paper does not constitute a standard, specification, or regulation.

REFERENCES

1. Major Point Diversion Demonstration Program, Austin-Laredo Corridor—I-35 in San Antonio, Route Redesignation. Texas State Department of Highways and Public Transportation, Austin, July 1976.
2. W. R. Stockton, C. L. Dudek, and D. R. Hatcher; Texas Transportation Institute. Human Factors Requirements for Real-Time Motorist Information Displays: Phase II—Interim Report: Evaluation of the I-35 Route Redesignation in San Antonio. Federal Highway Administration, Contract DOT-FH-11-8505, July 1978.
3. San Antonio-Bexar County Urban Transportation Study: Origin-Destination Survey, 1969. Texas Highway Department, Bexar County, San Antonio, Report 6B, 1969.
4. G. D. Weaver, C. L. Dudek, D. R. Hatcher, and W. R. Stockton. Approach to Real-Time Diversion of Freeway Traffic for Special Events. TRB, Transportation Research Record 644, 1977, pp. 57-61.
5. 1977 Annual Report—Permanent Automatic Traffic Recorders. Texas State Department of Highways and Public Transportation, Austin, 1978.

Publication of this paper sponsored by Committee on Freeway Operations.

Improved Air Quality Through Transportation System Management

John H. Suhrbier, Terry J. Atherton, and Elizabeth A. Deakin, Cambridge Systematics, Inc., Cambridge, Massachusetts

Many cities must reduce total automotive emissions if they are to meet the national ambient air quality standards set by the U.S. Environmental Protection Agency under the authority of the Clean Air Act. This paper summarizes the results of two recent transportation air quality analyses in the Denver metropolitan area: first, an examination of implementation experience with six program measures in Denver's 1973 Transportation Control Plan and, second, a more in-depth examination of the potential role of parking management in reducing vehicle kilometers of travel (VKMT). Conclusions are that meaningful VKMT reductions are possible (in the order of 6-8 percent), that air quality measures are cost effective, that few real cost or administrative barriers exist to impede implementation, and that most measures are within the current authority of one or more agencies. These jurisdictions often overlap, and support action and institutional cooperation are therefore greatly needed. Successful implementation is impeded by political and institutional unwillingness to generate controversy or to go against vested interests that conflict with the agency's priorities.

To meet the national ambient air quality standards promulgated by the U.S. Environmental Protection Agency (EPA) under the authority of the Clean Air Act, many American cities will have to reduce total automotive emissions. The development and implementation of air quality transportation control plans, which began in 1973, has been a frustrating experience for most people. Too often, potential transportation measures to improve air quality are viewed as ineffective or not implementable. They are also considered as disincentives, incompatible with ongoing state and local programs, that will incur large direct and indirect costs.

Our own conclusions, however, are much more positive. The tight deadlines for the 1970 Clean Air Act and the severity of the air quality problem in many cities have combined to make it impossible to meet the ambient air standards on time, but both the transportation control plan requirement and, more recently, the consistency requirement of Title 23 have contributed significantly to the initiation of studies and the implementation of measures that will improve air quality. These requirements have forced state and local transportation agencies to give air quality explicit and thorough consideration and have prodded the agencies to take reasonable steps toward improvement.

The provisions of the 1977 amendments to the Clean Air Act and the resulting implementing guidelines (1) provide significant opportunities to build on previous successes and to accelerate implementation of measures.

The amendments, which provide new deadlines for attainment of the air standards, have set in motion a second generation of air quality transportation plans. Initial revisions to the state implementation plan were due on January 1, 1979; cities that cannot meet the standards by 1982 must complete a more systematic and comprehensive alternatives analysis by July 30, 1980 (1). Emphasis by both EPA and the U.S. Department of Transportation (DOT) is on a truly coordinated and integrated planning process in which air quality measures are routine actions undertaken by state, regional, and local agencies to better manage their multimodal transportation systems.

Two recent studies in Denver provide an opportunity to assess the realism of this objective and in particular to examine issues of effectiveness, cost, institutional acceptance, and consistency. The first study examined implementation experience with six program measures contained in Denver's 1973 Transportation Control Plan (2); the second is a more in-depth examination of the potential of one particular form of transportation system management—parking management—to contribute to improved air quality (3).

Our answer to the question of whether the second generation of air quality transportation measures will be more successful than the first is one of guarded optimism. A realistic appraisal simply does not support the negative impressions mentioned above. While there certainly are problems and dangers, we are hopeful that these can be overcome. Keys to success, though, are, first, positive, open attitudes on the part of all participants, especially city and urban area transportation officials. Also of great import is a participatory planning and implementation process that stresses the need for careful, high-quality design; systematically analyzes available alternatives and their potential impacts; and is supported by satisfactory analytical techniques rather than relying exclusively on subjective judgment.

NEW PROGRAMS VERSUS BETTER MANAGEMENT OF EXISTING SYSTEMS

Air quality transportation measures frequently are viewed as overlays of entirely new programs on top of already implemented urban policy. In reality, they should be viewed more as a periodic reappraisal of the continued desirability of existing policy. Responsible management of public resources requires maximizing efficient use of existing systems. In practical terms, this means looking at the movement of people rather than the vehicles in which they are placed.

