Environmental Protection Agency

Region IX

100 California Street
San Francisco, California 94111

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Technical Support Document

For The San Diego

Intrastate Air Quality Control Region

Transportation Control Plan Final Promulgation

Published In

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I. Introduction:

This document is in support of the EPA promulgated California Transportation Control Plan for the San Diego Air Quality Control Region (AQCR), signed on October 30, 1973 by Acting Administrator John Quarles, and published in the November 12, 1973 Federal Register.

The determination of the maximum amount of allowable emissions consistent with the attainment of the Environmental Protection Agency (EPA) promulgated National Ambient Air Quality Standards, and the emission reduction strategies needed to reduce emissions to the maximum allowable levels, are outlined and discussed in the following two sections. More detailed information on the control strategies and technical details involved in the plan are found in the Appendices.

II. Determination of Allowable Emissions to Meet Federal Ambient Air Quality Standards:

The National Ambient Air Quality Standard for photochemical oxidant has been exceeded in this AQCR. The photochemical oxidant control strategy discussed in this report involves the control of high reactive hydrocarbon and other reactive organic gases (RHC). Where possible, the RHC are defined by the most recent EPA guidance on organic gas reactivity. Using the EPA definition of RHC, only the following five hydrocarbons are considered as low or non reactive: Methane, ethane, propane, benzene and acetylene. The EPA definition of RHC was applied to all mobile exhaust emission sources, and to gasoline vapor emissions from stationary as well as mobile sources.

Due to the lack of a detailed breakdown of the organic emissions from stationary sources, the San Diego County Air Pollution Control District (APCD) Rule 66 chemical definition of reactivity was used for the remaining stationary sources. Application of the Rule 66 chemical definition of reactivity means that only those organic gases listed under Sections 1., 2., 3. of paragraph k of Rule 66 (e.g. toluene, aromatic compounds with eight or more carbon atoms, olefinic hydrocarbons), are inventoried as RHC and considered for control. It is expected that in the future, a more detailed stationary organic gas emission inventory will be available, which will allow for a completely consistent definition of RHC to be made for both mobile and stationary emission sources of organic gases. An observation that can be made is that the RHC definition inconsistency between the mobile and stationary source emissions in the present RHC inventory, results in the stationary source emissions (except stationary gasoline vapor emissions) being artificially low in relation to mobile source emissions.

The nitrogen dioxide ambient air quality standard has not been exceeded in the AQCR, and no violation is foreseen in the future. Therefore, a control strategy for this pollutant is not considered.

The carbon monoxide (CO) standard has been exceeded, with a high 8-hour reading of 18 parts per million (p.p.m.) occurring in 1972, versus the standard of 9 p.p.m. The control of RHC for meeting the photochemical oxidant standard is the controlling or critical factor however, and the strategies required to meet the oxidant standard should more than result in the attainment of the CO standard.

The photochemical oxidant 1-hour standard is .08 p.p.m. The critical yearly high photochemical oxidant reading of .32 p.p.m., occurred in this AQCR at Escondido in 1972. The stationary RHC emissions in 1972 are estimated to be 55.2 tons/day, and the mobile RHC emissions are estimated to be 152.4 tons/day.

As a result of recommendations received at EPA public hearings and technical meetings, EPA did a statistical analysis of ambient photochemical oxidant data. The statistical analysis entitled "Methodology For Determining The Base Year Oxidant Level," is found in Appendix B. The results of this study validate the use of the observed AQCR yearly high 1-hour 1972 oxidant reading of .32 p.p.m., for control strategy planning purposes.

The high 1-hour ambient photochemical oxidant reading is considered to be directly proportional to the amount of RHC emissions occurring on the high oxidant day. In other words, a straight line proportionality is assumed to exist between the RHC emission inventory and the resulting yearly high ambient photochemical oxidant reading. Straight line proportional rollback is then used to predict or calculate the maximum emissions that can be allowed for attainment of the standard.

Based on the Federal .08 p.p.m. maximum 1-hour oxidant standard, the 1972 high 1-hour oxidant reading of .32 p.p.m. and the 1972 RHC emission inventory, the allowable RHC emissions are determined as follows, using the proportional rollback method:

$$\frac{.08}{.32} \quad (55.2 + 152.4) = 51.9 \text{ tons RHC/day}$$

III. Control Strategy Outline:

The EPA proposed rules and regulations that are to affect the emission reductions outlined in this and the previous section, are identified in Section "I. Introduction", of this document. A compilation of the strategies and their affect on emission reductions is shown in the following table.

SUMMARY OF IMPACT OF TRANSPORTATION CONTROL REGULATIONS IN THE SAN DIEGO REGION IN 1977

Emission Source and Control Measures	Emissions and Reductions of Reactive Hydrocarbons (tons/day)
Stationary source emissions[1/] without EPA control strategy	20.6
Expected reductions	
1. Surface coating restrictions, Dry-cleaning and Degreasing controls	-15.8
Stationary emissions remaining	4.8
Mobile source emissions without[2/] EPA control strategy	86.4
Expected reductions	
1. Reductions from only EPA promulgated* control strategies, assuming a conservative 11% VMT reduction[3/]	-6.4
2. Catalyst retrofit, and mandatory inspection and maintenance	-12.9
3. Motorcycle limitations	-1.4
4. VMT reductions and evaporative emission reductions necessary from additional control strategies to be implemented in 1977.	-19.0

Mobile emissions remaining	46.7
Total emissions remaining	51.5
Allowable emissions for attainment of standard for photochemical oxidant	51.9

*VMT is an abbreviation for "Vehicle Miles Traveled."

1/ Stationary Source Emission Breakdown:

Power Plants	.7
Paint Solvents	13.4
Degreasing Solvents	1.9
Drycleaning Solvents	2.1
Petroleum Marketing	2.5
	20.6

2/ Mobile Source Emission Breakdown:

Ships & RR	.6
Aircraft	11.4
Motorcycle	5.8
Heavy Duty Vehicle (HDV) Diesel	3.2
HDV Gasoline	7.5
Light Duty Vehicle (LDV) Gasoline	57.9
	86.4

3/ Using optimistic assumptions for both EPA and local VMT reductions measures, a total reduction of 29% VMT or 16.9 tons/day could occur. A discussion of the basis or rationale for the VMT reductions, is found in Appendix C "California VMT Reductions Summary".

Technical reports, control tactics (including such details as the emission control reduction factors, the population fraction affected by the tactics), and other data and information needed to calculate the emission inventory in the preceding table, are outlined or referenced in the appendices.

APPENDIX A

Data and References Used In Emission Inventory Calculations

A. Stationary, Aircraft, Ship, and Railroad Emissions

1) Stationary and aircraft RHC emissions are basically derived from Rand Corp. -IREM interim draft reports, and discussions with the San Diego Co. APCD. The Rand analysis categorizes aircraft emissions under the stationary emission category.

Future or projected emissions, not considering proposed or additional controls, are estimated by applying the appropriate growth factors (see Section D.) to the 1970 or 1975 emissions in the following table.

RHC Emissions Per Rand - IREM Estimates Without EPA Proposals (Exceptions & revisions where noted):

Emission Category	1970 (tons/day)	1975 (tons/day)
Petroleum Handling	27.4*	32.1**
Solvent Users	23.7	16***
Aircraft	13.2*	10.6*****
Ships & Railroads	.5*****	.6******
Power Plants	.6	.7

*Considering EPA reactivity factor, see Section E.
**Considering EPA reactivity factor and EPA growth projections, see Sections D. and E.
***This includes a Rand-IREM estimate of 6.7 tons/day plus an additional EPA estimate of 9.3 tons/day from uncontrolled painting operations
****Emissions are estimated by EPA to increase from 1975-1977
*****An EPA estimate

B. Emission Factors

1) Light and heavy duty vehicle (LDV & HDV) gasoline, HDV diesel, and motorcycle emission factors (including deterioration factors where applicable), were obtained from the following document:

   Compilation of Air Pollutant Emission Factors (AP-42) 1973 Edition

   Available from:
   EPA Office Technical Information & Publications, Office of Air Programs, Research Triangle Park, NC 27711

   The emission deterioration factors in the EPA AP-42 publication are presented as a function of vehicle age. This analysis, however, relates the deterioration factors to accumulated mileage. The accumulated mileages that are associated with the vehicle ages in AP-42, are as follows:

AP-42 Vehicle Age	Vehicle Accumulated Mileage
1	17,500
2	33,600
3	46,800
4	58,200
5	69,900
6	79,900
7	90,200
8	98,800
9+	109,700+

   The emission factors presented in AP-42, are listed for various model years in terms of grams of pollutant emitted per mile traveled by the vehicle.

