EFFECTIVENESS OF NEAR-TERM TACTICS IN REDUCING VEHICLE MILES (KILOMETERS) OF TRAVEL: CASE STUDY OF LOS ANGELES REGION

William T. Mikolowsky, William L. Stanley, and Bruce F. Goeller,
Rand Corporation

An analysis of near-term transportation alternatives for the Los Angeles region that uses the policy-oriented urban transportation model developed by the Rand Corporation is presented. The predicted effect on regional vehicle miles (kilometers) of travel of various levels of bus-system improvements, car-pooling incentives, and economic disincentives (distance surcharges or increased gasoline prices and parking surcharges) is given. Changes in personal mobility as reflected in changes in the total number of person trips also are included. The analysis indicates that a number of transportation management alternatives are available that could reduce vehicle miles (kilometers) of travel in the Los Angeles region by 20 percent or more while minimizing adverse impacts on personal mobility.

•IN 1972, the Rand Corporation undertook the development of a comprehensive methodology that could be used to predict the regional impacts of alternative air pollution control strategies (including strategies that could cause significant reductions in automobile use). This methodology was developed initially as part of the San Diego Clean Air Project (1) and subsequently was applied in a similar study of the Los Angeles air quality control region (LA AQCR) performed for the Environmental Protection Agency (EPA) (2). Most recently, the original methodology again was modified extensively for application in the Los Angeles region under the sponsorship of the Southern California Association of Governments (SCAG) (3).

SOUTHERN CALIFORNIA ASSOCIATION OF GOVERNMENTS SHORT-RANGE PROGRAM

The recently completed study sponsored by SCAG was performed as an element of the SCAG short-range program. The short-range program came about mainly because of a desire to improve air quality in the Los Angeles region by 1977 so that EPA requirements could be satisfied (4). In addition, gasoline shortages observed in late 1973 and early 1974 emphasized the need to develop plans for conserving petroleum resources. These requirements evolved into a specific goal of reducing vehicle miles of travel (VMT) (vehicle kilometers of travel) by 20 percent from that currently forecast for 1977. This VMT (vehicle-kilometer-of-travel) reduction was hoped to be accomplished while retaining or improving personal mobility, particularly for the underadvantaged.

The LA AQCR, which has an area of nearly 8,700 miles^2 (22 620 km^2), encompasses parts of 6 southern California counties, including the entire greater metropolitan Los Angeles area. The people of the region, nearly 10 million in number, are today largely dependent on the private automobile for their transportation needs. Basically, the only

Publication of this paper sponsored by Committee on Taxation, Finance, and Pricing.

major alternatives to the automobile are the publicly owned bus systems that operate in the region and that attract slightly more than 2 percent of the daily weekday person trips. The bus systems now cover roughly 16 percent of the area of the region and serve about 68 percent of the population. Most individuals within the region who commute to work by automobile do so alone; the average automobile occupancy for work-related trips is only about 1.13 occupants/vehicle. The automobile commuter is particularly reliant on the well-developed regional freeway system.

In the study for SCAG, we sought near-term transportation tactics that not only would offer the commuter an alternative to the automobile but also would tend to increase average automobile occupancy. We felt that the mobility provided by the extensive regional freeway network should be exploited in the formulation of these tactics.

ANALYSIS OVERVIEW

These thoughts, together with earlier work (1, 2), indicated that 3 types of tactics could be employed that might provide substantial VMT (vehicle-kilometer-of-travel) reductions in the near term. These are

1. Bus-system improvements (lower fares, increased frequency of service, and expanded service area);
2. Car-pooling incentives (preferential freeway treatment for car pools, computer matching to encourage formation of car pools, and exemptions from parking charges for car pools); and
3. Economic disincentives (distance surcharges and parking surcharges).

The effectiveness of each of these tactics was investigated in detail and, as we will discuss, the results form the basis of this paper. However, in the work for SCAG, the tactics were combined in different ways to form a number of alternative transportation strategies for the Los Angeles region. The strategies then were compared for their impacts on

1. Regional expenditures,
2. Transportation service,
3. Air quality,
4. Petroleum consumption, and
5. Households with different income levels.

For each category, a number of representative impacts were quantified. This comparison (3) then was used by local decision makers in formulating the short-range transportation plan for the Southern California region. The strategy judged most attractive by SCAG is now being implemented (5).

In this paper, we will show the effectiveness of the various transportation management tactics in terms of the resulting VMT (vehicle-kilometer-of-travel) reductions predicted by our analysis. When appropriate, the impact on personal mobility as manifested by a reduction in person trips (trips forgone) also will be shown. [The reader is cautioned, however, not to equate directly reductions in VMT (vehicle kilometer of travel) with improvements in air quality or reductions in gasoline consumption. The relationship in both instances is not straightforward, and the interested reader is urged to consult Mikolowsky et al. (3).]

POLICY-ORIENTED URBAN TRANSPORTATION MODEL

A key element of the overall Rand Corporation methodology is the policy-oriented urban transportation model originally developed as part of the San Diego clean air project (6, 7, 8). For the study discussed in this paper, extensive refinements were made to the original methodology primarily to allow a more detailed analysis of car-pooling incentives (3). We will begin by discussing the philosophy behind the transportation model; then we will show how it is used by providing a detailed example. All of the results presented later in this paper are based on the application of the transportation model to the Los Angeles region in the recent study for SCAG (3).

