to development approvals, jobs/housing balance approaches, and areawide growth management seems likely. This, too, raises uncertainties, however. Understanding of land use-transportation measures is incomplete, and in some cases the available evidence on their effects is contradictory (Deakin, 1989). Better information will be needed.

o New technologies also seem to be on the horizon: alternative fuels, improved emissions controls, and so-called "smart" vehicles and roadways are among the possibilities. While the prospects for a technological "fix" are always alluring, the actual benefits, costs, resource requirements, and institutional considerations for implementation still are unclear. Here, too, better information is critical, both to allow these new options to be evaluated fairly and to help assure that the shorter-term strategies selected do not foreclose preferable, but currently unavailable, choices. (PATH; Sperling)

o Finally, changes are occurring which may significantly alter the context in which transportation-air quality planning takes place over the coming years. In particular, post-Interstate transportation policies may create a substantially different decision process, perhaps involving a different set of actors, different alternatives, and different financing mechanisms from those of today. At the same time, changes in a host of other factors--demographic, social, political, economic, technological--may also create new opportunities, or new problems, for transportation-air quality planning. Transportation-air quality planning will have to respond to these changes. Understanding, and anticipating and even shaping them where possible, will be a challenge for all those concerned with transportation.

Overall, the next round of TCM planning will probably require 1) a more integrated, programmatic approach, 2) a willingness to try new options, 3) sensitivity and responsiveness to changing conditions, opportunities and problems, and 4) greater attention to evaluation and course corrections.

Programs of TCMs

For many TSM measures --ridesharing, traffic signal timing, flextime, and several others -- implementation has been sufficiently widespread that the question is not, What can be done? but rather, What more can be done? In order to obtain additional benefits from these measures, it may be necessary to:

o increase the funds available for their implementation--probably, by finding new sources of funding;

o increase their market penetration;

o introduce them into "thinner" markets; and

o implement them in integrated programs rather than individually.

Since we don't know with much confidence what will work and what won't, it also will be necessary to monitor the results and make adjustments as needed.

Funding is likely to be an immediate problem. Federal and state assistance for TSM activities is limited and few local governments feel they can afford them on their own. Consequently, attention will probably have to be focused on the development of new funding mechanisms, including ways to tap existing sources that in the past have not been fully exploited. These might include public finance mechanisms such as assessment districts, earmarked vehicle registration fees, and so on. Alternatively, private sector funding strategies could be explored: development fees, impact fees, business license fees, and payroll taxes are possibilities, as is direct project or program implementation by the private sector.

Increased market penetration and **introduction into "thinner" markets** both will require a sound understanding of those markets and consumers' choice processes. Research efforts might address such questions as who participates in commute alternatives programs, and how commuters respond to changes in their travel conditions. Work on the design and assessment of transportation services and programs for low density, suburban oriented commutes and for smaller employers would be particularly helpful.

Equally important will be work on how to **put together and implement packages of measures** that have a strong likelihood of being effective. Documentation of the ways in which TSM measures can be mutually supportive might be helpful, but probably a more important direction would be to investigate the new institutional arrangements and organizational structures for program implementation. Three such approaches currently receiving attention are trip reduction ordinances, multi-jurisdictional planning efforts, and transportation management organizations. In each case, the TSM measures being considered are not new--ridesharing programs are the core of most of these efforts--but the means of implementing them are.

Trip reduction ordinances (TROs) are local government requirements for actions designed to moderate the transportation impacts associated with development in a particular area or community. While early TROs focused on work trips to new commercial developments, an increasing number of the newer ones apply to all employers, existing and new. Some apply to other trip types and land uses as well.

Typically, a TRO establishes specific goals (e.g., level of service D, or a 10% reduction in auto use) and requires that responsive commute alternatives programs and incentives be developed, promoted, and monitored. Failure to devise or carry out the programs usually results in a fine or the withholding of building or occupancy permits. Lack of effectiveness usually leads to required program revisions. So far, most communities have shied away from imposing other penalties, although some would limit future business expansions in cases where acceptable success levels have not been achieved.