Informal carpooling already is common practice in most cities; ride sharing that accounts for 20 percent of modal choice for the home-work trip is not uncommon. Employer-based and areawide ride-sharing programs are not new; they have built on already existing practice. Their object is to help people make better use of a rather expensive household commodity—the personal automobile—and to facilitate a wider variety of ride-sharing forms, such as vanpooling.

As a second example, parking management typically is viewed as something new and, as such, something to be feared. But we know of no city that has no form of a parking management program.

In Denver, as in most other U.S. cities, providing parking spaces has historically been a response to the demand for parking. If there has been a perceived need for vehicle parking, the spaces generally have been provided. Thus, commonly accepted policy has been to ensure an equilibrium between the demand for parking, both regionwide and in specified locations, and the amount of parking available in these areas. Extension of this policy in Denver, in conjunction with anticipated changes in population, income, and automobile ownership, has led to the estimate that by 1985 the current regional parking inventory should be expanded by over 300 000 spaces. Within the Denver central business district (CBD), parking would expand by 21 percent, or about 7300 spaces. This corresponds to a projected growth in regional population of 19 percent.

An important question of public policy in Denver and other urban areas, then, is whether it is desirable to continue these parking management policies by initiating construction of much new parking or whether in fact there are other more preferable policies.

Further, it is improper to view parking management primarily as a disincentive. Parking management can be broadly defined as the control of parking supply, location, or rates in a manner that

1. Affects parking in certain areas, during certain times of the day, or for certain purposes;
2. Encourages transit use or other ride sharing by providing incentives or a convenient gathering point at a peripheral location; or
3. Establishes review procedures and criteria for the construction of new parking facilities to meet a variety of goals, including minimization of carbon monoxide hot spots, conservation of energy, and improvement of urban aesthetics.

Thus, parking management is an umbrella category for a variety of measures such as park and ride, preferential parking for residents in neighborhoods, removal of on-street spaces in conjunction with a transit mall or automobile-restricted zone, parking supply freezes, price increases, long- versus short-term rate-structure changes, off-street parking bans, and restrictions on the size or location of new parking facilities. Parking management strategies are intended to help areas establish control over their parking supplies to meet a variety of development objectives. As a result, a parking management program may contain several elements and is not limited to negative or disincentive measures.

POTENTIAL EFFECTIVENESS

The initial transportation control plans and the initial rounds of transportation system management (TSM) plans generally were developed with little or no supporting transportation analyses. Today, however, the available analytical capabilities are sensitive to the kinds of low-capital, short-range policies being proposed. These techniques, unlike traditional aggregate urban transportation planning models, are referred to as sketch-planning techniques because they are low cost and have a short response time. The use of these new analytic techniques greatly increases the realism of a transportation analysis both by providing differentiation among alternate designs and by decreasing the need for overly simplistic assumptions.

The travel demand analyses in the two Denver studies were based on a set of disaggregate travel demand models that are policy sensitive to a broad range of socioeconomic, transportation, location, and mode-specific variables (Table 1) (5, 6). A complete set of behavioral decisions is examined (5) on a household basis (Figure 1):

1. Mode choice for the work trip for both primary and secondary workers, including drive-alone, public transit, shared-ride, and vanpool alternatives;
2. Non-work-trip frequency, destination, and mode choice, differentiating between shopping or personal business trips and social and recreational trips; and
3. Automobile ownership.

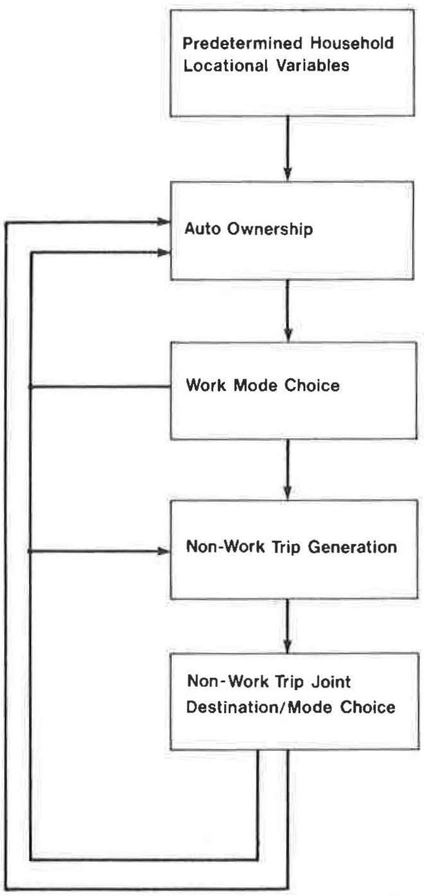
Appropriate submodels have been combined with the travel demand models to translate the predicted changes in travel behavior into changes in automobile emissions and fuel consumption. The emissions submodel predicts the amount of carbon monoxide, hydrocarbons, and nitrogen oxides emitted on a trip-by-trip basis as a function of vehicle-fleet composition, ambient temperature, trip length, cold start, and average speed and accumulates totals for these emissions on an areawide basis (5). The fuel-consumption submodel predicts the amount of gasoline consumed on a trip-by-trip basis as a function of the distribution of automobile types within the vehicle fleet, automobile occupancy (i.e., increased vehicle weight), the cold-start and trip-length factor, and average trip speed (5).