Philosophy Behind Rand Corporation Urban Transportation Model

The Rand Corporation urban transportation model is not a forecasting model in the sense that traditional transportation models forecast person trips, VMT (vehicle kilometers of travel), and the like on the basis of inputs that include physical descriptions (such as details of the highway network) and demographic descriptions of the region. Rather, to use the transportation model, one first must describe a base-line regional transportation system for the analysis year of interest. The base line includes forecasts of the number of weekday person trips, weekday VMT (vehicle kilometers of travel), frequency distribution of trip lengths, regional-bus-system description, characteristics of the highway network, and estimates of network capacity. We have termed this base line the reference case. The reference case is commensurate with current SCAG demographic and transportation system projections for the Los Angeles region through 1990 (9, 10). We have calibrated the transportation model to match closely the reference case for analysis year 1977 only, the year that currently is the deadline for full compliance with national air quality standards.

We emphasize that the transportation model is not simply a modal-split model. The transportation model adjusts the demand for travel in accordance with the service characteristics of the specified regional transportation system. For example, major improvements to the bus system not only may cause people to switch from the private automobile to the transit mode but also may induce new person trips on transit (trips not being made in the reference-case system). Alternatively, significant economic disincentives, such as a large gasoline tax, may cause some trips to be forgone and may increase car pooling and transit ridership. Thus the transportation model predicts many additional impacts such as total trips forgone; average trip times, speeds, and costs; and percentage of trips made in car pools.

How the transportation model is used to evaluate the effect of a given transportation management tactic can be illustrated best by an example.

Example Application—Effect of 25-Cent Bus Fare

Action by the Los Angeles County Board of Supervisors in early 1974 led to a temporary change in the fare structure of the bus systems operating in Los Angeles County. Before the change, the Southern California Rapid Transit District (SCRTD) base fare was 30 cents plus 8 cents for each additional transit zone crossed during the trip. A temporary supplemental subsidy provided by the board allowed a reduction to a 25-cent flat fare for all trips (Los Angeles County only). The transit district reported that, in November and December 1973, the SCRTD carried an estimated 500,000 passengers/average weekday. By March 1974, the effect of increased gasoline prices (and long lines at service stations) had increased ridership to about 550,000 passengers/weekday. By May 1974, after the 25-cent flat fare had been in effect for about a month, bus ridership increased to 630,000 passengers/weekday. Thus the near-term effect of the flat fare was to increase ridership by 15 percent. The flat fare plus the increase in gasoline prices that occurred during the 6-month period from November to May increased ridership by 26 percent. We will use the percentage increases for comparison because the transportation model is calibrated to the regional bus system not the SCRTD operations in Los Angeles County only.

We have used the transportation model to evaluate the effect of bus-fare reductions as a tactic for reducing VMT (vehicle kilometers of travel) in 1977. The reference-case bus system was designed to yield approximately the same level of service in 1977 as the existing regional bus system provided at the beginning of 1974. The bus-fare zone structure was approximated by describing the fare in the reference case at 25 cents/trip plus 2 cents/mile (1.25 cents/kilometer) traveled on the bus. This resulted in an average fare of 46 cents in the reference case, which is the equivalent of the original SCRTD base fare (30 cents) plus 2 additional transit zones (16 cents). The average peak-period headway of the reference-case system was estimated to be 17 min; the off-peak headway was estimated to be 40 min. The service area was assumed to be the same as the service area of the existing regional bus system (includes the SCRTD, Orange County Transit District, and municipal bus lines in Santa Monica and Long Beach plus 11 other smaller systems).

Evaluating the effect of different fare reductions is now straightforward. The transportation model is given different fare structures; the model then estimates the resulting changes to the regional transportation system. The data given in Table 1 (3) compare 6 bus systems with varying fare reductions with the reference-case bus system. The 25-cent flat fare case is highlighted. Certain information pertains to all cases in Table 1:

1. Peak-period headways are 17 min;
2. Off-peak headways are 40 min;
3. Service area is 1,380 miles^2 (3588 km^2);
4. Sixty-eight percent of population in service area are eligible; and
5. All counties are affected.

Note that the model predicts an increase in daily bus passengers of about 15 percent. The model also predicts that decreasing the fare to a flat 25 cents would require increasing the annual bus subsidy from about $32 million to $69 million. The 15 percent increase in ridership predicted by the model correlates extremely well with the increase observed by the SCRTD. The effect of increased gasoline prices also can be shown by using the transportation model. In the reference case, the pump price of gasoline is assumed to average 40 cents/gallon (10.6 cents/liter) in 1977. Remember that the reference case is based on an extrapolation of trends observed from 1970 to 1972. Thus gasoline price increases that occurred in 1973 and 1974 are not included in the forecast. By May 1974, when the reduced fare had been in effect for several weeks, the average price of gasoline had risen to almost 60 cents/gallon (15.9 cents/liter). The increase in gasoline price caused a corresponding increase in bus ridership that is not taken into account in Table 1. Later in this paper, we will consider in detail the effects of increased prices of gasoline brought about either by the market or by additional gasoline taxes. With the 60-cent/gallon (15.9-cent/liter) price of gasoline included, the increase in ridership predicted by the model as a result of a flat 25-cent fare is about 30 percent. Thus we are nearly in exact agreement with the range of observed data for this transportation management tactic. Other works (3, 6, 7, 8) offer a complete description of the formulation of the transportation model.

BUS-SYSTEM IMPROVEMENTS

We have considered 3 types of bus-system improvement tactics that result in reductions in VMT (vehicle kilometers of travel): reductions in fares, increased frequency of service (that is, shorter headways between buses), and expanded service areas (that is, increasing the population served by the bus system).