Multi-jurisdictional transportation planning efforts are gaining popularity in areas where attempts to reduce traffic on a strictly local basis have proven inadequate to the problem, and where local governments have been reluctant to move separately in imposing new requirements on developers. Carried out under memoranda of understanding and/or joint powers agreements, these efforts often include area-wide transportation planning, consolidated ridesharing and transit programs, and coordinated improvements to major arterials. A few have also looked at areawide land use policies. (Greenberg)

Supporters argue that the joint efforts can be more ambitious, less expensive, and more equitable than city-by-city TSM programs. However, because the multi-jurisdictional arrangements are largely ad hoc, their stability is uncertain. Some observers argue that they are a poor substitute for formal regional and/or state planning requirements for coordination and consistency.

Transportation management organizations (TMOs) are a private-sector variation of the multi-jurisdictional efforts--they are most often established by developers and employers as way to provide joint ridesharing programs, shuttle buses, and the like. Some TMOs also involve public agencies or elected officials, and may even involve public-private cost-sharing. Arguments in support of TMOs parallel those for multi-jurisdictional government efforts. (Schreffler). However, because some TMOs have been more active as lobbying organizations than as service agencies, they are not uniformly admired.

Approaches such as these seem likely to be the focus of considerable activity in the next few years, as urban areas struggle to cope with congestion, and transportation-air quality planning may be able to benefit by linking up with these efforts. However, whether performance will live up to expectations remains to be seen. This clearly is an area where considerable work remains to be done, from development of strategies for effective TROs, TMOs, and multi-jurisdictional programs, to assessment of whether they in fact work as intended.

Land Use-Transportation Strategies

Likely to receive considerably more attention in future TCM planning efforts than in the past are transportation-land use strategies such as jobs-housing balance efforts and traffic-minimizing site designs. Perceptions of these types of strategies have changed recently. Once viewed as long-term and of uncertain value even then, such land use strategies are now being actively pursued in a number of jurisdictions.

Table 3 lists a number of land use - transportation strategies. Although several of these measures are in use in various parts of the US, there is little concrete information on their effects on congestion or air quality, nor on their feasibility, acceptability, or efficacy in other areas, Some of the more commonly raised questions are:

o whether/how/under what circumstances trip-making associated with mixed use development differs from that associated with more conventional single use development

o whether on-site transportation amenities such as pedestrian paths, bikeways, showers and lockers, etc. make any difference in mode choice.

o whether/under what circumstances the mode shift potential created by higher building densities, clustering of buildings, etc. offsets the congestion effects also produced

o whether the availability of on-site services reduces midday vehicle trips significantly, and/or increases employee willingness to commute by modes other than the single-occupant auto

Federal Legislative Prospects

The Clean Air Act Amendments of 1977 established a date of December 31, 1987 for attainment of the ambient air quality standards. Provisions of the Act were extended, as an interim action, until August 31, 1988 when Congress was unable to agree on a comprehensive extension; several legislative proposals are now under consideration.

Both Senate and House drafts, as well as proposed EPA policy, would continue to assign an important role to transportation control measures. The Senate Bill defines eight categories of TCMs as being reasonably available and requires "consideration" of these types of transportation actions. In particular, transportation measures would be used to offset the emissions associated with VMT growth. Legislation under consideration in the House also would encourage the use of TCMs, with one proposal authorizing the EPA Administrator to promulgate a fee on gasoline and diesel fuel (up to five cents per gallon in severe nonattainment areas) in order to cover a share of the cost of TCM implementation.

EPA itself has proposed a post-1987 policy for areas that had not attained either the ozone or the carbon monoxide standards. (US EPA, November 1987.) Designated non-attainment areas would be required to submit a revised State Implementation Plan demonstrating a minimum average annual emissions reduction of three percent from a baseline emissions inventory (i.e., in addition to reductions required to offset emissions increases due to growth.) EPA analyses indicate that most non-attainment areas would have to utilize transportation control measures in order to achieve such an annual emissions reduction target.