C. Vehicle Population, Age Distribution, and Mileage Data

1) Population data obtained from California Air Resources Board:

a) 1972:
Statewide gasoline LDV population - 11,331,900
Statewide gasoline HDV population - 296,300
Statewide diesel HDV population - 94,800
Statewide motorcycle population - 672,000

San Diego AQCR % of statewide population is 6.08%

b) 1977:
San Diego AQCR % of statewide population is 6.52%. (This factor is used only for projecting the AQCR 1977 motorcycle population, see Section D.2.)

2) Vehicle Age Distribution

a) 1972 (July)

Average Vehicle Age* (Yr)	LDV Percent** of Population	Gasoline and Diesel** HDV Percent of Pop.
3/8	7.8	7.6
1 1/4	9.3	8.0
2 1/4	9.0	8.2
3 1/4	9.8	8.6
4 1/4	8.6	6.9
5 1/4	7.4	5.7
6 1/4	7.9	6.4
7 1/4	8.2	6.9
8 1/4	7.0	6.2
9 1/4	5.7	5.3
10 1/4	4.5	4.3
11 1/4	2.9	3.1

12 1/4	2.6	3.3
13 1/4	1.9	2.9
14 1/4	1.1	1.8
15 1/4	1.3	2.2
15 1/4+	5.0	12.8

*The 3/8 year old vehicles are 1972 models, the 1 1/4 year old vehicles are 1971 models, etc.

**Based on State of California Air Resources Board and Dept. of Motor Vehicle data

b) Post 1972 (July)

Average Vehicle Age* (yr)	LDV** % of population	HDV** % of Population
3/8	7.9	7.2
1 1/4	9.9	8.9
2 1/4	9.5	8.0
3 1/4	9.2	7.5
4 1/4	8.9	7.1
5 1/4	8.5	6.9
6 1/4	8.2	6.8
7 1/4	7.8	6.6
8 1/4	6.7	5.9
9 1/4	5.4	4.9
10 1/4	4.2	4.0
11 1/4	2.9	3.4
12 1/4	2.2	3.0
13 1/4	1.7	2.7
14 1/4	1.5	2.5
15 1/4	1.4	2.4
15 1/4+	4.4	12.5

*The 3/8 year old vehicles are the current year models in the base year or strategy year, the 1 1/4 year old vehicles are prior year models, etc.

**Based on State of California Air Resources Board and Dept. of Motor Vehicle data.

3) Vehicle VMT/yr rate as of July:

Average Vehicle Age	LDV* VMT/yr	Gasoline HDV** VMT/yr	Diesel HDV** VMT/yr
3/8	20,000***	28,000***	128,000***
1 1/4	16,300****	21,100****	96,000****
2 1/4	13,500	17,950	81,600
3 1/4	10,500	17,950	81,600
4 1/4	9,700	13,960	63,600
5 1/4	8,200	13,960	63,600
6 1/4	7,200	11,000	50,200
7 1/4	6,770	11,000	50,200
8 1/4	6,350	8,420	38,400
9 1/4	5,920	8,420	38,400
10 1/4	5,490	4,270	19,440
11 1/4	5,070	4,270	19,440
12 1/4	4,640	4,270	19,440
13 1/4	4,640	4,270	19,440
14 1/4	4,640	4,270	19,440
15 1/4	4,640	4,270	19,440
15 1/4+	4,640	4,270	19,440

Motorcyle VMT/yr***** = 4000

*Based primarily on California State vehicle age vs. mileage study

**Based on U. S. Dept. of Commerce study "U. S. Truck and Inventory Study - 1967"

***The accumulated mileage of a 3/8 yr. old vehicle is determined by multiplying this number by 3/8

****The accumulated mileage of a 1 1/4 yr. old vehicle is determined by multiplying this number by 1 1/4

*****Per EPA 1973 Edition of "Compilation of Air Pollution Emission Factors: (AP-42)

The accumulated mileage for vehicles older than 1/4 years, is determined by adding the accumulated mileage of a 1 1/4 year old vehicle (see **** above) to the VMT/yr values found in the previous table, for each vehicle age after 1 1/4, up to and including the vehicle age of interest. This is illustrated by the following example.

Calculate accumulated mileage for 4 1/4 year old LDV:

mileage = 16,300 x 1 1/4 + 13,500 + 10,500 + 9.700 = 54,100

The accumulated mileage is used for determing vehicle emission deterioration factors (See Section B).

D. Growth Projections

1) EPA Stationary and mobile source growth projections, except motorcycles, are as follows for the San Diego AQCR:

1970-72 growth factor = 1.070
1970-75 growth factor = 1.171
1970-77 growth factor = 1.242
1972-77 growth factor = 1.172
1975-77 growth factor = 1.071

The above factors are California Air Implementation Plan growth projections and EPA interpolation of these data, based on a California Dept. of Finance Population Research Unit Report "Provisional Projections of California Counties To 2000" dated September 15, 1971.

2) Motorcycle growth projections for the entire state:

Growth factors are determined using the ratio of estimated statewide motorcycle population projections in the California Dept. of Motor Vehicle Report No. 31 March 1970. The motorcycle growth rate factors derived from Report No. 31 are as follows:

1970-75 growth factor = 1.46
1970-80 growth factor = 1.91

E. Hydrocarbon Reactivity Factors

Per recent EPA guidelines, the following factors indicate the weight fraction of total hydrocarbon emissions that are considered to be reactive (i.e., do not contain unreactive hydrocarbons, which are methane, ethane, propane, benzene, acetylene):

Emission Source	Weight Fraction of RHC
Gasoline LDV exhaust	.77
Gasoline LDV exhuast after/catalyst treatment*	.64
Gasoline HDV exhaust	.79
Diesel HDV exhaust	.99
2 stroke motorcycle exhaust	.96
4 stroke motorcycle exhaust	.86
Piston & turbine aircraft exhaust	.90
Gasoline vapor	.93

Crankcase emissions are estimated to consist of equal amounts of uncombusted gasoline vapor and combustion exhaust.

A Rule 66 chemical definition of reactivity is used for the remaining emission sources.

*This factor is to be applied to the exhaust of emissions of all 1975 and later LDV models, and to those Pre 1975 LDV models that are to have retrofit catalyst devices installed.

F. Strategy Application & Reduction Factors

1) State and local programs in effect or committed:

Program	Population Base (Vehicle Model Yrs. or Sources) Affected	Pop. Affected in 72	% Pop. Affected in 77	RHC Red Factor
NO_x retrofit control	1955-65 LDV Exhaust	0%	67%	.25
NO_x retrofit control	1966-70 LDV Exhaust	0%	100% approx.	.12
Crankcase (PCV) retrofit control	1955-62 LDV Crankcase	93%	100% approx.	1.00
Petrol. Marketing Controls	Petroleum Marketing	0%	100%	.87

2) EPA programs:

Program	Population Base (Vehicle Model Yrs. or Sources) Affected	Pop. Affected in 72	% Pop. Affected in 77	RHC Red Factor
Annual Insp. & maintenance	All LDV Exhaust	0%	100%	.15
Oxidizing Catalyst Retrofit	1971-74 LDV Exhaust	0%	75%	.58*
Oxidizing Catalyst Retrofit	1966-70 LDV Exhaust	0%	20%	.58*
Dry Cleaning Solvent Control	All RHC Dry Clean Sources	0%	100%	.95
New Motorcycle Emission standards, 1976 and later models	All Motorcycle Emissions	0%	100%**	.25
Degreasing Solvent Control	All RHC Solvent Sources	0%	100%	.98

Program	Population Base (Vehicle Model Yrs. or Sources) Affected	% Pop. Affected in 72	% Pop. Affected in 77	RHC Red. Factor
Metal Surface Coating Control	All Sources Metal Coating	0%	100%	.90
Parking surcharge and review, car pool matching, bus and car pool priority treatment, and employees mass transit incentives***	All gasoline LDV and petroleum marketing emissions	0%	100%	.11
Gasoline rationing	All gasoline LDV and petroleum marketing emissions	0%	100%	.42

*This factor accounts for a total hydrocarbon reduction factor of .5 and a lowering of the exhaust reactivity factor from .77 to .64 (See Section E).