First, different levels of intensiveness of each of the individual tactics were considered. The effect of different bus-fare structures has been described earlier. These individual tactics then were combined with the goal of providing the largest reduction in VMT (vehicle kilometers of travel) with the smallest increase in the required bus subsidy (3). By using this technique, we developed 12 composite bus systems for further analysis. The data given in Table 2 (3) show how the 12 composite bus systems were constructed in stages.

Second, each of the composite systems was evaluated by using the urban transportation model. Figure 1 shows the reduction in VMT (vehicle kilometers of travel) resulting from each composite bus system in terms of the required additional annual bus subsidy. [An LDMV is a light-duty motor vehicle. LDMVs weigh less than 6,000 lb (2700 kg) gross weight. These vehicles account for more than 90 percent of total motor VMT (vehicle kilometers of travel) (3).] We have chosen to present these results in terms of the additional subsidy required because we feel that this represents the "cost" of bus-system improvements as perceived by local decision makers. The composite systems are represented by the circular symbols. For example, the stage-1 system reduces VMT (vehicle kilometers of travel) by about 0.8 percent for an additional annual subsidy of $9 million. At the other extreme, the state 12-bus system requires an additional subsidy of more than $650 million/year and reduces VMT (vehicle kilometers of travel) by about 9.5 percent.

Third, our development of the composite bus systems was intended to approximate the most cost-effective set of bus-system improvements possible; cost was measured in terms of additional bus subsidy required, and effectiveness was measured in terms of the reduction in VMT (vehicle kilometers of travel) obtained. Our success in this respect also is shown in Figure 1. The triangular symbol represents the cost and effectiveness of reducing the bus fare to 0 while making no other improvements; the square symbol is a result of using 0 fare with peak-period headways reduced to 10 min but with no increase in service area. In both instances, substantially larger reductions in VMT (vehicle kilometers of travel) can be obtained for the same subsidy expenditure as can be seen by the composite bus-system curve.

Of course, we realize that many factors other than the required subsidy must be considered when describing the feasibility of different bus-system improvements. For example, the number of buses required by a new system may be affected by the number manufactured annually. In this instance we note that the reference-case bus system requires 2,082 buses (including spares), stage 5 requires 3,294 buses, stage 10 requires 5,489 buses, and stage 12 requires more than 9,000 buses. The stage-5 and possibly stage-10 systems are probably realistic for consideration in 1977. Stage 12, however, does not appear to be a practical alternative in the near term.

CAR-POOLING INCENTIVES

Three different car-pooling incentives were considered as tactics to provide regional reductions in VMT (vehicle kilometers of travel): (a) preferential freeway treatment for car pools (and buses), (b) computer matching for car poolers, and (c) exemptions of car poolers from parking surcharges. Again, each of these tactics was first evaluated individually (3). We will discuss one of the most promising combinations.

The evaluation of each tactic indicated that the preferential freeway treatment and computer matching showed the most promise for achieving substantial reductions in VMT (vehicle kilometers of travel). Figure 2 shows the effect on regional VMT (vehicle kilometers of travel) of providing preferential freeway treatment for car pools and buses if 40 percent of the employed people in the region participate in a car-pool matching program and are matched successfully. The results are presented in terms of the number of occupants required to quality for preferential treatment. Figure 2 shows that reductions in VMT (vehicle kilometers of travel) approaching 20 percent can be achieved if the required occupancy is 3, 4, or 5.

Two additional pieces of information are shown in Figure 2. First, the effect on modal split for each occupancy is described. In each case, the bus modal split decreases, implying that some persons currently making trips by bus will switch to the car-pooling mode. The loss in bus revenue will cause the required bus subsidy to increase. Second, resulting average automobile occupancy for essential trips also is shown. (All essential trips are work-related trips.) We assume that the demand for such trips is constant (that is, that alternative transportation policies will not affect the number of work trips occurring in the region in the short term even though the number of vehicle trips may change substantially). For the reference case, the essential-trip automobile occupancy is 1.13. Note that reduction in VMT (vehicle kilometers of travel), which was obtained from providing preferential freeway treatment for buses only, includes the effect of the computer matching. Preferential treatment for buses only, without computer matching, would yield only about a 1 percent reduction in VMT (vehicle kilometers of travel) (3).

The effectiveness of the car-pooling incentives shown in Figure 2 in reducting VMT (vehicle kilometers of travel) should be considered upper-bound estimates. We say this because of 2 important assumptions made in our analysis. The first assumption is that, in the case of preferential freeway treatment, all qualified car poolers travel the freeway portion of their trip at the average uncongested freeway speed (this also implies that all freeways are modified to provide preferential treatment). We also have assumed that vehicles not qualifying for preferential treatment encounter the same time delay as they currently do because of freeway congestion. This approach to preferential freeway treatment for car poolers reflects the policy orientation of the transportation model. There are at least 2 ways preferential treatment could be implemented: exclusive freeway lanes for car poolers or preferential ramp metering for car poolers. In the first instance, the time delay for those who are not car poolers can be guaranteed by limiting the number of non-car-pool lanes on each freeway to deliberately ensure congestion. In the second instance, the required time delay could be built into the freeway ramp meter. Note, however, that the manner in which the preferential treatment is provided is an implementation problem. The policy question concerns whether the preferential treatment will be effective. The second assumption is that 40 percent of the work force participate in computer matching and are matched successfully. We believe that 40 percent is an absolute upper limit on the number of employed people who could be incorporated into a matching program. Even considering these assumptions, however, preferential treatment and computer matching appear to be very attractive tactics.