From the Denver home interview survey 2027 households were randomly selected, and costs and socioeconomic and transportation characteristics were updated to reflect both 1977 and 1985 conditions (5). Each

Table 1. Independent variables incorporated in travel demand model systems.

Variables	Automobile Ownership	Work-Trip Mode Choice	Nonwork Trip Generation		Nonwork Destination and Mode	
			Shopping	Social and Recreational	Shopping	Social and Recreational
Socioeconomic						
Household income	X	X	X	X	X	X
Automobile ownership and availability	X	X			X	X
Primary worker		X				
No. of workers		X				
No. of nonworkers				X		
Household size	X	X	X	X		
Residence type	X					
Automobile ownership costs	X					
Level of service						
In-vehicle travel time		X			X	X
Out-of-vehicle travel time		X			X	X
Out-of-pocket travel cost		X			X	X
Walk versus automobile access to transit		X				
Location						
CBD destination		X			X	X
Employment density	X		X	X	X	X
Employment					X	X
Population density						X
Population						X
Composite						
Work-trip accessibility	X					
Shopping-trip accessibility	X		X			
Social and recreational trip accessibility				X		

Figure 1. Interrelations among travel demand models.



household's travel response to one or more candidate control measure then was simulated probabilistically by sequentially proceeding through the individual demand models (4).

To illustrate the kinds of analysis results that can be obtained, the potential travel effectiveness of alternate parking management strategies for Denver are summarized in Table 2. Each policy was described by identifying applicable changes in modal or parking availability or in transportation level-of-service variables. In the table the projected change in VKMT was tabulated in terms of a percentage change relative to

1. VKMT of the particular population group affected (i.e., CBD workers, those employed by large employers, etc.),
2. Regionwide work-trip VKMT,
3. Total regionwide non-work-trip VKMT for those measures affecting nonwork travel, and
4. Total regionwide VKMT.

Changes in emissions and fuel consumption are roughly similar, though generally somewhat smaller, and depend on the characteristics of the vehicle affected, trip lengths (i.e., cold-start effects), and vehicle occupancy. In addition, for carbon monoxide one should examine changes in emissions on other than a regionwide basis. This more detailed output, though available, is not provided as part of this paper.

An assessment of these particular parking management strategies, based on data collected and analyzed during the two studies, is provided in Figure 2. Overall findings of the travel behavior analyses include aspects of effectiveness, availability, mode choice, and measures analyzed and combined.

Effectiveness

The effectiveness of a particular parking management strategy in achieving reductions in areawide VKMT is directly related to two factors: the severity of the strategy and the number of people affected by the strategy. The parking strategies analyzed have produced regionwide work-trip VKMT reductions that ranged from 0.04 to 11.30 percent. Within the particular segment of the population most directly affected, however, reduction in VKMT ranges from 0.4 to 43.3 percent.

For example, the strategy that restricts the 10:00 a.m. occupancy of commercial parking facilities to 60 percent achieves a 3.1 percent decrease in VKMT for those work trips directly affected by this measure. In

Table 2. Effectiveness of parking management strategies in reducing VKMT.

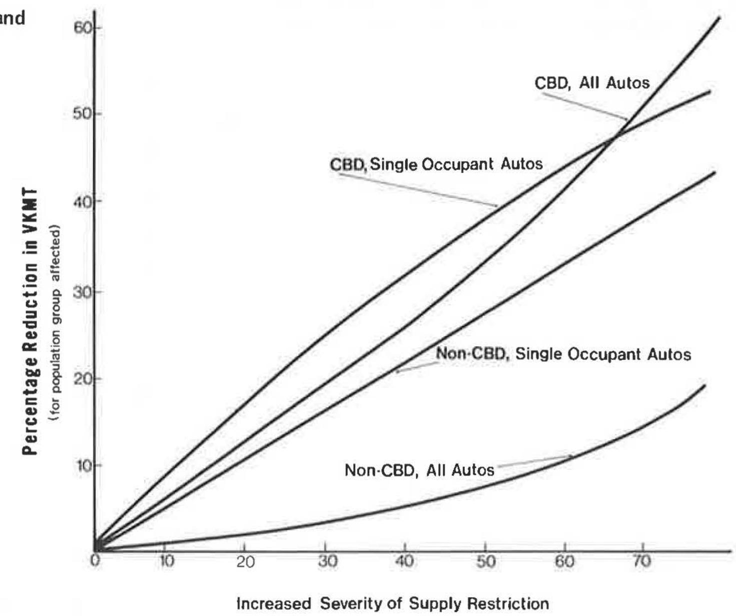
Strategy	Percentage Change in VKMT: VKMT of Group Affected	Areawide Work VKMT	Areawide Nonwork VKMT	Areawide Total VKMT
Short-term supply				
10:00 a.m. occupancy restricted at commercial facilities, 50 percent	-8.7	-1.0	-	-0.5
Employer-provided spaces restricted to HOVs[a] at large employers	-15.8	-4.1	-	-1.9
Long-term supply				
New parking construction restricted	-22.7	-6.8	-	-3.2
Pricing				
$3.00 parking charge at large employer-provided facilities	-3.2	-0.8	-	-0.4
100 percent price increases for long-term parking at commercial facilities	-2.4	-0.3	-	-0.13
Rate structure at commercial facilities altered to $4.00/day and $0.25/half hour	-3.7	-0.4	+0.13	-0.05
Parking charge for all parking of daily $1.00 surcharge/space	-0.9	-0.9	-1.8	-1.4
Ride-sharing incentives				
Preferential employer-based parking locations for HOVs	-3.4	-0.9	-	-0.4
Employer-based carpool program for employers of at least 50 employees	-3.1	-1.4	-	-0.7
For large employers of more than 250 employees	-3.1	-0.8	-	-0.4
Employer-based carpool-vanpool programs	-14.4	-3.7	-	-1.8