**While only new 1976 and later model years are affected, the entire population is included here because the reduction factors are derived on the basis of the total population.

***See Appendix "C" "California VMT Reductions Summary" for a discussion of these and other VMT reduction measures.

The June 8, 1973 Federal Register discusses various mobile source control programs or tactics, and outlines the reduction factors associated with the tactics.

APPENDIX B

Methodology for Determining the Base Year Oxidant Level

INTRODUCTION

This paper discusses a method for selecting the maximum values used in the calculation of emission reduction requirements.

The methodology described in this paper is neither new nor original. Dr. R. I. Larsen, Meteorology Laboratory, NERC, Research Triangle Park, outlined such a technique in 1967 and has published numerous papers since that time explaining the use of his model in the establishment of standards and in relating air quality measurements to such standards (Reference 1, 2, and 3).

The rationale for selecting this method is outlined and some of the advantages and shortcomings are covered. A comparison of actual measured values with model calculations is provided.

BACKGROUND

The development of a control strategy to achieve a National Ambient Air Quality Standard is frequently based on the premise that the concentration of a man-made pollutant in the ambient air is linearly related to the rate at which the pollutant is emitted in the atmosphere.

This assumption permits the use of a simple proportional (or rollback) model to determine emission reduction requirements. Such a model states that:

$$(100)\ \frac{(\text{current air quality}) - (\text{air quality standard})}{(\text{current air quality}) - (\text{background})} = \text{required reduction in percent}$$

Current air quality is defined as the maximum measured concentration.

The development of the transportation control strategies did not rely totally upon the rollback model. A non-linear relationship between oxidant levels and hydrocarbon emissions developed by Schuck (See Appendix B) was also employed. In some areas data was not available for the verification of such a non-linear model and the simple proportional relationship had to be applied.

Regardless of which of these models was used, the selection of an appropriate maximum concentration was a critical factor in determining the emission reduction requirements.

There are several methods that can be used to determine the maximum value needed for these"roll-back" calculations. Among such methods are:

a. Diffusion modeling

b. Selection of a maximum value from a base year

c. Choosing the highest value over a number of years

d. Determining a maximum value by statistical analysis

Diffusion modeling, where validated models can be applied, probably represents the best method for determining both the concentration and the location of high pollutant levels. Unfortunately, a model with the required accuracy is not yet available for determining specific oxidant concentrations.

The selection of a value from a base year, where the year is usually selected as the year of the latest emission inventory, has the advantage of being most closely related to the emission data. It also provides a convenient base for comparing data at different locations. However, high concentrations of oxidant occur under certain, as yet not fully quantified, meteorological conditions and different sets of these conditions may apply to the production of high levels at different locations. Since meteorological parameters do not necessarily follow an annual cycle, the adverse conditions producing high levels may not always occur every year at any given location. The data indicate that maximum levels at a particular monitoring station may vary from year to year by as much as a factor of two. High values within a given region do not always occur at the same site and maximum concentrations selected from all stations within a region may also vary considerably, although not usually by as much as they do at a single location.

Extreme values can occur either because of unusual meteorological conditions or because some abnormal periods would not necessarily be expected to occur every year but perhaps only once in 5 or 10 years. Thus, the selection of such an extreme value could require overly stringent control measures. Conversely, abnormally low values could also be selected if the data record is short.

A statistical analysis of data collected over a period of years tends to smooth out the variations due to the meteorology and to local anomolies. Such an analysis can also provide a prediction with a specified probability of occurrence and the extreme or outlying values can be weighed.

This paper compares the results obtained by applying a particular statistical method to the calculation of maximum oxidant levels with the actual measured maximum concentrations at selected stations from data collected over the past three years.

THE ANALYSIS

Selection of Technique:

The objective of the analysis was to find an oxidant level (concentration) that represented the highest level expected to be achieved with a frequency of one hour per year. The rationale for this objective is the National Ambient Air Quality Standards for oxidant: 160 ug/m3 (0.08 ppm) - maximum 1 hour concentration not to be exceeded more than once per year.

Although there are a number of statistical methods that could be applied, a technique described in the Office of Air Programs publication No. AP-89, "A Mathematical Model for Relating Air Quality Measurements to Air Quality Standards" by R. I. Larsen, November, 1971, seemed to best fit the objective. This model is based on the assumption that the air quality data fit a log-normal distribution. There is some disagreement about whether or not this is an appropriate assumption. For example, Mitchiner & Brewer (5) have suggested the use of a 'double-exponential' distribution. This is a widely known extreme value technique. Their analysis, however, was limited to data collected in three summer months and used only the maximum daily hour data. A report by Mosher, Fisher, and Brunelle (6) indicates peak oxidant concentrations of 0.50 ppm or greater have occurred in Los Angeles County in all months of the year except January and February. The selection of only certain months could, therefore, tend to bias the results. Additionally, extreme value techniques seem most applicable to the selection of an absolute maximum concentration and not necessarily to the concentration expected to occur once per year. However, a comparison of the values calculated by the Mitchiner-Brewer method indicate that they do not differ greatly from Larsen's method, at least at the one station covered in their analysis, even though a different data set was used.

Larsen (7) analyzed all oxidant data for all California stations for the period 1963-1967 and presented the cumulative frequency distributions and a calculated maximum concentration for each station. The tables in that publication were used in conjunction with later available measured data to determine the location (or areas) of the highest concentrations. Stations within those areas were then selected for further analysis. An attempt was made to obtain a three-year period of record for each station. It was felt that the period should be comparable to the latest emission inventory data available (in most cases this was 1970 data) and also should contain a sufficiently long period to help overcome the problem of meteorological variability. A period of 5 to 10 years would have been desirable, but because of the changing patterns of emissions and changing vehicular emission factors, it was felt that a period longer than three years would tend to introduce more emission variability than the meteorological variability that would be factored out. Data for 1972 were not available so the period January, 1969, through December, 1971, was selected. Unfortunately, there were many gaps in the record and data was not available for some of the desired stations.

Fourteen stations were finally selected for analysis and cummulative frequency distributions for the selected stations for the three-year period were then obtained. The data were analyzed according to Larsen (4). A sample of the frequency distribution used is shown in Figure 1.

CALCULATION OF MAXIMUM CONCENTRATIONS

The frequency distribution as given in Figure 1 is plotted on a logarithmic probability graph as indicated in Figure 2. If the data were perfectly log-normally distributed, all points on the graph would be on a straight line. As can be seen in Figure 2, this is not the case. However, the points in the frequency ranges from 10% to .01% do appear to closely approximate a straight line. Since these are the frequencies of most concern when considering very high values, only those points are considered. To find the value that would be expected once a year, Larsen (4) suggested using the .01 and the .10 frequency points and extrapolating the line connecting these points to the desired once per year frequency point. This was done for each location for which frequency distributions were available. The extrapolation can be done either graphically or mathematically. The mathematical method is as follows:

The desired frequency using this log-normal distribution is obtained from

$$f = \frac{r-0.4}{n} \quad (100\%)$$

where: r = the rank of the desired concentration if all the concentrations were ordered from one through the number of possible samples within a selected time period

f = the frequency of occurrence in percent

n = total number of samples

FOR EXAMPLE: To find the frequency corresponding to the highest one-hour average in a year, all of the 8760 one-hour averages in a year would be listed in order from 1 (the highest) to 8760 (the lowest). The rank order, r, then is equal to 1, n, or the total number of samples, is 8760, and

$$f = \frac{1-0.4}{8760} \quad (100\%) \quad = \quad 0.00685\%$$

Next, the extrapolation of the data to this desired frequency, using the two known concentration vs. frequency points, is as follows:

The equation of a straight line passing through two known points x_1y_1 and x_2y_2 is:

$$\frac{y - y_1}{y_2 - y_1} = \frac{x - x_1}{x_2 - x_1}$$

this can be rearranged so that

$$y = y_1 + \frac{y_2 - y_1}{x_2 - x_1} (x-x_1)$$

In this case the x and y without subscripts are the intercepts of the unknown point on this line.

Where we are using the log-normal distribution, the y intercepts are logarithms and the x intercepts are in terms of standard deviations from the median. In a normal distribution each frequency can be located as a distance (standard deviations) from the center of the profile (median).