We note that the effectiveness of the combined tactics in reducing VMT (vehicle kilometers of travel) is greater than the sum of the reductions in VMT (vehicle kilometers of travel) realized by the 2 tactics when evaluated separately (3). This synergistic effect can be explained. If preferential treatment only is considered, the potential car pooler must weigh the time advantages of no freeway congestion against the pickup-time penalty associated with collecting the other car poolers. When computer matching is included, the pickup-time penalties will decrease because each participant will become aware of additional neighbors closer to the potential car pooler's home who are eligible for his or her car pool. Without the preferential freeway treatment, computer matching lessens only the pickup-time penalty; congestion on the freeway portion of the trip still will be encountered.

ECONOMIC DISINCENTIVES

Two types of economic disincentives were considered in the SCAG study. The first is a surcharge based on VMT (vehicle kilometers of travel); this could be implemented by an additional gasoline tax (although many other possibilities exist). The second is a surcharge on vehicle trips, which most logically would be implemented by imposing a parking surcharge.

To show the effects of using a distance surcharge as a disincentive, we have chosen to present our results in terms of the equivalent pump price of gasoline. This technique allows us to consider simultaneously increases in the base price of gasoline attributable to the market mechanism and increases reflecting a higher gasoline tax.

Distance Surcharge (Increased Gasoline Price)

The effectiveness of the distance surcharge tactic has been evaluated for a range of bus-system improvements and a range of car-pooling incentives. The specific bus-improvement and car-pooling tactics used in this context were selected in consultation with the SCAG staff and were based on the results presented earlier in this paper.

Before describing the results of this part of the analysis, we must first discuss some of the implications of using the increased pump price of gasoline as a substitute for distance surcharge. The purpose of a distance surcharge is to increase the total cost per mile (kilometer) of driving an automobile. We can best explain by considering a hypothetical example. Suppose that the average cost (excluding fuel) of operating an automobile is 6 cents/mile (3.65 cents/km). (This cost includes amortized investment, insurance, license, and the like.) Suppose also that the average vehicle travels 10 miles/gallon (4.25 km/liter) of gasoline and that the pump price of gasoline is 40 cents/gallon (10.6 cents/liter) including taxes. Thus the total cost would be 10 cents/mile (6.25 cents/km).

Now assume that an additional 20-cent/gallon (5.3-cent/liter) gasoline tax is imposed. The immediate effect would be to make the fuel cost 6 cents/mile (3.75 cents/km); the total cost then would be 12 cents/mile (7.5 cents/km). However, if the additional gasoline tax remains in effect for some time, motorists will likely begin to adjust their behavior in an important way—they will buy new cars with better fuel economy. Suppose that after several years the fuel economy of the average vehicle increases to 15 miles/gallon (6.37 km/liter). The 60-cent/gallon (15.9-cent/liter) gasoline price would result in a fuel cost of only 4 cents/mile (2.5 cents/km) and the total cost would return to 10 cents/mile (6.25 cents/km). Although fuel consumption would still be decreased, there would be no cost-per-mile (cost-per-kilometer) penalty, and, hence, regional VMT (vehicle kilometers of travel) would no longer be affected. To achieve the earlier effect on VMT (vehicle kilometers of travel), one would have to increase the total pump price of gasoline to 90 cents/gallon (23.9 cents/liter).

When we evaluated increased gasoline prices by using the transportation model, we assumed that the fuel economy of the average vehicle does not change from that prescribed in the reference case [about 13.2 miles/gallon (5.6 km/liter)] (3). Thus the effects we present in this section should be regarded as completely valid only in the short term. Stated another way, when we show a result for an 80-cent/gallon (21.2-cent/liter) gasoline price, we assume that the price has just changed from the reference-case value of 40 cents/gallon (10.6 cents/liter). If several years pass between the change in gasoline price and the analysis year, then the reduction in VMT (vehicle kilometers of travel) should be less than we show because motorists will have had time to increase the average fuel economy of the fleet through their choice of new cars that have better fuel economy. Alternatively, if the policy decision is to maintain the same reduction in VMT (vehicle kilometers of travel) obtained initially with a gasoline tax, then the amount of the tax will need to be adjusted upward each year to account for the change in average vehicle fuel economy. Of course, we also are assuming that the local gasoline supply is perfectly elastic at the prevailing local market price. With this in mind, we will now discuss the effect on VMT (vehicle kilometers of travel) of increases in gasoline price.

Range of Bus-System Improvements

The impacts of gasoline price increases will depend on the level of bus-system improvement being considered. Therefore, we have analyzed the economic disincentives for 3 different systems: reference-case, stage-5, and stage-10 bus systems. The stage-5 system was chosen because it represents, at this time, the minimum likely improvement to the regional bus system by 1977. On the other hand, the stage-10 system with nearly 5,500 buses required can be considered the maximum feasible improvement for 1977.

The reduction in regional VMT (vehicle kilometers of travel) caused by increased gasoline prices for each of these bus systems is shown in Figure 3. The most evident feature of Figure 3 is that very large VMT (vehicle-kilometers-of-travel) reductions can be obtained if gasoline becomes expensive. However, some more subtle observations can be made. For example, with the reference-case bus system, a 20 percent reduction in VMT (vehicle kilometers of travel) would occur if gasoline were 85 cents/gallon (22.5 cents/liter). The stage-10 bus system would yield the same reduction in VMT (vehicle kilometers of travel) for a pump price of only about 65 cents/gallon (17.2

cents/liter). Figure 3 also is useful for considering alternative ways of alleviating gasoline shortages. If the shortfall in supplies were 10 percent [VMT (vehicle kilometers of travel) would need to be reduced by 10 percent to eliminate the shortfall], then the required free-market price of gasoline would rise to about 60 cents/gallon (15.9 cents/liter) with the reference-case bus system. Alternatively, the gasoline supply shortfall would be eliminated with the stage-10 bus system if the price rose to only 45 cents/gallon (11.9 cents/liter).