Appendix C of the proposed policy identifies 14 categories of TCMs that in the EPA's judgment are effective in achieving emissions reductions (Table 1). The first ten of these measures are commonly included in programs to manage transportation and mitigate traffic impacts, while the last four are technology- and regulation-oriented, an approach similar to that used in most industrial emissions control efforts.

At the time of this writing (Feb. 1989) the Bush Administration has not yet announced a position on Clean Air legislation. EPA, however, is proceeding to develop up-to-date guidance documents on TCMs. Meanwhile, state laws such as the Sher bill in California will necessitate TCM activity in the near future.

Table 1. TCMs in EPA's Proposed Post-1987 Policy

Voluntary No-Drive Days
Trip Reduction Ordinances
Employer-Based Transportation Management
Work Schedule Changes
Ride Share Incentives
Improved Public Transit
Traffic Flow Improvements
Road Pricing/Tolls
Parking Management Programs
Park & Ride/Fringe Parking
Control of Extended Vehicle Idling
Reduction of Cold Start Emissions
Gasoline Fuel Additives
Conversion of Fleet Vehicles to Cleaner Fuels or Engines

percentage of jobs and housing can simply be "shifted" from one part of a region to another.) Both additional research and monitoring efforts will be needed to establish a body of reliable information, and to address questions of where and under what conditions the land use strategies are likely to be effective.

Strategies Based on New Technologies

Strategies based on new technologies, including alternate fuels, more effective emissions controls, computer-aided traffic control and management, and telecommunications-based strategies, also will receive active consideration. These options have moved from being thought of as risky, impractical, and excessively costly to being the focus of major R & D efforts and, in several cases, demonstration projects. Advocates for full-scale implementation are increasingly heard.

Better information dissemination is probably in order concerning the extent to which these strategies are, in fact, "proven and available." This information may be especially needed in working with transportation agencies. For example, the oxygenated fuels strategies being considered in several areas, including Arizona and California, may be well understood by air pollution control agency staff, but few transportation specialists are knowledgeable about such options. Air agency staff, in turn, may need to become better informed about the effects of some of the traffic management strategies currently being tested, such as real time corridor management and navigation technologies.

For many of the newer technologies--"smart" highways, for instance--considerable research remains to be done, and the main role for transportation-air quality staff may be to keep abreast of developments and encourage adequate consideration of air quality implications as the strategies are developed and refined.

Two additional pressures may be present to push things along:

Consistency Requirements

Consistency provisions in the 1977 Clean Air Act Amendments were intended to transmit a sense of urgency (and responsibility) to urban transportation organizations. Under these provisions, various federal funds destined for a metropolitan area could be withheld if the planning organization did not demonstrate 'consistency' between the transportation control plan and the transportation plans and programs of the MPO. For practical purposes, 'consistency' meant that measures in the TCP should appear at the appropriate point in the TIP (i.e., there must be demonstrated intent to implement); EPA and state air agencies also took the position that that no measure which demonstrably worsened air quality should proceed, but this second provision was resisted by most transportation agencies.

For a number of reasons, the effects of consistency requirement were less than environmentalists had hoped. In the first place, there was the temptation to comply with the requirement by starting with the adopted TIP and working backwards (in order to guarantee consistency from the start)--in that way no organizational behavior had to change. Sufficient VMT reduction could be demonstrated by choosing assumptions carefully and by adding measures to the TCP which would not be expected to appear in the TIP. In the second place, the sanctions to result from a failure to demonstrate consistency were overly strong. Hundreds of millions of dollars were involved in some cases, enough to cost the Clean Air Act essential political support. EPA was reluctant to use the sanctions for this reason.