If the y intercepts are logarithms, then the equation for the straight line becomes:

$$\ln y = \ln y_1 + \frac{\ln \frac{y_2}{y_1}}{(x_2 - x_1)} (x - x_1)$$

The concentration at an unknown point 'x,y' is then equal to the anti-logarithm of

$$\left(\ln y_1 + \frac{\ln \frac{y_2}{y_1}}{(x_2 - x_1)} (x - x_1)\right)$$

or to put it in another form:

$$\text{concentration at } y = \exp\left[\ln y_2 + \frac{\ln \frac{y_2}{y_1}}{(x_2 - x_1)} (x - x_1)\right]$$

where 'exp' indicates that 'e', the base of natural logarithms, is raised to the power in the brackets. 'e' is approximately equal to 2.71828.

Following Larsen's suggestion (8), the two known points at the .01 and the .10 percentile levels are used to define the straight line we wish to extend. From a statistical table, such as is given in Reference 3 on Page 30, the x intercepts at these percentile points can be determined. In the case of a log-normal profile, the .01 percentile point is 3.72 standard deviations from the median; the .10 percentile point is 3.09 standard deviations; and the unknown point at .00685% is 3.81 standard deviations from the median. The y intercepts are the concentrations at each of these percentile points. These x and y values are then substituted into the above straight line equation and the unknown concentration at the .00685% frequency is determined.

To illustrate the procedure, the data from Figure 1 have been replotted on Figure 3, and the points that are used below have been labeled.

frequency f(%)	concentration y(ppm)		standard deviations x	
.00685	to be determined	(y)	3.81	(x)
.01	.27	(y_1)	3.72	(x_1)
.10	.23	(y_2)	3.09	(x_2)

Substituting these values into the straight line equation:

$$\text{concentration at } y = \exp\left[\ \ln .27 + \frac{\ln\left(\frac{.23}{.27}\right)}{(3.09-3.72)}\ (3.81-3.72)\ \right]$$

$$= \exp\left[\ -1.30933 + \frac{(-0.16034)}{(-0.63)}\ (0.09)\ \right]$$

$$= \exp\left[\ -1.286424\right]$$

concentration at y = 0.28 ppm

From the example, a concentration of 0.28 ppm would then be the highest concentration expected to be reached (or exceeded) once each year.

These maximum concentrations were calculated for each of the selected stations within each Air Quality Control Region. The results are listed in Table 1.

TABLE I. Hourly average concentrations for selected frequencies of occurence.

LOCATION	Percent of time given concentration equaled or exceeded		
	0.10%	0.01%	0.00685%(Annual Maximum)
South Coast AQCR			
Riverside	0.34	0.56	0.60
Azusa	0.42	0.51	0.52
Pasadena	0.39	0.51	0.53
San Diego AQCR			
San Diego (8th & E)	0.16	0.23	0.24
El Cajon	0.27	0.30	0.30
Sacramento Valley AQCR			
Creekside	0.18	0.24	0.25
Chico	0.14	0.15	0.15
San Joaquin Valley AQCR			
Fresno (So. Cedar)	0.20	0.25	0.26
San Francisco Bay AQCR			
Livermore	0.24	0.32	0.33
San Leandro	0.19	0.27	0.28
Fremont	0.22	0.27	0.28

Data used in this Table were hourly averages for the period of January, 1969, to December, 1971.

It should be noted that these calculated concentrations are not necessarily the highest values to be expected. It is quite possible that this value could be nearly twice as high on an unusually "smoggy" day. Based on this analysis, however, such very "smoggy" days would not normally occur every year.

COMPARISON WITH MEASURED MAXIMA

The calculated maximum values were compared with the actual maximum values that have been reported within each of the Air Quality Control Regions since 1969. These values are shown in Table 2. In all cases the calculated maximum concentration is within .03 ppm of the actual measured maximum, even though an additional year of measured data was considered and the high value for the region may have been reported at a station other than one included in the calculations.

TABLE 2. Comparison of measured and calculated highest hour average oxidant concentrations calculated.

AQCR	Calculated Maximum	Station	Measured Maximum	Station	Year
South Coast	.60	Riverside	.62	Riverside	1970
San Joaquin	.26	Fresno	.24	Modesto	1972
San Diego	.30	El Cajon	.32	Escondido	1972
S.F. Bay Area	.33	Livermore	.36	San Leandro	1971
Sacramento	.25	Creekside	.28	Creekside	1972

The number of occurrences of concentrations in excess of the calculated maximum within each Air Quality Control Region was also tabulated. For comparison, the daily maximum hourly averages from 1969-1972 were used. The calculated maximum was equaled or exceeded three times in the San Francisco Bay Area, once in 1969 and at two separate locations on the same day in 1971. In the South Coast Basin the calculated concentration was exceeded once. In the San Diego Area twice, once each in 1971 and in 1972 in Sacramento once and once in the San Joaquin Air Quality Control Region.

Again, it should be noted that the calculated value represents a level that is expected to be reached or exceeded once per year and that the analysis does not attempt to predict the highest possible concentration. Thus, the occurrence of a concentration greater than the predicted value tends to verify the procedure if no other concentration measured during the year was equal to or greater than the calculated maximum.

EVALUATION OF METHOD

The fact that the calculated values are close to the actual measured concentrations and that the values have been reached or exceeded only once in a given year, would tend to indicate that reliability of Larsen's technique. There are, however, some obvious shortcomings to the analysis presented here. A full three-year period of record was not available from all of the air monitoring stations within each basin, nor from each of the stations listed in Table 1. The shorter the period of record that is available, the less reliable are the calculated values. To improve the reliability, additional data should be analyzed and a larger sample from each Air Quality Control Region should be selected.

Also, it was assumed that the stations selected represented the highest concentrations within the given Air Quality Control Region. This is not necessarily a valid assumption. Although only limited data is available, newly established monitoring sites appear to be recording higher values than some of the listed stations. For example, data from Escondido was used to develop the strategy in the San Diego Air Quality Control Region. The station was established in mid-1972 and the .32 ppm oxidant measured there represents the highest concentration within the San Diego metropolitan area in recent years. Agencies are usually continually expanding their networks to include new areas of high concentrations, and additional analyses should be performed as new data become available.

The calculations were based on the data measured during the years 1969-1971. They reflect only the emissions during that period of time. Assuming no changes in emission patterns or emission controls at the source, these values could be used to predict future air quality. However, none of the areas considered are static with respect to growth, or to the numbers and ages of motor vehicles in operation, or even with respect to the numbers of and outputs from stationary sources. Some care should be exercised in attempting to relate the concentrations to emissions in areas of rapid growth.

The oxidant data do not exactly fit a long-normal distribution and the degree of fit varies at different locations. Thus, use of this method may result in more reliable results in some areas than in others. Also, the calculated maximum is quite sensitive to the selection of the percentile points used in the calculations especially where the log-normal fit is poor. Larsen (4) has suggested the use of the concentrations at the .01 and .1 percent frequencies as being most representative of the distribution of the higher concentrations. In some instances it appears that the point at the .01 percentile fits the overall log-normal distribution least well. The problem is particularly evident when a short period of record is used. In most of the data examined, use of the .1 and the 1 or the 10 percentile points would result in higher maximum levels than when the .01 percentile is included. This would indicate that for some reason, probably meteorological, the maximum possible values are not achieved. In other cases the .01 percentile value seems too high. A study of the individual days could perhaps provide an answer to the reasons why some of the high values seem out of line.

The calculation of the maximum value is quite simple, but it does require the preparation of cumulative frequency distributions. These distributions are best processed by computer because of the large amounts of data required. Once they are available, several other analyses can be performed (see Larsen, 3). Additionally, a comparison of the different yearly and three-year distributions suggests a possible method for trend analysis.

SUMMARY

Air quality data for a number of California air monitoring stations were reviewed and analyzed according to a method suggested by Larsen. The objective of the analysis was to determine a maximum oxidant concentration for certain Air Quality Control Regions that could be related to the available emission data and used to determine the emission reductions needed to achieve the National Ambient Air Quality Standards.

Because of the variability of concentrations from year to year, at least a three-year period of record would appear to be required for analysis. This limits the selection of maximum concentrations to these stations where data have been collected over that long a period and could eliminate areas where higher concentrations are possible.