The reductions in VMT (vehicle kilometers of travel) shown in Figure 3 came about because of 3 basic changes in trip-making behavior. First, some trips made by automobile in the reference case will switch to the transit mode. Second, some trips made in low-occupancy automobiles will be made in car pools. [Although no specific car-pooling incentives are included in this part of the analysis, the increased cost per mile (kilometer) of driving will induce some people to form car pools and this effect has been included.] Third, some trips made in the reference case will no longer be made; we call these the trips forgone.

The number of trips forgone is one of the important impacts that needs to be included in evaluating economic disincentives. Trips forgone can be used to represent the loss of personal mobility brought about by the implementation of such tactics. The number of trips forgone is equivalent to the number of person trips that are no longer made because of the policy in effect. We have assumed that only inessential trips (all non-work-related trips) can be forgone as the result of a particular policy. Note, however, that essential vehicle trips can decrease, and, indeed, will decrease, as individuals either participate more heavily in car pools or switch from automobile to bus mode. Figure 4 shows the effect of gasoline prices on trips forgone for all households and for households in the Los Angeles region with less than $5,000 annual income (1972 dollars).

Consider first the effect of a 20 percent reduction in VMT (vehicle kilometers of travel) on the average household. From Figure 3, we saw that an 85-cent/gallon (22.5-cent/liter) price was required with the reference-case bus system; the resulting trips forgone would be about 6 percent (expressed as a percentage of the number of person trips taken in the reference case). The stage-10 bus system needs only a 65-cent/gallon (17.2-cent/liter) gasoline price; the corresponding number of trips forgone is less than 2 percent.

The effect of gasoline price is even more dramatic on the lower income groups. For example, consider that the average price of gasoline in Los Angeles in May 1974 was about 60 cents/gallon (15.9 cents/liter). This price causes the lower income group households to forgo about 4 percent of their trips with the reference-case bus system. However, if the stage-10 bus system was available, these households would not forgo trips but would actually make more trips than in the reference case (trips forgone are about -2 percent).

These examples show the importance of improving the regional transit system to reduce losses in personal mobility caused by increasing gasoline prices particularly for low-income households. Remember, the gasoline price can increase either through additional taxes as part of a strategy to reduce VMT (vehicle kilometers of travel) or through the market mechanism.

Range of Car-Pooling Incentives

We also have considered 3 different car-pooling-incentive policies for analysis in conjunction with the increased gasoline prices:

1. No additional car-pooling incentives [except the disincentive automatically included in the increased cost per mile (kilometer) of driving],
2. Preferential freeway treatment for buses and car pools with 3 or more occupants, and
3. Preferential freeway treatment plus computer matching with 40 percent of the work force presumed to be matched successfully.

Table 1. 1977 impacts of bus-fare reductions as predicted by the policy-oriented urban transportation model.

Bus System	Fares (cents) Per Trip	Fares (cents) Per Mile	VMT Reduction (percent)	Annualized System Cost (millions of dollars)	Annual Subsidy Required (millions of dollars)	Average Modal Split (percent)	Daily Bus Passengers	Average Trip Speed (mph)	Average Bus Occupancy	Buses Required	Bus-System Employees
Reference case	25	2	0	132	32	2.2	636,000	14	22	2,082	7,510
Case 1	25	1	0.8	132	43	2.4	705,000	14	27	2,082	7,510
Case 2	25	0	1.3	131	69	2.5	728,000	14	30	2,072	7,490
Case 3	20	0	1.5	131	79	2.6	762,000	14	31	2,072	7,490
Case 4	10	0	1.9	131	103	2.8	834,000	14	34	2,072	7,490
Case 5	5	0	2.1	131	116	2.9	872,000	14	35	2,072	7,490
Case 6	0	0	2.3	131	131	3.1	913,000	14	37	2,072	7,490

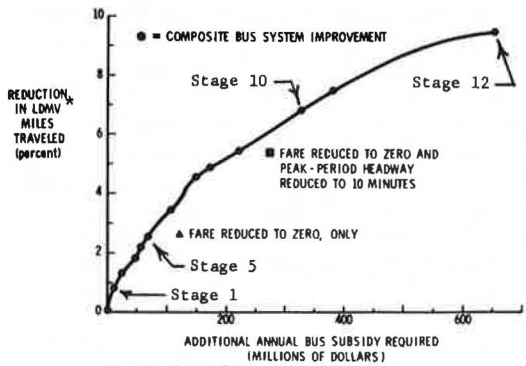
Note: 1 cent/mile = 0.625 cent/km. 1 mile = 1.6 km.

Table 2. Staged development of the 12 composite bus systems.

Stage	Description	Stage	Description
0	Reference bus system (fare = 25 cents plus 2 cents/mile, peak-period headway = 17 min, and existing service area = 1,380 miles^2)	6	Lower peak-period headway to 10 min
		7	Lower fare to 25 cents/trip and have no zone charges
		8	Lower fare to 20 cents/trip
1	Lower fare to 25 cents plus 1 cent/mile	9	Lower fare to 10 cents/trip
2	Lower peak-period headway to 15 min	10	Lower peak-period headway to 7.5 min
3	Lower peak-period headway to 12.5 min	11	Increase service area in Los Angeles County
4	Increase service area[a] to 1,488 miles^2		
5	Increase service area[a] to 1,613 miles^2	12	Lower peak-period headway to 5 min

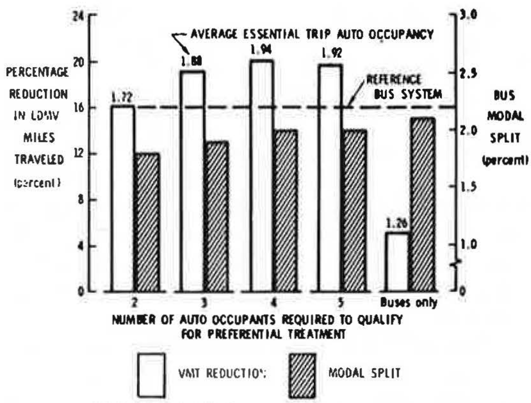
Note: 1 cent/mile = 0.625 cent/km. 1 mile^2 = 2.6 km^2.
[a]Service area expansions are in Orange County.