[a] High-occupancy vehicles.

Figure 2. Assessment of parking management strategies.

Assessment		Short Term Supply: 10 AM occupancy restrictions at all commercial facilities	Short Term Supply: Restrict parking to HOV at large employers	Long Term Supply: Restrictions on new parking constructions	Pricing: Parking charge at large employers	Pricing: Long term rate increase at commercial facilities	Pricing: Alter rate structure at commercial facilities	Pricing: Surcharge for all parking	Preferential Treatment: Preferential parking for carpools	Preferential Treatment: Employer based carpool program	Preferential Treatment: Employer based carpool and vanpool programs
Potential Effectiveness	Effective on an areawide basis		●	●							
Potential Effectiveness	Moderately effective on an areawide basis							●			●
Potential Effectiveness	Effective within individual market segments	●			●				●	●	
Potential Effectiveness	Not effective					●	●				
Ease of Implementation	Definitely practicable			●					●	●	●
Ease of Implementation	Potentially practicable					●	●				
Ease of Implementation	Probably not practicable	●	●		●			●			

Figure 3. Percentage reduction in work VKMT versus type and severity of supply restriction.



terms of areawide work-trip VKMT, this translates into a 0.34 percent reduction and is further diluted to -0.16 percent when expressed in terms of a percentage change in total areawide VKMT. By comparison, the pricing strategy that imposes a $3 daily parking charge at facilities provided by large employers achieves a similar percentage change in VKMT for that group affected (-3.2 versus -3.1 percent), but, because this group is more than twice as large, the effectiveness in terms of areawide work-trip VKMT is much greater (-0.8 versus -0.3 percent).

Availability

The availability of alternate modes of travel that offer levels of service comparable to that offered by the automobile is an important factor in determining the effectiveness of parking management strategies in reducing VKMT.

In situations where alternate modes are characterized by relatively poor service levels, travelers would resist a shift from automobile in response to parking management strategies much more vigorously than in those where travel alternatives with relatively good levels of service are available.

To demonstrate this effect, curves were developed that gave the percentage change in work-trip VKMT (relative to VKMT of the population group affected) as a function of increasing severity of parking management strategies. Using the accessibility of parking at the work site as one possible dimension of parking availability, separate curves were developed for each of two population groups: one with relatively good transit service (such as that available to those working within the Denver CBD), the other with relatively poor transit service (similar to that experienced by commuters working outside the CBD). Further, for each of these population groups, different curves were developed to represent measures aimed at all automobiles versus those affecting single-occupant automobiles only (Figure 3).

The most striking comparison is that between workers well served by transit and those poorly served for those measures that apply to all automobiles. In this case, the curves indicate that strategies aimed at those groups well served could be as much as five times as effective in reducing VKMT of the particular group affected as strategies reaching groups poorly served (i.e., reduced VKMT expressed in terms of a percentage change relative to the VKMT of the group affected). Note, however, that in most situations the group well served by transit will be much smaller than that not well served, and therefore the relative scale of these curves would be quite different if the percentage changes in VKMT were expressed in terms of areawide work-trip VKMT.

Another interesting comparison can be made between supply restrictions applied to all automobiles versus single-occupant automobiles only for that group receiving relatively poor transit service. In the former situation, commuters have no good alternative and, therefore, continue to use the automobile mode despite severe decreases in levels of service. On the other hand, if only single-occupant automobiles are affected, carpooling appears as an increasingly attractive alternative as supply restrictions increase in severity for single-occupant automobiles.

Mode Choice

Choice of mode for work travel (and therefore work-trip VKMT) appears to be relatively insensitive to most of the strategies that are designed to discourage automobile use by making parking more expensive or less conveniently located or both. On the other hand, strategies that limit the number of spaces available can be quite effective.

The effectiveness of parking supply constraint measures ranged from a 0.4 to a 24.3 percent reduction in VKMT relative to the group affected. For those measures designed to discourage automobile use, VKMT reductions ranged from 0.5 to 3.7 percent (relative to VKMT of the particular group affected).