Although values obtained in this analysis compare favorably with measured conentrations, other statistical approaches may provide equally meaningful solutions and should be compared with this method. The method outlined in this paper, however, is relatively simple and well documented and is applicable to all pollutants. The use of some statistical approach is certainly less arbitrary than the selection of one particular measured concentration.

ACKNOWLEDGEMENTS

The author is indebted to Dr. R. I. Larsen of the Meteorology Laboratory for his assistance and Mr. Don Worley of the Data Systems Division for providing the necessary frequency distributions.

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Figure 1

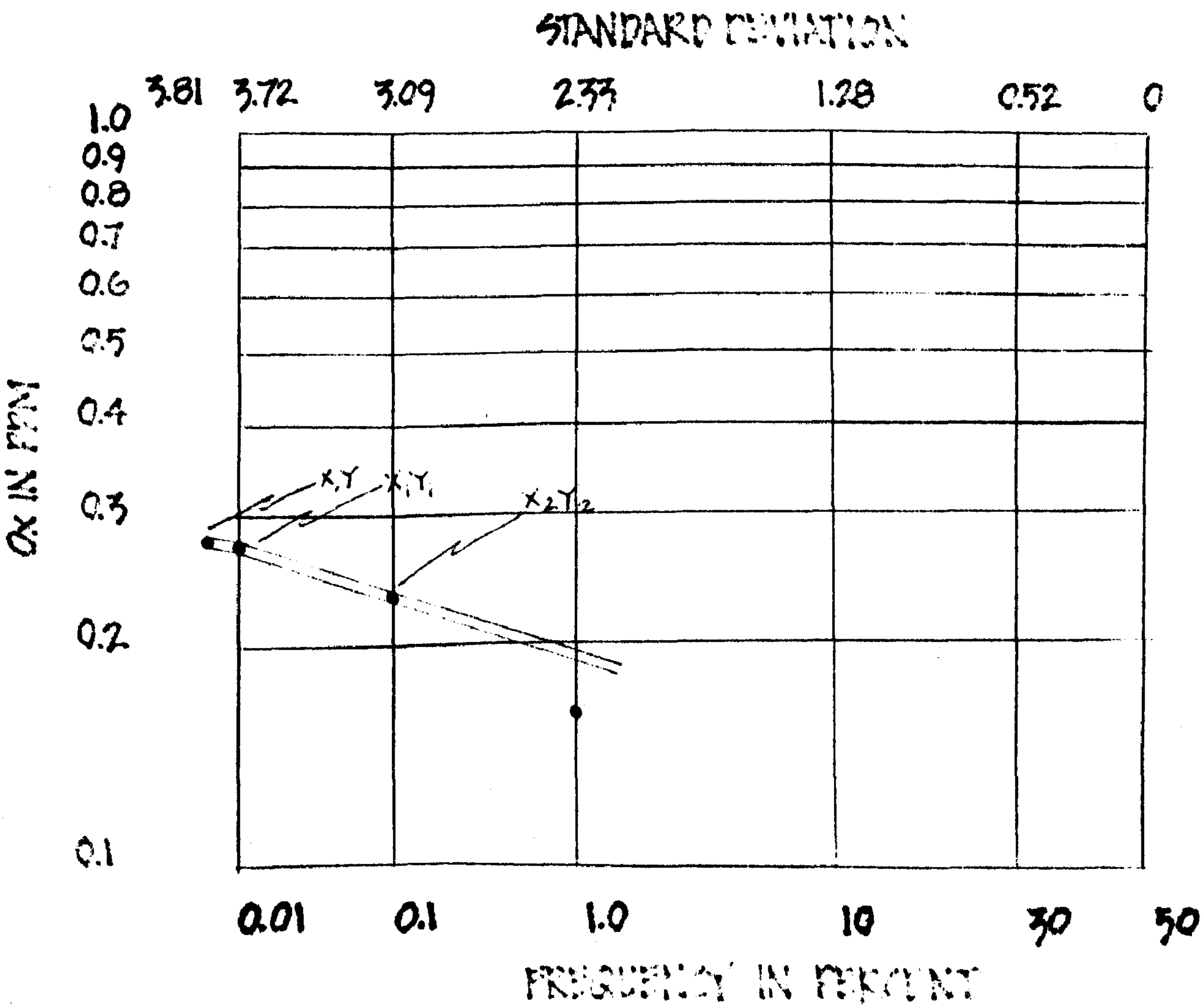
CONCENTRATION VS AVERAGING TIME AND FREQUENCY FOR

OXIDANT (PPM): LOS ANGELES, S. SAN PEDRO ST. STATION 001

JANUARY 1, 1968 TO DEC. 31, 1971

PERCENT OF TIME CONCENTRATION IS EQUALED OR EXCEEDED

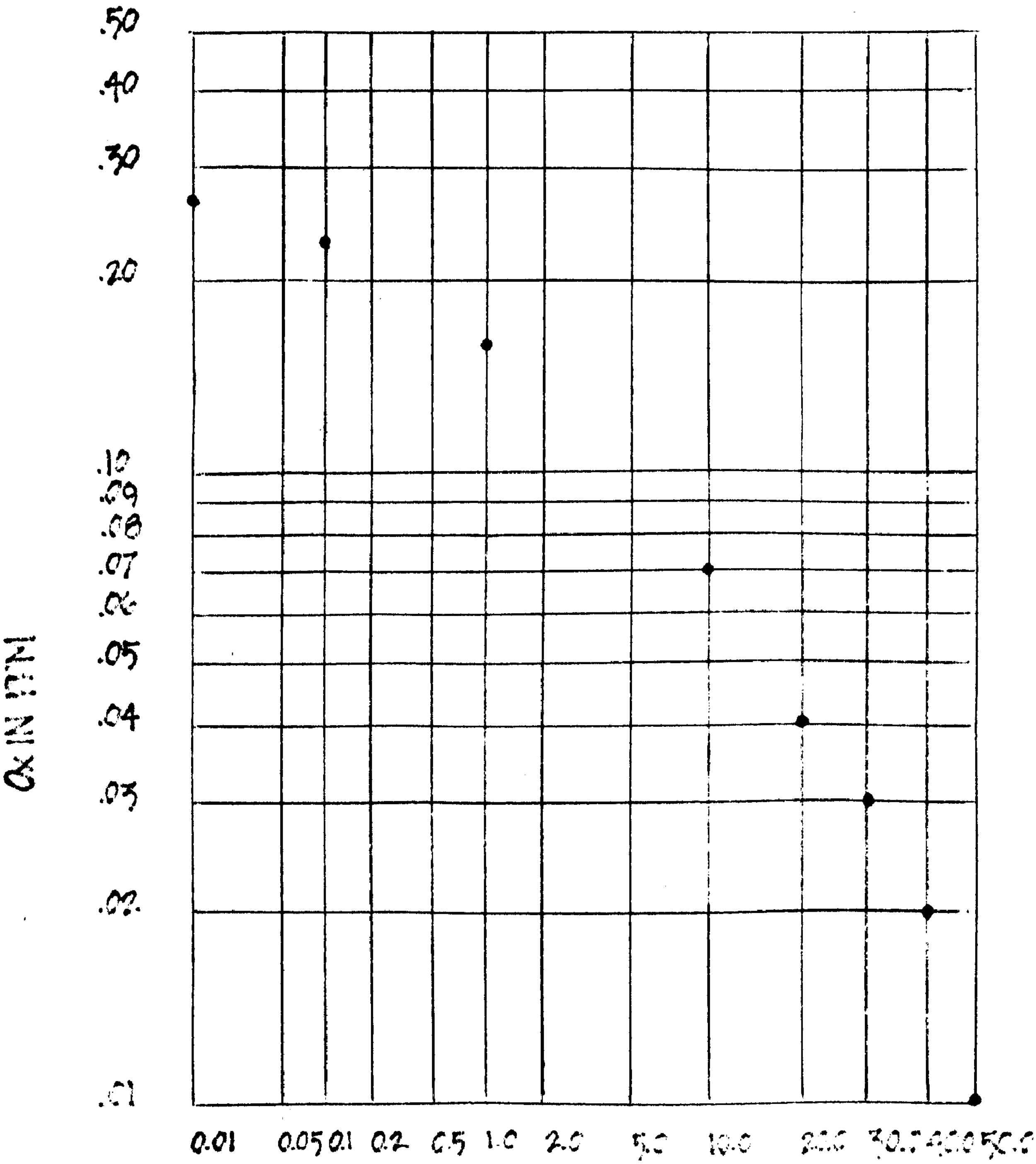
AVERAGING TIME	MEAN	MAX	MIN	PERCENT	0.001	0.01	0.1	1	10	20	30	40	50	60	70	80	90	99	99.9	99.99	99.999	99.999
5 MIN	000.	000.	000.	000.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	000.	000.	000.	000.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	000.	000.	000.	000.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	000.	000.	000.	000.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 HOUR	0.03	0.33	0.01	069.	0.33	0.27	0.23	0.16	0.07	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3	0.03	0.27	0.01	072.	0.27	0.27	0.21	0.15	0.07	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3 6-9 AM	0.01	0.05	0.01	073.	0.05	0.05	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
8	0.03	0.21	0.01	073.	0.21	0.21	0.18	0.13	0.07	0.04	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
12	0.03	0.12	0.01	073.	0.12	0.12	0.10	0.08	0.05	0.04	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
1 DAY	0.03	0.10	0.01	074.	0.10	0.10	0.09	0.07	0.05	0.04	0.04	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2	0.03	0.09	0.01	074.	0.09	0.09	0.09	0.07	0.05	0.04	0.04	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
4	0.03	0.07	0.01	075.	0.07	0.07	0.07	0.06	0.05	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
7	0.03	0.06	0.01	075.	0.06	0.06	0.06	0.06	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
14	0.03	0.06	0.01	075.	0.06	0.06	0.06	0.06	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
1 MONTH	0.03	0.05	0.01	075.	0.05	0.05	0.05	0.05	0.04	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
2	0.03	0.05	0.01	075.	0.05	0.05	0.05	0.05	0.04	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
3	0.03	0.04	0.02	075.	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
6	0.03	0.03	0.02	075.	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
1 YEAR	0.03	0.03	0.02	075.	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
2	0.03	0.03	0.03	050.	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
3	0.03	0.03	0.03	100.	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
6	000.	000.	000.	000.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00