Figure 1. Effectiveness of the composite bus systems in reducing vehicle miles (kilometers) of travel in terms of additional bus subsidy required.



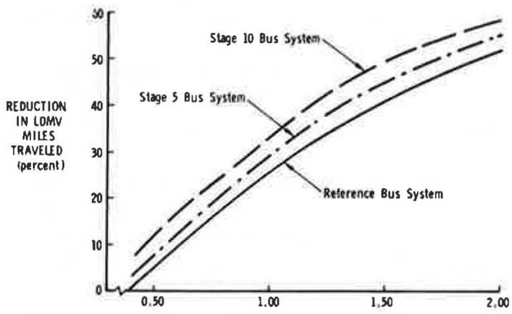
Note: 1 mile = 1.6 km.

Figure 2. Effect on vehicle miles (kilometers) of travel of providing preferential treatment for buses and car pools with 40 percent of the work force participating in computer matching.



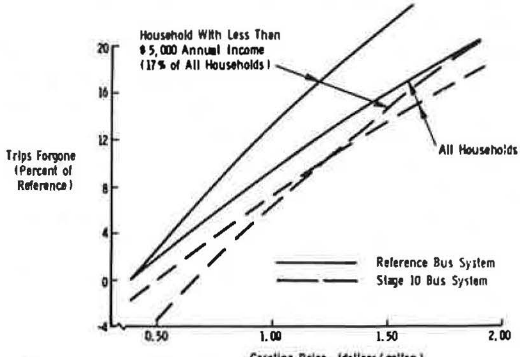
Note: 1 mile = 1.6 km.

Figure 3. Effect of gasoline price on vehicle miles (kilometers) of travel for 3 bus systems.



Note: 1 mile = 1.6 km.
$1/gallon = $0.265/liter.

Figure 4. Effect of gasoline price on trip-making behavior for 2 bus systems.



Note: $1/gallon = $0.265/liter.

Each incentive has been analyzed with the reference-case bus system.

Figure 5 shows the effect on VMT (vehicle kilometers of travel) of gasoline prices for the 3 car-pooling-incentive policies. Again we see that major reductions in VMT (vehicle kilometers of travel) can be obtained with high gasoline prices. Note also in Figure 5 the saturation effect on a reduction in VMT (vehicle kilometers of travel) that occurs after the price of gasoline has passed $1/gallon (26.5 cents/liter). That is, the additional reduction in VMT (vehicle kilometers of travel) obtained from the car-pooling incentives begins to taper off at about that point.

Another aspect of the car-pooling incentives should be realized. We have assumed that car pools are formed for essential trips only, and we further assume that an inelastic demand exists for essential trips (all essential trips must be made by low-occupancy automobile, in car pools, or on transit). Thus the car-pooling incentives have no effect on the number of trips forgone as a consequence of increased gasoline price. Specifically, the number of trips forgone at some gasoline price for any of the car-pooling policies will be the same as that shown in Figure 4 for the reference-case bus system. Therefore, car pooling can be used to achieve substantial reductions in VMT (vehicle kilometers of travel), but reductions in personal mobility caused by increasing gasoline prices can be alleviated only by improving the regional bus system.

Parking Surcharges Versus Distance Surcharges

The parking surcharge aimed at reducing the number of vehicle trips is more straightforward than a gasoline tax used as a distance surcharge. For example, one of the tactics in the final implementation plan for Los Angeles promulgated by EPA was an additional parking tax of 25 cents/hour on essentially all nonresidential parking (4). An examination of the travel patterns in the Los Angeles region indicates that parking surcharges may not be the most effective economic disincentive for reducing VMT (vehicle kilometers of travel). Such an analysis reveals that trips less than 4 miles (6.4 km) in length represent only 12 percent of the regional VMT (vehicle kilometers of travel) yet account for 50 percent of all trips. On the other hand, trips of approximately 11 miles (17.6 km) or more represent almost 55 percent of the regional VMT (vehicle kilometers of travel) but account for only 20 percent of the total trips (2). Thus an economic disincentive applied on a per-trip basis, such as a parking surcharge, may be less effective in reducing VMT (vehicle kilometers of travel) than one applied on a per-vehicle-mile (per-vehicle-kilometer) basis (for example, an additional gasoline tax). Stated another way, the parking surcharge will be most visible for short trips that account for only a small percentage of the regional VMT (vehicle kilometers of travel).

To further clarify the differences between distance and parking surcharges, we have compared their effectiveness in reducing VMT (vehicle kilometers of travel) by using the transportation model. A uniform basis for the comparison was provided by expressing the reduction in VMT (vehicle kilometers of travel) in terms of the annual expenditures by motorists in the region for the distance or parking surcharges. The expenditure caused by the tactic represents the total out-of-pocket costs to motorists. This comparison is shown in Figure 6a. Note that, for the same level of expenditure, the distance surcharge always yields a greater VMT (vehicle-kilometers-of-travel) reduction than the parking surcharge yields. The disparity becomes larger for increasing levels of VMT (vehicle-kilometers-of-travel) reduction. As we explained earlier, however, the effect on personal mobility also should be taken into account when economic disincentives are considered. The relative effects of distance and parking surcharges on trips forgone are shown in Figure 6b. Again the parking surcharge looks somewhat less favorable than distance surcharge for the range of VMT (vehicle-kilometer-of-travel) reduction shown.