Measures

The parking measures analyzed result in transit ridership increases varying from 0.6 to 43 percent for the trip between home and work, relative to a 1977 base modal share of 3 percent. The majority of the policies analyzed, though, produced increases in transit ridership of less than 10 percent.

Other modal use changes occur as well with a maximum of a 62 percent increase in ride sharing and an ab-

Figure 4. Percentage reduction in work VKMT based on effectiveness of combining employer-based incentive and disincentive measures.

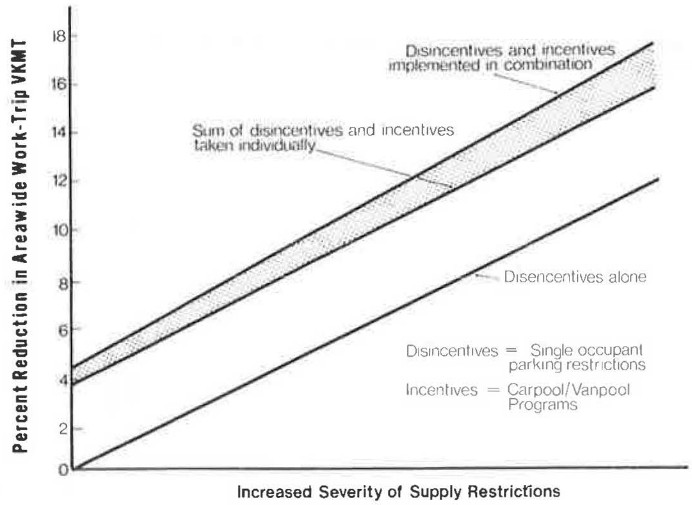


Table 3. Cost-effectiveness of ride-sharing projects.

Location	Annual Project Cost ($)	Estimated Annual Cost/New Carpooler ($)	Estimated Cost/New Carpooler Trip[a] ($)	Estimated Cost/ Vehicle Kilometer Reduced ($)
Tucson[b]	58 000	7	0.015	0.005
Los Angeles	660 000	85	0.18	0.143
Sacramento	85 000	32	0.07	0.018
San Diego	210 000	98	0.21	0.048
Denver	125 000	88	0.19	0.068
Connecticut	65 000	23	0.05	0.008
Boise[b]	45 000	75	0.16	0.069
Louisville[b]	65 000	9	0.02	0.008
Boston[b]	325 000	37	0.08	0.034
Minneapolis	60 000	13	0.028	0.005
Omaha	84 000	69	0.15	0.061
Raleigh	20 000	26	0.06	0.029
Portland[b]	190 000	26	0.06	0.021
Pittsburgh	134 000	71	0.15	0.055
Rhode Island	70 000	46	0.10	0.026
Dallas	60 000	38	0.08	0.024
Ft. Worth	30 000	15	0.033	0.011
Houston	220 000	112	0.24	0.061
San Antonio	160 000	34	0.07	0.027
Seattle	215 000	99	0.22	0.103
Washington, D.C.	110 000	11	0.024	0.010
Milwaukee[b]	100 000	12	0.027	0.016
Average[c]	140 000	47	0.10	0.039

[a]At 2 trips/day for 230 days/year, or 460 annual trips to or from work.
[b]Based on broad impacts of ridesharing programs; impacts for other locations are directly attributable to carpool matching.
[c]Arithmetic averages of the individual city data. If averages are computed from total annual project costs for all above cities divided by number of new carpoolers and annual VKMT reductions, the cost-effectiveness indicators are $35/new carpooler, $0.75/new carpooler trip, and $0.014/VKMT reduced.

solute vanpool modal share of 2 percent.

Measures can also be combined into program packages that are more effective in terms of reducing VKMT than the sum of the individual measures. For example, if employer-based carpool and vanpool programs are combined with measures restricting employer-provided spaces to carpools, the resulting percentage change in VKMT is about 14 percent greater than the summed VKMT reduction of the measures taken individually.

This is demonstrated by the three curves shown in Figure 4, which relate a percentage change in areawide work-trip VKMT to increasing severity of supply constraints. The lower curve represents the effectiveness of the supply restrictions alone; the middle curve represents the summed effect of the supply restriction and employer-sponsored carpool and vanpool programs, if we assume that each is implemented individually and that the two programs do not interact. The upper curve represents the effectiveness of these measures implemented in combination; the shaded area represents the increased effectiveness attributable to the synergistic effect of the combined implementation of these measures.

PROGRAM COSTS

Many VKMT reduction measures are relatively inexpensive, and most are within the current authority of one or more agencies (3, 6). This does not necessarily imply, though, that successful implementation can be easily accomplished; a variety of other administrative and institutional barriers may exist.

A legal authority for implementation of parking measures is the police power delegated by states to local areas to protect the public health, safety, and welfare. Zoning ordinances and on-street parking regulations are commonly accepted uses of this police power.