MAXIMUM OXIDANT CONCENTRATIONS

EXAMPLE CALCULATION

FIGURE 3



CUMULATIVE FREQUENCY DISTRIBUTION PLOT

DOWNTOWN LOS ANGELES 1969-71

FIGURE 2

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION IX

Appendix C

CALIFORNIA VMT REDUCTION SUMMARY:

Presentation of Analytic Basis for VMT Reduction Estimates

SUMMARY

Purpose

It is the purpose of this paper to summarize recent studies relating various transportation control measures such as car pooling, bus lanes, gasoline sales limitations, etc., to VMT reductions. In particular, the paper includes those measures proposed for California Transportation Control Plan (TCP).

Concentrating on the measures proposed by EPA and local AQCR task forces, the paper shows the range of VMT reductions that can be expected from the TCP measures individually and combined in a complementary strategy for each AQCR. Determinations of the effective range of VMT reductions achieveable are based on application of various transportation modal split models developed for the purpose of predicting commuter transportation patterns.

Most of the effects of measures promulgated by EPA are predictable within a range of certainty. Results of pilot studies and public reaction attitude surveys have been used as inputs to the data base. Measures that can not be assessed quantitively at this time or that have delayed effects and are unable to effect air quality fast enough for the Clean Air Act standards are not included in EPA promulgation. However, many of these measures have future short and long-term potential. EPA encourages local proposal and implementation of these measures.

Although the socio-economic impact of VMT reduction measures is important, the scope of this analysis is limited to the technical effects. Many of the studies done for EPA have addressed the socio-economic questions.

I. INTRODUCTION

THE ROLE OF VMT MEASURES

In the majority of air quality control regions requiring additional controls, the combined impact of stricter controls on stationary sources and the establishment of an inspection and maintenance system will not provide emission reductions adequate to achieve the air quality standards by 1975. Consequently, EPA has promulgated a variety of measures to reduce vehicle miles traveled in these regions. In several urban areas a shift from present reliance on automobiles occupied by one or two persons to a greater reliance on other forms of transit is essential to the achievement of the air quality standards. Significant reductions in vehicle miles traveled can also be accomplished within a limited time span.

The States have had practically no experience with transportation control measures as a means of dealing with air quality problems and the success of particular VMT reduction measures is difficult to predict. However, recent developments involving bus lanes, mass transit improvements, carpool programs, bikeways, and other innovations indicate that many VMT reduction measures are available and feasible. Furthermore, attitude surveys show that the public in many of our urban areas recognizes the need to place less emphasis on the automobile for urban mobility and is already encouraging the implementation of steps to develop alternative forms of transit.

Some of the regulations being promulgated will have significant effects on the future development of urban transportation in the major cities of this country. A clear implication of these air plans is that future augmentation of mass transit must focus not only on the center city streets but also on urban/suburban routes. It is expected that the regulations will lead not only to substantial reductions in air pollution, noise, congestion, and energy comsumption, but to the development of more mass/rapid transit to serve the growing urban and suburban regions of the nation. The need, desirability, and feasibility of reducing urban auto use are no longer issues. The problem is determining the degree to which VMT reductions can be reasonably implemented within the limited time frames.

The amount of VMT reduction that can be considered "reasonably available" varies greatly according to a city's individual characteristics and the ability of other modes of transportation to absorb the demand that would be created by a significant VMT reduction. A measure cannot be considered "reasonably available" if putting it into effect would cause severe economic and social disruption. Although some reduction in personal travel could certainly be absorbed without disruption, to achieve a significant VMT reduction, the bulk of the travel displaced from single-passenger automobiles must be absorbed by such other modes of transportation as carpools, walking, bicycling, or public transit.

The significant expansion of public transit facilities that can be accomplished by 1975 depends on the upgrading and expansion of bus service. Much can be done in this regard. Scheduling and service can be improved. Individual lanes of freeways and other major roads can be set aside for the exclusive use of buses. Significant numbers of new buses can be purchasds and put into service by 1975; according to the Department of Transportation figures, 2,500 transit buses were sold in this country in 1972, but there is considerable potential for expansion of the transit industry's production by two or three-fold. Foreign sources of supply could provide additional resources.

The Environmental Protection Agency is working with the Department of Transportation to assure increased Federal support for short-term augmentation of mass transit capacity and appropriate modifications of highway facilities to permit increased utilization of mass transit.

In addition to public transit, part of the transportation demand created by VMT reductions can be absorbed by carpools. Private automobiles, which are designed to carry four to six persons, carry an average of 1.1 to 1.4 persons per trip for work trips in major urban areas, and thus represent the largest unused pool of transportation capacity presently available.

The measures mentioned above are primarily concerned with providing an alternative to low-occupancy use of private automobiles. Although measures such as buying more buses and improving bus service, providing for carpool programs, building bicycle paths, and (possibly in the long run) building new rapid transit systems increase the availability and attractiveness of alternative transit forms, VMT reductions will not necessarily be achieved unless disincentive restrictions are placed on the use of automobiles.

The applicability of both measures--incentives such as bus lanes that increase the attractiveness of alternative transit forms and disincentives such as parking limitations that discourage the low-occupancy use of private automobiles--varies according the the conditions in the individual urban area. For example, bus lanes are a more appropriate strategy in Washington, D.C. than certain other areas. Similarly, parking restrictions are more applicable to a major center like Boston than to a small city with few transit alternatives like Fairbanks, Alaska.

After consideration of the already available transit alternatives, the city's local conditions, and the applicability of various incentive and disincentive measures, the

EPA has determined that varying degrees of VMT reduction are feasible in particular areas. The Agency believes a 3 to 10 percent VMT reduction can be achieved in some of the regions by 1975. Since the Clean Air Act specified that all reasonable available measures be instituted before any time extension is granted, the Administrator is taking into consideration all VMT-related measures presently being implemented by a municipality and augmenting those measures with methods that are available, applicable, and adoptable in the individual area by 1975.

Through studies and the public hearing process, the Agency has also determined that it may be unrealistic to expect reductions in auto use greater than 10 to 20 percent by 1977. Generally, reductions beyond 10 to 20 percent would require a special and, in most cases, unreasonable effort unless driving is to be cut without a corresponding increase in mass transit. Achievement of even the levels provided for in these plans will require a strong commitment by local areas to implement strict disincentive programs, improve mass transit, and make carpooling or other programs work.