Thus far, we have considered the distance and parking surcharges to be in effect for all trips. (Of course, the parking surcharge is applicable only to the nonresidential end of the trip.) We distinguish between 2 types of trips: (a) essential trips are all home-work-related trips, and (b) inessential trips are all other trips. Demand for essential trips remains constant, and these trips will be made either by low-occupancy automobiles, in car pools, or on transit. Inessential trips (shopping, recreation), however, have an elastic demand, which means that all forgone trips come from this category.

The parking-surcharge tactic provides another flexibility. We believe that the surcharge could be implemented to affect essential trips only. The advantage to using the parking-surcharge tactic in this context would be that practically no trips would be forgone as a result of the surcharge. Therefore, we also show in Figure 6b the effectiveness of the parking surcharge on essential trips only in reducing VMT (vehicle kilometers of travel). With a VMT (vehicle-kilometers-of-travel) reduction of up to about 25 percent, the parking surcharge used in this way is approximately identical in effectiveness to the distance surcharge. Consequently, in our analysis of the parking surcharge, we have assumed that it is applied to the nonresidential ends of essential trips only.

Parking Surcharge on Essential Trips

The effectiveness of the parking-surcharge tactic was investigated, first, in conjunction with the 3 previously described bus systems. We have expressed the parking-surcharge policy in terms of the daily surcharge imposed at the nonresidential end of each essential trip. These results showed that the incremental VMT (vehicle-kilometer-of-travel) reductions obtained as a consequence of the surcharge were almost independent of the bus system under consideration.

Finally, Figure 7 shows the effect that a parking surcharge would have on VMT (vehicle kilometers of travel) for different car-pooling-incentive policies. In addition to the no-additional-car-pooling-incentives case (which includes the reference-case bus system), we have considered the following policies:

1. Parking surcharge exemptions for car pools with 3 or more occupants,
2. Policy 1 plus preferential freeway treatment for car pools with 3 or more occupants and buses, and
3. Policies 1 and 2 plus computer matching with 40 percent of the work force being successfully matched.

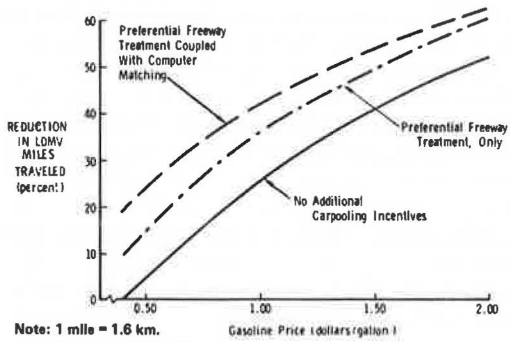
We can see in Figure 7 that parking-surcharge exemptions yield only modestly larger VMT (vehicle-kilometer-of-travel) reductions than the surcharge alone yields. The reader should remember, however, that parking-surcharge exemptions will lessen the motorist's out-of-pocket costs. We also can observe from Figure 7 that, if all the car-pooling-incentive policies are in effect, we begin to encounter a saturation effect after the surcharge is increased above about $1/day. That is, given all these incentives and disincentives on essential trips, the maximum total VMT (vehicle-kilometer-of-travel) reduction that apparently could be obtained is approximately 30 percent. Greater reductions in VMT (vehicle kilometers of travel) can be achieved only by concentrating on the inessential trips with additional economic disincentives and, to a lesser extent, with bus-system improvements.

SUMMARY

In this paper, we have provided a number of insights into the possible effectiveness of different tactics in reducing VMT (vehicle kilometers of travel) in the Los Angeles region and some of the consequences implied by use of these tactics. Six of the more important observations we have made can be summarized.

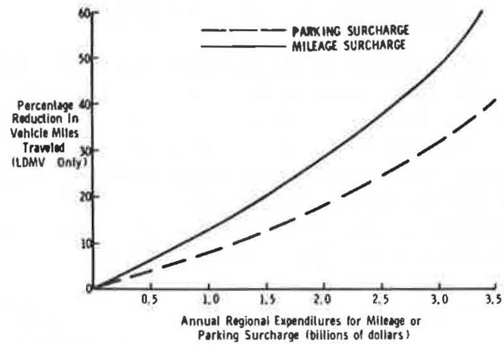
1. The maximum reduction in VMT (vehicle kilometers of travel) achievable by bus-system improvements alone is about 10 percent. The bus system required to accomplish such a reduction in the Los Angeles region probably should be considered impractical for implementation by 1977.

Figure 5. Effect of gasoline price on vehicle miles (kilometers) of travel for 3 car-pooling-incentive policies.

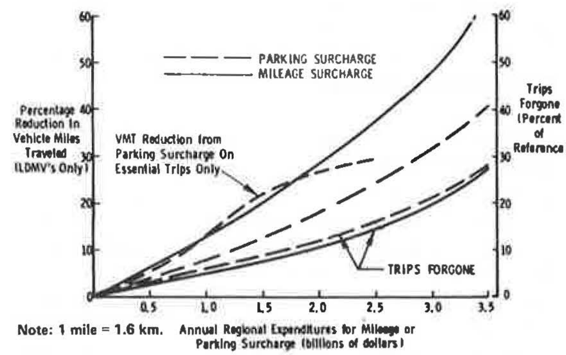


Note: 1 mile = 1.6 km.
$1/gallon = $0.265/liter.