Most of the parking measures analyzed in Denver can be planned and implemented within the existing staff resources of Denver-area city agencies (4). While costs of enforcement vary according to design details, consideration of enforcement aspects at the time of planning will increase the likelihood that low-cost, self-enforcing designs will be developed. As one example, long-term limitations on parking supply emerged as an effective policy on an areawide basis and would involve minimal enforcement costs, since violations would be in the form of unauthorized construction rather than daily-use violations.

An examination of ride-sharing programs performed by Wagner (5) demonstrates the relatively good cost-effectiveness of a second type of TSM policy. The Denver Regional Council of Governments has been funded at an annual average level of approximately $125 000, which corresponds to an annual cost of $0.10 per capita.

As shown in Table 3, this corresponds to funding levels in a number of other urban areas. Shown are various cost-effectiveness measures for 22 of the Federal Highway Administration's carpool demonstration projects. For example, annual project cost per new carpooler averaged $47 for the cities shown. Most of the available impact data, however, include only direct impacts of carpool matching. For the six cities where broader impact estimates were made, the cost-effectiveness indicators—$28 annually/new carpooler, 6 cents/new carpooler trip, and 2.7 cents/VKMT reduced—are much better.

For purposes of comparison with a capital-intensive transportation measure, a recent analysis of one proposed heavy rail rapid transit extension (not in Denver) derived an annual cost per new transit passenger in the range of $3000. This does not necessarily imply that more capital-oriented transit expenditures are a poor investment but rather that many air quality transportation measures are highly cost-efficient means of improving the short-range management effectiveness of existing transportation systems.

Transit, if properly designed and coordinated, may contribute to a number of long-range objectives not only for air quality improvement and energy conservation, but also for improved spatial distribution of urban activities and a stronger long-range economic infrastructure (2).

INSTITUTIONAL RESPONSIBILITIES

Given an assessment of the effectiveness of a TSM measure in changing travel behavior patterns, it is equally important to examine institutional, legal, enforcement, and other administrative issues that would be associated with implementation to determine a measure's actual potential (Table 3). These considerations influence not only the overall effectiveness of a program of action but also the acceptability of the measures to the public and to the various institutions and interest groups involved in the implementation effort.

Whereas a variety of transportation measures can be shown to be cost effective in terms of improving air quality, experience in Denver and elsewhere has shown that the primary barriers to successful implementation can be characterized as being institutional or political in character (3). For example, only one of the alternate parking management strategies examined—restrictions on new parking construction—that proved to be effective on an areawide basis also was judged to be definitely practicable in terms of ease of implementation (Figure 2).

One of the difficulties in implementing transportation management programs for air quality improvement (as well as for energy conservation) is that a sizable number of the population, as well as many agency officials and elected representatives, do not understand the nature of air pollution and are not convinced that a problem exists or that the problem is serious enough to justify special action. However, well-designed public information programs can be combined with the actual planning and implementation of control measures in order to increase general awareness and appreciation of air quality as an issue. This consciousness raising may in turn stimulate additional voluntary action that will contribute to air quality goals.

The lack of consensus on growth and development policy for the Denver region, as evidenced by recent intense debates over highway, transit, and water projects, has further complicated all planning and implementation efforts, including population and land-use forecasting, highway and transit systems development, and water resource and air quality programs. Competing recommendations on each of the programs and the state of flux inherent in a rapidly growing region have made the always-difficult job of predicting future conditions especially fraught with uncertainty. This uncertainty further complicates the problem of getting support for a particular course of action.

Many air quality transportation measures do not easily coincide with the traditional way in which the state, regional, and local transportation agencies have done things, which necessitates a degree of change in organizational procedures, responsibilities, and objectives. Experience has shown that these changes may be actively and successfully resisted by numerous forces.

The requirements for institutional cooperation often are relatively greater for air quality transportation measures, particularly those that are more innovative, than they are for many large-capital projects. Jurisdictions often overlap and support actions often are needed. The cost of administration and coordination also can be a higher percentage of the total costs of such a project than of a more traditional highway or transit project. These factors tend to make agencies reluctant to take on responsibility for measures that are intended primarily to improve air quality. They also make it easier for agencies to pass the buck with regard to implementation responsibility.

Because air quality transportation measures are usually both short range and low capital, they often are viewed as being simple. Experience has shown just the opposite: Each measure has numerous design details and problems to be worked out that require the skills and knowledge of a trained professional.

Active, inspired leadership and continued follow-up by a small number of individuals are needed to get a measure going and to keep it going. Unfortunately, these conditions may not exist, and even when they do success may be slow. Barriers exist in terms of political and institutional unwillingness to generate controversy or to go against vested interests and in the sense that implementation of the measures may not match the cognizant agency's priorities.

These general observations are derived from an examination of Denver-area institutional responsibilities and responses but are felt to be equally applicable to many other large urban areas as well (2). Before the Denver region's present effort on the state implementation plan revision, operations of the Denver Regional Council of Governments (DRCOG), the Regional Transportation District (RTD), the Colorado Department of Highways (CDH), the city and county of Denver, and the Colorado Department of Health, the state's air quality agency, were characterized by an atmosphere of cooperative autonomy. The agencies' activities and plans occurred largely independently of each other. While recent changes in Denver's institutional arrangements are improving this coordination, it is still too early to determine the degree of long-term success associated with effective implementation that will actually be achieved.