The proposed Post-1987 EPA policy would reinforce the conformity provisions of the 1977 Amendments, making it clear that EPA's broader interpretation would apply. The provision would require federally approved or financially assisted actions (projects, plans, approvals, assistance, etc.)

to conform to the SIPs for the areas in which those actions will take place, and would prohibit MPOs from approving any project, program, or plan that does not so conform. Several state air agencies are considering similar provisions of their own, so that state- and locally-funded projects also would have to conform to the SIP.

Conformity matters because of its role in triggering sanctions. The EPA policy continues the penalties of construction bans and highway sanctions for designated non-attainment areas having inadequate SIPs. Sanction provisions in both the Senate and House versions of proposed Clean Air Act Amendments are stronger than the corresponding provisions contained in the 1977 Amendments. Criteria for application are broadened and sanctions could be applied statewide.

Litigation

There also is evidence that lawsuits based on the Clean Air Act may play an important role in urban areas that have been slow in implementing reasonable measures toward attaining the clean air standards. Lawsuits filed in Arizona against EPA, the U.S. Department of Transportation, the Arizona Department of Health Services, the Governor and State of Arizona, the Cities of Phoenix and Tucson, and Pima County charging non-compliance with various provisions of the Clean Air Act led to an August, 1987 court order requiring EPA to proceed with promulgation of a Federal Implementation Plan (FIP), an action that EPA has long resisted in favor of locally prepared plans. Similar public interest lawsuits are under discussion in California, New York, and Illinois, where environmental groups are concerned that state agencies are not in compliance with the Clean Air Act and will continue to drag their feet on transportation demand management unless court action is threatened.

4 POLICY OPTIONS AND RESEARCH NEEDS

Government and private sector traffic mitigation activities over the past few years are evidence that transportation and land use controls are becoming more acceptable than they were in the past. At the same time, growth effects are likely to erode the transportation sector's air quality gains of the last two decades unless additional control measures are implemented. In particular, increases in both the number of vehicles in use and the total vehicle-miles of travel will more than offset the reductions expected from vehicle emissions controls and inspection/maintenance programs. Thus both short term and longer term actions will be needed.

In the short term, important actions might include pursuit of the following measures:

- o additional traffic flow improvements (improved traffic signal equipment and timing, "super street" treatment of arterials, etc.)
- o systematic implementation of commute alternatives programs, by means of trip reduction ordinances (TROs) meeting minimum standards of effectiveness and enforceability
- o requirements for land use/transportation consistency and conformity to air quality goals in all state and local plans and project approvals
- o parking pricing and removal of parking subsidies
- o phasing out of severely polluting vehicles
- o testing and monitoring of the benefits and costs of various land use strategies.

Over the longer term, additional measures which deserve consideration include:

o road pricing (possibly using automatic vehicle detection systems, and applied on major arterials as well as on limited access highways)

o emissions fees (implemented through a fuel tax or registration fee surcharge, and/or through road pricing)

o more rigorous emissions standards on motor vehicles

o more widespread use of clean fuels and/or clean engines

o incentives for implementing those land use strategies found in earlier studies to be beneficial

o tests of new highway technologies: route guidance systems, automated roads, etc.

Legislative options which would support these proposals include the following:

o earmark sufficient funds for aggressive implementation of TSM measures

o redefine the circulation element of the General Plan to require a modern transportation element (to include sections on streets and highways, transit, and TSM)

o require air quality elements (or air quality sections in the conservation elements) in all General Plans in nonattainment areas

o require General Plan and state transportation program consistency with state and regional air quality goals

o require trip reduction ordinances for all nonattainment areas

o strengthen requirements for traffic mitigation as a condition of project approval in nonattainment areas (e.g., make mitigation requirements a condition for consistency findings; tie mitigation to EIR approval--make it harder to find overriding considerations)

o increase fuel taxes to cover the social and economic costs of air pollution and use the additional funds for air pollution reduction programs

o phase out free parking for employees by treating parking as a taxable employee benefit (and possibly, also allow local governments to tax all employee parking and use the funds for specified traffic mitigation programs)

o restrict registration of severely polluting vehicles (with exemptions or other compensatory assustance for low income owners)

o give Caltrans an explicit mandate to take responsibility for air quality improvements.