Figure 6. Relative effectiveness of distance and parking surcharges in reducing vehicle miles (kilometers) of travel and changing trip-making behavior.



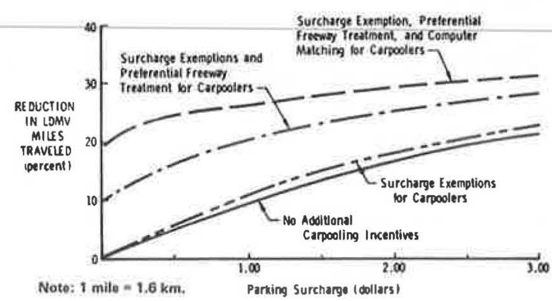
(a) VMT reduction only.



Note: 1 mile = 1.6 km.

(b) Added curves show trips foregone if there are surcharges on all trips; also the effect on VMT of parking surcharges solely on essential trips.

Figure 7. Effect on 1977 vehicle miles (kilometers) of travel of parking surcharges for essential trips only for 4 car-pooling-incentive policies.



Note: 1 mile = 1.6 km.

2. Reductions in VMT (vehicle kilometers of travel) as great as 20 percent can be obtained by combining preferential freeway treatment for car pools and buses with computer matching to encourage and simplify the formation of car pools.

3. Substantial reductions in VMT (vehicle kilometers of travel) can be achieved with increases in the pump price of gasoline. For example, with no bus-system improvements or additional car-pooling incentives, regional VMT (vehicle kilometers of travel) could be reduced by about 20 percent if gasoline were 85 cents/gallon (22.5 cents/liter).

4. An additional implication of increased gasoline prices is the resulting loss of personal mobility that is reflected in the number of trips forgone. Only improvements to the regional bus system can reduce the number of trips forgone because of increased gasoline prices.

5. The parking-surcharge tactic, if applied to essential trips only, is as effective as a distance surcharge in reducing VMT (vehicle kilometers of travel) [for VMT (vehicle-kilometer-of-travel) reductions that are less than 20 percent].

6. The maximum reduction in VMT (vehicle kilometers of travel) obtainable through transportation management tactics that concentrate on essential trips is about 30 percent. Larger VMT (vehicle-kilometer-of-travel) reductions can be obtained only by causing some of the inessential trips to switch to the transit mode or to be forgone.

We repeat that all of the effects of increased gasoline prices given in this paper are valid only in the short term, that is, only for several years after the increased prices occur. Some recent estimates of the long-term effects of increased gasoline prices are provided elsewhere (11), however.

We remind the reader that the results presented in this paper are specific to the Los Angeles region. The effectiveness of some of the tactics (particularly the car-pooling incentives) is undoubtedly related to the extensiveness of the Los Angeles freeway system. Thus, direct application of these results to other urban regions should not be attempted, although the policy-oriented urban transportation model with minor modifications could be used to generate corresponding results for other specific regions of interest. The principal requirement for transfer to another region is a rather complete forecast of the aggregate transportation system for the analysis year of interest (6, 8).

ACKNOWLEDGMENTS

We gratefully acknowledge the assistance of Frances Bolger Banarjee of the Southern California Association of Governments, who coordinated the SCAG Short-Range Program. We also are indebted to Rand Corporation colleagues James Bigelow, Robert Petruschell, and Thomas Kirkwood, who were instrumental in the development of the original transportation model, and Jean Gebman for his development of the companion air quality methodology. Gail Burkholz of the Rand Corporation provided her considerable skills in helping with the numerous computations required.

REFERENCES

1. B. F. Goeller et al. San Diego Clean Air Project. Rand Corp., R-1362-SD, Dec. 1973.
2. B. F. Goeller et al. Strategy Alternatives for Oxidant Control in the Los Angeles Air Quality Control Region. Rand Corp., R-1368-EPA, Dec. 1973.
3. W. T. Mikolowsky, J. R. Gebman, W. L. Stanley, and G. M. Burkholz. The Regional Impacts of Near-Term Transportation Alternatives: A Case Study of Los Angeles. Rand Corp., R-1524-SCAG, June 1974.
4. Environmental Protection Agency. Air Programs: Approval and Promulgation of Implementation Plans, California Transportation Control Plan. Federal Register, Vol. 38, No. 217, Nov. 12, 1973.

5. SCAG Short-Range Transportation Plan. Southern California Association of Governments, April 11, 1974.
6. J. H. Bigelow, B. F. Goeller, and R. L. Petruschell. A Policy-Oriented Urban Transportation Model: The San Diego Version. Rand Corp., R-1366-SD, Dec. 1973.
7. R. L. Petruschell and T. F. Kirkwood. A Generalized Bus System Cost Model. Rand Corp., R-1365-SD, Dec. 1973.
8. W. T. Mikolowsky et al. A Tradeoff Model for Selecting and Evaluating Regional Air Quality Control Strategies. Rand Corp., R-1367-SD, Dec. 1973.
9. Scenario Plan for 20 Percent VMT Reduction. Southern California Association of Governments, Dec. 1973.
10. SCAG Development Guide, Growth Forecast Selection. Southern California Association of Governments, Progress Rept. 74-1, Jan. 10, 1974.
11. S. Wildhorn, B. K. Burright, J. H. Enns, and T. F. Kirkwood. How to Save Gasoline: Public Policy Alternatives for the Automobile. Rand Corp., R-1560-NSF, Oct. 1974.