Each of the Denver area's transportation agencies that has a responsibility in transportation and air quality has had its own agenda of actions programmed for implementation, some of which are compatible with air quality objectives. These agencies have multi-million-dollar annual budgets, and implementation of transportation air quality measures is within their financial capabilities, although in most cases it would require shifting their priorities and reallocating existing staff resources. The agencies frequently have been unwilling to change their priorities to projects that would improve air quality, particularly when such measures are not consistent with agency objectives.

Many potential transportation air quality measures, particularly automobile disincentives, are perceived as having a low level of public acceptability. Agencies with high visibility and accountability, such as a mayor's office, are skeptical about implementing such measures because of anticipated adverse public reaction. Thus, many transportation measures that initially appear to be implementable in the short run can become long-term efforts when institutional and political factors are taken into account.

THE FUTURE

The 1977 amendments to the Clean Air Act and the resulting implementing guidelines jointly developed by DOT and EPA acknowledge both the potential effectiveness of air quality transportation measures and the institutional problems that can impede their successful implementation. Methods for avoiding many of the problems faced by previous transportation control plans are provided. The responses of city transportation officials and metropolitan planning organizations (MPOs) to these opportunities will in large part determine the degree to which future efforts will be more successful than those during the past five years.

Air Quality Transportation Planning Guidelines

The amendments and resulting guidelines emphasize the establishment of a process for transportation air quality planning characterized by leadership responsibility at the regional level; shared and agreed-on state, regional, and local authorities and obligations; requirements for consideration of alternative measures and programs and for evaluation of social and economic impacts; a standard of reasonable incremental progress in implementing measures to improve air quality; and shared federal responsibility for ensuring that transportation air quality measures are in fact introduced.

In addition, this process is to be integrated with other metropolitan planning efforts, and the assessment of the results will no longer be made on the basis of a separate transportation air quality plan but instead on the overall achievements in air quality improvement taking all relevant activities into consideration.

The emerging process, then, would have self-enforcing provisions for the compatibility of air quality planning and transportation planning: The separate state implementation and transportation plans would be, simply, documentation of the same planning process and implementation activities. And the process would include a system of procedures, incentives, and sanctions designed to ensure that reasonable progress in implementing air quality improvements actually would occur.

Changing Role of the Urban-Area Traffic Engineer

If the objective of shifting away from merely considering air quality to actual implementation of air quality improvement measures is to be achieved, it is essential that those who have traffic engineering and transportation responsibilities in a metropolitan area assume major and visible leadership positions. In most large urban areas, the city traffic engineer's role has evolved into that of the principal transportation advisor to the mayor. Concerns have shifted from traditional intersection signalization, vehicle flow, and on-street parking to those associated with the overall movement of people, including transit, off-street and residential-area parking, preferential treatment for particular vehicle types, and the distribution and density of spatial activity patterns. To cite but four examples: Boston's automobile-restricted zone is being coordinated by the mayor's commissioner of traffic and parking; Cambridge's director of traffic and parking is responsible for administering on-street commuter parking restrictions in residential neighborhoods; Seattle's ride-sharing and parking management programs are being managed by their traffic engineering office; and the city of Berkeley has an appointed transportation commission that has helped develop that city's successful programs of transportation for the handicapped and restricted automobile movement in residential areas.

Mentioning these broader transportation responsibilities does not imply, however, that traditional traffic engineering measures cannot also contribute to improved air quality. An important focus of concern in developing revised state implementation plans will be the identification and correction of carbon monoxide (CO) "hot-spot" problems. Unlike photochemical oxidants that require areawide measures, violations of CO standards frequently occur on a highly localized basis. Because vehicle CO emissions decrease with vehicle operating speed and smoother traffic flow, traffic engineering design changes that affect the operation of streets, intersections, and parking facilities can make an important contribution to achieving ambient CO standards on a localized level.

An integrated program of localized traffic engineering improvements that concentrates on arterial streets may lead, as well, to overall regional air quality improvements. For example, in Denver an approximately 12 percent decrease in regionwide automobile travel-time rates results in about a 3 percent short-term decrease in vehicle emissions. This takes into account the 1 percent projected increase in VKMT as a result of an improved level of service and leaves a net improvement in emissions comparable to that obtainable with many other types of air quality transportation measures.

MPO Capabilities and Relations with Other Agencies

Many MPO staffs have been limited to performing feasibility studies and conducting certain areawide planning efforts that give primary emphasis to summarizing and compiling planning and programming activities of local and state agencies and operators. State and local agencies retain the primary responsibility for implementation.