Although it is relatively easy to list such policy options, simple solutions should not be expected, The results of transportation control planning reveal many sources of resistance to change in urban transportation institutions, including phenomena at the individual, organizational, and inter-organizational levels. Successful air quality policy implementation will require that at least some of

these sources of resistance be addressed or circumvented. It may be necessary to create new organizations, or to stimulate major change in existing ones by overriding earlier commitments and modes of behavior. Providing financial incentives may be a way to accomplish some change. Alternatively, new alliances might be forged between those concerned about air quality and those most interested in managing growth and relieving congestion.

Institution Building

The problems encountered in implementing the transportation provisions of the Clean Air Act demonstrated the structural complexity of the institutions that administer urban transportation. These institutions appear fragmented, weakly articulated, and sometimes redundant. They are composed of many organizations often with competing responsibilities; their resources and legislative imperatives derive from many loci of power. It became clear during the years of TCP development that these institutions presented a difficult implementation environment for comprehensive, centralized transportation policies and, indeed, for any planned change that did not arise within existing implementation organizations.

A striking feature of this institutional setting is the degree to which transportation organizations are scoped to particular technologies and specific clients. This works against comprehensive solutions to transportation problems, because each organization is most receptive to change within the framework of present technology and consonant with the demands of client groups. Such an institutional structure arises through the accumulation of organizations created to address successive policy initiatives.

Resistance to change results from phenomena that operate at individual, organizational, and institutional levels. The individuals who make their careers in an organization develop patterns of behavior that become less flexible over time. These patterns are keyed to the tasks, technologies, and ideologies prevalent in the early stages of a career; as expertise builds, it becomes a kind of intellectual 'capital' that is mentally (and perhaps monetarily) costly to discard. As a consequence, individuals seek to avoid non-incremental change in their work environments.

There is an analogous tendency for an organization to codify behavior in a way that retards change. As a new organization evolves, knowledge about how to carry out its work accumulates. Managers codify this so that new employees can learn basic work patterns quickly. The resulting guidelines exert a conservative force on the behavior of the organization; the procedure for changing a guideline is often cumbersome, and the existence of guidelines may deter employees from experimenting with new approaches. Another example of such a conservative force is the classification of positions to match skills required early in the history of an organization; this can make it difficult to hire new workers with needed job titles.

Legislators can circumscribe organizational action by direct statute or by budgetary authorization. If new authorizations are simply added to the old, a change in direction is unlikely. The implicit agreements and restraints necessary to maintain the political coalition that supports an organization are left in place, and in most cases will dominate the new authorizations. In particular, funding commitments far into the future can retard change in the organization's behavior..

Yet there clearly are conditions under which change can occur. Some involve circumvention of the normal institutional processes that create barriers to change. For example, new organizations with dedicated funding sources stand a good chance of implementing new policy (but not necessarily so if the new organizations have to be staffed with experienced individuals from existing organizations). Alternatively, it may be effective to alter the existing institutional structure in a way

that overrides prevailing patterns of authority; to suspend, invalidate, or supplant existing political commitments; or to induce rapid evolution in patterns of individual and organizational behavior. These all have the characteristic of addressing barriers to implementation directly, at the organizational levels where such barriers arise.

One means of inducing change is to put forward persuasive moral (or economic) arguments that change is necessary, to create a sense of urgency about the new policy that leads to its being given priority in cases of conflict with older policies. Both moral and economic arguments have been made in favor of clean air. Moral arguments stress responsibility for the 'web of life', as well as more immediate concern for those whose health is severely impacted by pollution. Economic arguments reason that clean air is a public good, with all of the attendant resource allocation problems, and that auto emissions (like congestion) are negative externalities not reflected in user costs.