EPA has promulgated a number of measures designed both to increase the attractiveness of alternative forms of transit and to discourage the low-occupancy use of automobiles. The measures include: regulatory fees for mass transit augmentation, bus/carpool lanes, carpool matching systems, and carpool programs stressing preferential treatment. Local task forces have proposed additional measures, applicable to their particular regions, that will be implemented along with EPA strategies. These measures include: traffic flow improvements, ramp metering, fringe parking for park and ride, dial-a-ride service, bicycle lanes and facilities, reduced transit fares, four day work weeks, and taxation and pricing measures.

State, Local, and Federal Implementation of Control Measures

In order to preserve the intent of the Clean Air Act that pollution problems be dealt with primarily at the local level, the Agency is requiring that State and local governments take action wherever possible and will involve the Federal Government only in the direct implementation of some programs. State and/or locally enforced, Federal promulgated requirements are: retrofit programs; parking supply and surcharge; bus and carpool lanes; inspection and maintenance; and stationary source controls. Federally operated programs will be: motorcycle controls, gasoline limitation, and a bus/carpool incentive regulation directed at major employers.

DESCRIPTION OF EPA PROMULGATED VMT REDUCTION MEASURES

Bus Lanes

Bus priority treatment consists of allocating highway facilities preferentially to buses for the purpose of improving the quality of bus service. Methods of effecting bus priority treatment in the transportation plans include reserved lanes for buses (and/or carpools), preferential access for buses at metered freeway ramps, and certain traffic engineering improvements. The forms of bus lanes set forth in either the plans proposed or approved by the States or promulgated by EPA include normal bus flow lanes, and contra-flow lanes. In California, the Department of Transportation suggested that only certain freeways or major roads be dedicated to the bus lane concept and EPA agreement with this suggestion is reflected in these promulgations. The method of selecting the lanes has been changed from one based on the number of lanes in the road to one looking to the establishment of a coherent network of such lanes along transportation corridors. In some regions, pilot programs will be conducted to discover the best way to implement a full-scale program. In some cases, measures such as the conversion of entire streets to bus and carpool use may prove preferable to limited lanes.

The use of bus (and/or carpool) lanes has been observed to increase mass transit freeway speeds by a factor of two or more. Through the elimination of congestion problems, bus service dependability is increased as late arrivals are significantly reduced. Furthermore, bus ridership will increase, and the fares may eventually be reduced. Because of these factors, the regulations set forth for bus lanes are expected to be a positive inducement to increased bus patronage. The timetables for implementation of bus lanes will vary according to regional situations.

Carpool Systems

Experience to date with carpool programs suggests that policies to encourage carpooling might double auto occupancy rates for downtown peak period work trips. If a 10 to 50 percent increase in auto occupancy is adopted as a realistic range of possible effects, the net effect of carpool policies on total urban area auto use might be a 5 to 10 percent reduction.

EPA is promulgating measures that provide computerized carpool matching programs and preferential carpool treatment programs. The matching program provides for the formation of carpools and the preferential treatment programs provide incentives such as free parking to encourage carpools. Under the measures included in some plans, disincentives such as parking space reduction or paid, rather than free parking, are included to discourage single occupancy on commuter trips.

In all Regions EPA is requiring the establishment of carpool matching systems to enable persons with similiar daily travel patterns to make contact with each other and arrange carpools. In some regions, pilot programs will be established prior to establishment of the system throughout the region. Such a measure is necessary if the restraints on individual vehicle use contained in this plan are to have the desired effect of reducing VMT.

The EPA Regional Office in San Francisco has contacted various Federal agencies in order to facilitate the implementation of the pilot programs called for in the regulation. The Regional Office has experienced initial success in its first contacts, and this effort is continuing. A detailed guide for the operation of a bus/carpool matching program, along with a discussion of a number of successful programs in operation in many areas of the country is found in a U. S. Department of Transportation Federal Highway Administration Publication "Carpool and Buspool Matching Guide (Second Edition)", May 1973. This report discusses the considerations involved in a successful program such as public information, incentives, data processing, and a continuing updating of the service, and is an excellent guide and reference for conducting such a program.

The EPA believes that this approach to reducing vehicle miles traveled is an excellent short-term strategy. It involves a minimum investment and deserves the active promotion and support of government and industry.

<u>Employer Provisions for Mass Transit Priority Incentives</u>

As was pointed out in the public hearings by some of those testifying, employer-paid privileges for employees tend to encourage employees to drive to their place of employment rather than use carpools or mass transit. The promulgated regulation therefore, provides for employer-paid mass transit fares and special parking privileges to those who travel in a carpool. It also requires that individuals who drive may not be provided with free unlimited parking, but must pay the prevailing surrounding parking rate.

This regulation will be implemented in stages, the first stage applicable to employers of 700 or more employees, and the second to employers of 70 or more.

The purpose of this regulation is to effect sizeable reductions in VMT caused by commuting, with appears to be the mode of travel most easily diverted to mass transit and car-pools.

Control of Existing Parking Spaces: Surcharge on Parking

The proposal that spaces in public parking facilities be reduced by 20 percent drew almost universal adverse comment during the rulemaking proceedings. At the same time, the use of regulatory fees to discourage pollution-causing activities was widely supported. In particular the use of fees to control parking was mentioned.

EPA also believes that the use of such parking fees has much to recommend as a matter of policy. Accordingly, EPA is not promulgating a reduction in publicly owned parking spaces and is instead promulgating a regulatory fee to increase the price of parking in, and so discourage traffic to, selected trip attraction centers in the three most heavily polluted AQCR's. The regulation's coverage will be increased in three phases. At least 50 percent of the revenues will be used for mass transit.

Several of the plans call for the imposition of regulatory fees on parking. In earlier Notices of Proposed Rulemaking, the Agency expressed some doubt about its authority to impose such fees. That legal question has been extensively reexamined, and EPA has now concluded that such a step is authorized by the statute. The transportation control measures promulgated by EPA will require a significant change in the driving habits of the American people. The use of fees can help to bring that change about with a minimum of social disruption of the wide latitude they leave to individual choice. Those whose needs or preferences are strongly in favor of using the single-passenger automobile may continue to do so, although at a somewhat higher cost; those who can easily adapt to the use of other modes of transportation have a financial incentive to do so. Many public comments supported the adoption of such fees. In addition, the enforcement of such fees will be less difficult than some other measures. Finally, such fees will be used to support mass transit. Expansion of mass transit is essential if the disin-centives to automobile use imposed by transportation control plans are to have the desired effect. Such a use of the proceeds will also greatly mitigate the potentially regressive nature of such fees.

In requiring the States and EPA to impose transportation controls where they are needed to meet air quality standards, the Congress imposed a regulatory task whose difficulty and complexity are virtually unparalleled. The legislative history shows that Congress fully recognized the magnitude of the problem. At the same time, the statute's description of the exact types of measures that may be imposed is extremely broad and general. In the face of this broad language, the Administrator concluded that the Congress intended him to impose the method of control that he determined was best able to achieve the purposes of the statute.

Parking Management Program

The proposal for review of new commercial parking facilities has been modified, from an earlier proposal, to allow a wider range of variables to be considered. In essence, the regulation promulgated today would forbid the construction of any facility that could be expected to lead to a VMT increase unless either (1) the application retired from service or caused the retirement from service of an equal number of spaces elsewhere in the AQCR, or (2) the applicant could show in a separate hearing devoted only to that question that the impact of the proposed facility on VMT, and thus air quality, would be insignificant.

The promulgated regulations will require that the appropriate local government submit to the Administrator a plan outlining the locally planned expansion of parking facilities for the next five years. If a submittal is not made that shows to the satisfaction of the EPA that such planned parking expansion does not conflict with the California State Implementation Plan, the EPA will review each proposed new parking facility individually. Such review by either the State or EPA will be consistent with the previously discussed complex sources regulations to be promulgated shortly.

Motorcycle Controls

In the July 16, 1973, proposal, regulations were included that would have restricted 2-stroke motorcycle operations during the "smog season" in California. This action was taken due to the very high pollution potential of the 2-stroke motorcycle. The average 2-stoke motorcycle emits approximately 31 times as much exhaust hydrocarbons per mile as a new California 1975 automobile will emit. Consequently, prevention of increases in the number of motorcycles was proposed to prevent counter-productive shifts from automobiles to motorcycle as a result of other elements of the control strategy. The Agency has evaluated the feasibility of establishing emission standards for new motorcycles and is currently evaluating the availability of motorcycle emission control technology for existing motor-cycles to reduce emissions.