In order to achieve the goal of regional and subarea air quality improvement, it will be necessary to mobilize these disparate agencies and organizations for coordinated action. As planning agencies, MPOs simply do not have the authority or the mandate to direct other agencies to conduct studies or implement measures. Therefore, if coordinated action on air quality is going to occur, it will be largely dependent on the MPO in its role as a consortium of local (and state) officials, orchestrating an agreement that the members individually will assume the appropriate responsibilities. MPO actions including "lend-a-planner" programs, pass-through funding earmarked for particular studies or projects, and MPO-conducted studies of promising actions would be valuable. Nevertheless, the proposed process will necessitate goal-oriented commitment and responsibility on the part of local agencies and officials to a greater degree than has typically occurred in the past, plus stronger direction from the MPO as a forum and as a planning staff than has been common.

In summary, the outlook for improved consideration of air quality in transportation planning is promising, but there remains the potential for controversy and conflicting objectives. The emerging process should correct many of the problems that occurred in the past, but a great deal of work is ahead for regional, local, and state agencies and officials in establishing the process and for EPA and DOT in managing it.

ACKNOWLEDGMENT

The work described in this paper was supported, in part, by the U.S. DOT in cooperation with EPA and, in part, by DRCOG. The basic analytical methodology employed in the travel demand analyses was developed for the

U.S. Department of Energy. We, however, are solely responsible for the views expressed.

REFERENCES

1. U.S. Environmental Protection Agency and U.S. Department of Transportation. Transportation-Air Quality Planning Guidelines. Federal Register, June 16, 1978.
2. Cambridge Systematics, Inc. Implementation and Administration of Air Quality Transportation Measures: An Analysis of the Denver, Colorado Region. U.S. Department of Transportation and the U.S. Environmental Protection Agency, Summary and Final Rept., April 1978.
3. Cambridge Systematics, Inc. Parking Management in the Denver Region: Analysis of Transportation Impacts and Implementation Issues. Denver Regional Council of Governments, May 1978.
4. Cambridge Systematics, Inc. Urban Transportation Energy Conservation: Analytic Procedures for Estimating Changes in Travel Demand and Fuel Consumption. U.S. Department of Energy, Final Rept., Vol. 2, Sept. 1978.
5. Cambridge Systematics, Inc. Urban Transportation Energy Conservation: Case City Applications of Analysis Methodologies. U.S. Department of Energy, Final Rept., Vol. 3, Sept. 1978.
6. F. A. Wagner; JHK and Associates. Evaluation of Carpool Demonstration Projects. Federal Highway Administration, Phase I Rept., Oct. 1978.

Publication of this paper sponsored by Committee on Urban System Operations.

Results of Implementing Low-Cost Freeway Incident-Management Techniques

Gary L. Urbanek, Peat, Marwick, Mitchell and Company
Samuel C. Tignor, Federal Highway Administration
Gary C. Price, Florida Department of Transportation, Tallahassee

The purpose of this paper is to report on the demonstration of a low-cost freeway incident-management methodology. The results of the demonstration indicated that the delay caused by accidents, spills, breakdowns, and other incidents was reduced by 45 percent by implementing three different solutions. This paper presents before-and-after incident data and estimated versus actual delay savings. The major finding of this research was that the method developed to estimate delay caused by incidents and to evaluate proposed solutions is appropriate and merits further testing.

One of the research projects in the federally coordinated program of research and development deals with analysis and remedies of freeway traffic disturbances (1). It is concerned with the planning, design, and operation of traffic-responsive incident-management systems. Emphasis has been placed on the use of low-cost freeway incident-management systems as well as on the more expensive electronic surveillance and control systems.

It is known that freeway incidents occur with sufficient regularity to be considered a major problem. In fact, approximately half the delay on urban freeways is caused by unexpected incidents such as spilled loads, collisions, and stalled vehicles (2). It is estimated that in the United States motorists lose 750 million vehicle-hours/year waiting for freeway incidents to be cleared (3). Although such incidents occur randomly with respect to time and place, they are predictable in the sense that they will occur sufficiently often during peak-period flow conditions to further complicate the continued movement of traffic in the traffic stream.

One of the advantages of using low-cost freeway incident-management approaches is that, by using preplanned incident-response procedures, the delay in detecting, responding to, and removing the incidents can often be significantly reduced. Electronic surveillance and control systems may also achieve the same end result. However, many agencies may not have the extensive freeway distance and associated operation problems needed to justify the installation of these advanced systems.

The purpose of this report is to describe the selection, planning, operation, and results of several low-cost technical options for providing for freeway incident management (FIM). These particular options and the deployment methods used for them were developed jointly by the Federal Highway Administration (FHWA), Florida Department of Transportation (DOT), and Peat, Marwick, Mitchell and Company in a project on alternative surveillance concepts and methods for freeway incident management. This report describes the specific application of three low-cost freeway incident management options evaluated on the I-275 Howard Frankland Bridge (HFB) in Tampa, Florida.

HISTORY AND SITE DESCRIPTION

HFB, which spans upper Tampa Bay, was built in 1959 as part of I-4 and is now part of I-275. It serves as the major artery between Tampa and St. Petersburg, Florida. Since its completion, the bridge has had a history of traffic problems such as high accident rates, insufficient servicing of disabled vehicles, and long delays associated with capacity-reducing incidents. The bridge, 4.8 km (3 miles) in length, has 3.2 km (2