The Clean Air Act experience demonstrates that there can be varying perceptions of urgency in policy implementation, by different actors and at different levels in the institutional hierarchy. While air pollution can serve as a leadership issue for legislators and can also be an important local issue, it does not appear to have enough weight to cancel out commitments to existing ways of conducting business in transportation and land use. Nor does it appear to have enough significance to the average person to warrant a sacrifice in personal mobility. Transportation-air quality programs thus coexist with policies and programs concerning transportation, land development, and taxation, among others, which often undermine or directly conflict with air quality goals, and implementing agencies feel no special sense of urgency about air quality, nor any particular pressure to change course.

In the short run, arguments in favor of restraint on behalf of air quality have had only slight effect on transportation agencies, who countered with moral and economic arguments of their own: that TCMs unjustly interfere with personal freedom, and by interfering with markets reduce economic efficiency. Over the years, however, transportation professionals seem to have become more receptive to air quality as a transportation system (rather than simply a vehicle) problem. This can be seen in the gradual inclusion of emissions among substantive design criteria, e.g., for coordinated signal timing plans and the like. Whether this reflects the introduction of new personnel with new views, a gradual acceptance of the arguments over time, or a recognition that the air quality arguments and strategies parallel those made concerning congestion, the point is not that a moral or ethical case could not be made for air quality as a transportation system problem, but that it took about a decade for the argument to influence the behavior of transportation organizations. Fundamental changes in individual and organizational behavior simply required longer gestation periods than the legislative framework had allowed.

Funding

Another means of implementing policy is to provide funds sufficient to stimulate new activity, either within or outside existing organizations. If funds are available, articulation with existing systems is not critical, and staffing does not depend on the existing pool of professionals, then creation of a new organization with dedicated funding can be an effective means of implementing policy. Alternatively, it often is possible to induce change within organizations by offering funds to underwrite the formation of new groups or to significantly expand the resources of existing groups within existing organizations. This strategy can be effective when the new policy does not conflict with prior responsibilities of the organization. In the case of transportation air quality planning, neither option is a good fit; the involvement of transportation agencies (or, at least, staff with transportation planning and design skills) is needed, but other transportation agency responsibilities may be in conflict with clean air goals.

A third choice is to fund appropriate projects whereever they are found, whether at the state, regional, or local government level or with the private sector. Perhaps the best way to illustrate this potential is with an example of a program that actually was funded by EPA. Using Section 175 discretionary funds, EPA supported the development of a local ridesharing agency in Berkeley, California [Deakin, et al., 1982]. Berkeley, a medium-sized city (population just over 100,000) in the San Francisco Bay Area, has one very large employer (the University of California) and many small employers having 5 to 100 workers. City transportation officials and local interest groups felt that the regional ridesharing agency was oriented toward large CBDs and major suburban development nodes (perhaps understandably), while offering relatively poor service to a smaller city such as Berkeley. It was argued that a ridesharing agency with a physical presence and direct knowledge of local conditions could be more effective. The new agency became a successful local ridesharing broker, gaining financial support from the City and from the private sector through development agreements. It now plays an important role in traffic mitigation for new development.

There was nothing extraordinary about conditions in Berkeley. With adequate funds to underwrite organizational development, this experience could have been repeated in many localities, with demonstrable congestion and emissions benefits. But EPA's funds for such projects were extremely limited, so few such projects had a chance.

A transportation-air quality funding strategy devised to provide resources where there are new implementation opportunities, either within or outside the existing institutional structure of the urban transportation sector, could be a way to make a difference.

Creating Alliances

A third means of implementing policy is to form alliances with people, organizations, and programs that can be instrumental in gaining acceptance for the policy. In general, this approach requires that significant actors come to perceive a direct stake in the implementation of policy. This can arise, for example, through involvement in the decisions which lead to a policy, or through responses to groups that express a strong interest in the policy. To the extent that actors can influence the behavior of their own organizations (and there are many limiting factors), such alliances help to overcome the inertia that retards policy implementation.

Like other elements of federal transportation policy, the 1977 Clean Air Act Amendments rested on a hierarchically-based strategy of institutional alliance. The transportation sector was conceptualized as a hierarchy of organizations with influence that flowed from the top to the bottom. Relations formed at appropriate points in the hierarchy were thought to be sufficient to influence behavior at lower levels. In most areas, attention focused on the Metropolitan Planning Organization. Because of its role in planning and programming, the MPO would be capable of devising adequate TCP's and seeing to their implementation. Money was provided to aid in planning but not in implementation; routine sources of transportation funds could be redirected as necessary for implementation. EPA was expected to have little direct contact with the MPO (although EPA Regional staff monitored progress in each region, resources permitted only a cursory review). To engage the cooperation of the MPO, EPA negotiated agreements with the Federal DOT detailing organizational responsibilities (as required in the 1977 Amendments). The hierarchical relationship between the MPOs and DOT would ensure compliance.

The problems with this 'top-down' approach are readily apparent from earlier discussions. The MPO did not in fact exert much control over organizations lower in the hierarchy. Federal policy, particularly in the highway sector, has been process-oriented rather than outcome-oriented;

organizations such as the MPO) have served to foster communications among existing implementors rather than to provide new implementation opportunities. Thus the Federal DOT could not easily manipulate the outcomes of MPO planning and was hardly inclined to try. In many regions, the MPO was functioning as a buffer between local transportation organizations and higher levels of government (federal and state). The TIP was the primary 'planning' document, but it was assembled largely from the budgets of lower-level implementing organizations. Formal regional planning processes (i.e., comprehensive long-range planning) tended to occur in virtual isolation from programming activities. In most cases, then, the MPO did not possess the ability to perform effective transportation control planning, and top-down assumptions alone could not provide an adequate institutional framework for transportation-air quality policy. This problem has plagued the entire gamut of policies that the federal (and state) governments have tried to implement through the MPO.

Today, however, there may be new opportunities for alliances. Public concern and frustration over traffic congestion is leading to a new willingness to implement transportation controls. Some of the policies that were resisted so vehemently in the 1970's have achieved grass-roots acceptance in urban areas in the 1980's. 'Trip reduction' programs and other traffic mitigation measures now are essential local tools for dealing with congestion. While this development has complex origins, including intensified suburban growth, it can be understood partly in terms of responses to and results of transportation control planning. It has been helpful for politically sensitive (e.g., redistributive) policies to have local roots; few transportation controls had any semblance of local origin. It also is helpful that staff maturation and turnover have made local transportation agencies more receptive to non-traditional policies. But another important factor is the availability of studies providing implementation scenarios and estimating the potential impacts of key measures. Many of these studies were carried out as part of transportation control planning, often by consultants using sophisticated analysis tools. They had little influence in that context, but were at hand when the same policies arose in a different framework.

The success of transportation control-type measures suggests that policies which are capable of delivering local benefits eventually will muster grass roots support for implementation. Hence, an alternative strategy for federal and state policy implementation would be to stress local benefits and to provide reliable information for local policy-makers to use in building support, and then to offer at least some funds (or other support) for implementation when local interest is apparent. Because of the institutional phenomena discussed earlier (i.e., individual and organizational resistance to change), policy implementation under this strategy is bound to occur over a much longer time frame than typically assumed; perhaps ten year lead times would be routine. This may not be politically acceptable among the originators of a policy. Nevertheless, it is clear that (in the absence of an emergency) any serious effort at policy initiation must be scoped to the political and institutional levels at which implementation will occur, and that this usually will entail delays.

Overall, then, a strategy that creates forces for change in existing institutions, provides funds to willing partners, and forms alliances with grassroots movements with con*mpatible goals offers some chance of success to transportation-air quality planning.

Research Needs

In closing, a reminder that additional research is needed seems appropriate. The next round of transportation control planning will have to probe deeper, extend more broadly, and adjust more quickly than has been the case in the past. Research, monitoring, evaluation, and information dissemination will be important activities in such a situation because they provide a basis for action, as well as reassurance.

Many of the approaches now being tried out for air quality improvement purposes (and for congestion relief) are not yet fully understood. Research and evaluation will be critical to provide policy-makers with information on their costs and benefits. In addition, in the longer run new opportunities for changing the nature of our transportation systems may develop if the research needed to make this possible is carried out. For both of these reasons investment in research itself should be considered a valuable transportation-air quality measure.

Research can also help develop a better understnding of changes in the planning context, so that responses will be apt. Understanding changes in the planning context is admittedly a longer-term, less mission-oriented undertaking. Yet, especially if transportation-air quality planning efforts move away from deadline-oriented "attainment" plans toward longer-term air quality problem management programs, it will be important to pay attention to these matters. Both policy studies and investigations of "exogenous" factors directly and indirectly affecting transportation seem appropriate.

One immediate need will be to assess the implications for transportation-air quality planning and programs of post-Interstate transportation policy and financing shifts. Keeping abreast of these matters, and helping to keep air quality considerations on the agenda, could be extremely helpful. Opportunities to better incorporate air quality issues into "mainstream" transportation planning may arise, but are unlikely to be pursued unless there are concerned participants and observers.

More generally, investigations of changing demographic, social, and economic factors may provide new insights into the ways in which individuals and households make travel choices. Among the questions that may be relevant to transportation-air quality planning are the following:

- o effects of changing population characteristics, household composition, and lifestyle choices on location decisions and travel behavior

- o impact of two-worker households on location choice and travel choices

- o child care as a consideration in location and travel choices, and the effects of public policy on child care, school hours, etc. on these decisions

- o impacts of time constraints on trip chaining, and hence on mode choice, number of trips generated, resulting emissions, etc.

Some research has been done on each of these matters, but additional work will be needed before the implications will be clear. While only some of the findings will speak to matters of immediate import to those developing TCMs, a better understanding of travel behavior ultimately should help transportation-air quality planners (and transportation planners in general) to devise more relevant, effective strategies.

Appendix: A Glossary of Transportation-Air Quality Abbreviations

AQCR - An Air Quality Control Region designated under section 107 of the Clean Air Act.

DOT - A Department of Transportation. When it appears alone, 'DOT' usually refers to the U.S. Department of Transportation, a cabinet-level secretariat. Many states, counties, and municipalities have DOTs as well.

EPA - The U.S. Environmental Protection Agency.

FHWA - The U.S. Federal Highway Administration, a sub-unit of the U.S. DOT.

HOV - A freeway or arterial lane reserved for or giving preference to high-occupancy vehicles.

HUD - The U.S. Department of Housing and Urban Development, a cabinet-level secretariat.

MPO - Metropolitan Planning Organization. The MPO is designated for each urbanized area by the Governor to serve as "the forum for cooperative (transportation) decision-making by principal elected officials of general purpose local government".

MOU - A 'memorandum of understanding' executed between two or more government agencies.

SIP - The State Implementation Plan, required from each state under Section 110 of the Clean Air Act. The SIP must spell out how the primary and secondary ambient air quality standards will be implemented, maintained, and enforced in each AQCR.

SMD - The Services and Methods Demonstration Program, administered by UMTA.

TCM - A transportation control measure considered for inclusion in a TCP.

TCP - A Transportation Control Plan to be included in the SIP, as stipulated in Section 110(a)(2)(B) of the Clean Air Act.

TIP - Transportation Improvement Program. The TIP is a "staged multi-year program of transportation improvement projects" consistent with MPO and local transportation plans.

TSM - Transportation Systems Management. The stated purpose of TSM was to "provide for the short-range transportation needs of the urbanized area by making efficient use of existing transportation resources and providing for the movement of people in an efficient manner".

UMTA - The U.S. Urban Mass Transportation Administration, a sub-unit of the U.S. DOT.

VMT - Vehicle-miles of travel, often used in emissions analysis under the assumption that the total mobile source emissions burden will be roughly proportional to the aggregate distance of vehicular travel.

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