Based upon testimony presented by motorcycle manufacturers, testimony presented by motorcycle trade associations, and an independent analysis by the Environmental Protection Agency, it appears that significant reductions in the emissions from new motorcycles can be achieved.

Accordingly, the EPA is no longer requiring an unconditional ban on motorcycle operations. Instead, the ban regulation has been rewritten to provide that it will not go into effect in the event that nationally applicable Federal regulations are promulgated that require at least a 50 percent reduction of 2-stroke motorcycle emissions by 1976 and conformity with the 1976 automobile standards by 1979. Comparable emission reductions will be required of 4-stroke motorcycles.

Vehicle Free Zones - Not Promulgated

Traffic free zones are primarily promulgated to control local carbon monoxide problems. The zones are necessarily restricted in size (approximately ten blocks or less) in order to provide foot access. Consequently, the zones can be put into effect by 1975 since no additional transit facilities are required. Although increasing the size of the vehicle free zone tends to increase the potential air quality improvements, such action also increases the problems of access, circulation, and peripheral congestion and pollution.

Selective Vehicle Use Prohibitions - Not Promulgated

In several regions, EPA proposed a regulation under which the vehicle population would have been divided into five categories. Each category of vehicles would have been required to display prominently a tag of distinctive color; on one day of each working week vehicles marked with one such color would have been forbidden to operate.

Testimony at all the public hearings indicated that measures of this type so far proposed would be unenforceable because of their severeness and arbitrary nature. In addition, the number of additional enforcement personnel necessary to implement such a program would then have been so great as to preclude the reasonable availability of this measure. Were they to be implemented, many very workable methods of evading the requirements would doubtless be devised.

Gasoline Supply Limitations

The proposed transportation controls included measures to limit the gasoline supply in certain areas in order to reduce vehicle miles traveled. The measure included two types of regulations: (1) a gasoline supply lid that would become effective in 1974 to limit the quantity of gasoline sold to fiscal 1973 levels; and (2) a regulation to be implemented on May 31, 1977, to reduce an area's gasoline supply, and thus VMT, to the extent necessary to achieve the standards.

The gasoline supply requirement has been dropped as a primary measure. The Act requires that all "reasonably available" measures must be implemented by May 31, 1975, before granting an extension. Based upon the comments received at the public hearings on this measure and the Agency's evaluation of the feasibility of implementing and administering successful gasoline supply limitations, the Administrator has determined that a gasoline supply lid cannot be considered "reasonably available." The possibilities of evasion, the likelihood of noncompliance, and the difficulty of enforcement are too great to make this measure practicable at this time.

The gasoline supply reduction regulation to be implemented on May 31, 1977, however, has been retained in several plans. As was noted above, the Clean Air Act required air quality standards to be achieved by 1977 without regard to cost or social disorganization that may result as a by-product of achievement. If gasoline supply limitations are needed to achieve the standard, the "reasonableness" criteria is not a determining factor. Accordingly, the Administrator was obligated to use gasoline supply limitations as a final resort measure in certain areas with severe air pollution problems. Most of these areas required reductions in vehicle miles, traveled far in excess of 10 to 20 percent. In some regions, however, the required VMT reductions may well be accomplished through the specified VMT reduction measures. Gasoline supply limitations were required in these areas only to assure the attainment of the standards by 1977. If a review of air quality data and VMT reduction monitoring information prior to 1977 indicates that the gasoline reduction measure is not required, supply limitations will not be implemented.

ADDITIONAL VMT REDUCTION MEASURES - LOCAL PROPOSALS

State/Local Task Forces

State/local task forces have been formed in all AQCRs (except the Southeast Desert) covered by this promulgation to develop alternatives to the EPA-proposed control measures, with the goal of developing draft plans by mid-October 1973. Meetings were held between the task force and EPA representatives to discuss potential alternatives for inclusion in the EPA control plan promulgated for each AQCR. Although the EPA promulgations are not wholly comprised of recommendations of the task forces, EPA hopes that they will more properly reflect reasonable and locally acceptable measures to improve air quality in each AQCR. EPA also hopes that the recommended alternative plans being developed by the task forces later this fall will be approvable by EPA and will allow EPA to rescind its regulations.

The membership of the task forces follows:

Los Angeles: District VII Cal/Trans, California Air Resources Board, City and County of Los Angeles, California Highway Patrol, Southern California Association of Governments, Los Angeles County Air Pollution Control District, Southern California Rapid Transit District, South Coast Air Basin Coordinating Council, the League of California Cities.

San Francisco: District IV Cal/Trans, California Air Resources Board, San Francisco Bay Area Metropolitan Transportation Commission, Association of Bay Area Governments, and the Bay Area Pollution Control District.

San Diego: District XI Cal/Trans, California Air Resources Board, San Diego Comprehensive Planning Organization (CPO), San Diego County Office of Environmental Management, San Diego County Pollution Control District, City of San Diego, the San Diego Unified Port District, and San Diego Rapid Transit District.

San Joaquin Valley: Cal/Trans, California Air Resources Board, County, City, Regional, Fresno Community Council, local transit officials, and county, city, and governmental bodies including the Fresno County Air Pollution Control District.

Sacramento Valley: Cal/Trans, California Air Resources Board, Sacramento Regional Area Planning Commission, county, city and regional governmental bodies, and the Sacramento Regional Transit District.

Four-Day Work Week Schedule

The four-day week would reduce VMT generated in work commute travel. Like staggered work hours, this would be a useful measure if there were a localized, temporal problem in employment concentration areas. However, indications are that increased recreational and other non-work travel will fully replace if not exceed the reductions in VMT resulting from decreased work commuting. Thus, this measure does not respond well to hydrocarbon emission problems.

Staggered Work Hours

Changes in work schedule by staggering work hours have been proposed as a control measure in some cities as they tend to produce some flow improvements by reducing commute period traffic congestion. This measure, however, would produce only marginal reduction in emissions.

Staggered work hours do not decrease total daily VMT but simply spreads the time of VMT generation. Such a strategy is most applicable when the problem is a short duration, localized concentration of pollutant, which results from temporal concentration of traffic flow. High concentrations of carbon monoxide are most typical of this type of problem. Staggered work hours, however, also tend to reduce the potential for car pooling, a measure which relates well to hydrocarbon emission reduction, since it tends to directly reduce VMT.

Traffic Flow Improvements

Measures to achieve emission reductions through improved traffic flow fall into two categories: construction of new major traffic facilities (freeways, expressways and major arterial linkages); and operational improvements to existing streets and highways. The emission reductions are brought about by increases in vehicle speeds, reduced idling, and a general shortening of trip times.

Major facility construction normally enables significant increases in vehicle travel speed in the corridors affected but also tends to activate latent travel demand. In the long run this reinforces auto dependence and increases vehicle miles traveled. Over the short-range time frame of primary concern in this study, the air quality impacts of new traffic facilities can be assumed positive.

Operational improvements to existing streets and highways cover a broad range of programs. These include freeway improvements such as ramp metering and removal of bottlenecks; and surface street improvements such as area wide signal system integration, intersection channelization, minor widening of streets and intersection approaches, institution of one-way street systems, and the like. Because they do not produce dramatic shifts in accessibility, operation improvements generally do not lead to activation of latent travel demand and their near-term impact on emissions and air quality is assessed as positive but their specific contribution to areawide emission reduction is small and difficult to quantify. At best, the planned operational improvements can be expected to accommodate an ever increasing amount of travel without decrease in the level of service.

Ramp Metering

Ramp metering is used to optimize the efficiency of traffic movement in a freeway corridor. Metering also has potential utility for shutting down the freeway for episode control, and as a means to provide preferential entry for vehicles that have a higher utilization (car pools, buses).

Mass Transit Improvements

Since personal travel requirements cannot be diminished, some form of transportation alternatives must be provided if vehicle use is to be reduced, particularly if vehicle restraints are implemented. One form for these alternatives is public transit.

Improvements to public transit systems include both extensions and/or upgrading of bus systems and provision of rapid transit on separate rights-of-way. In conventional bus operation, improvements include level of service (area of coverage, headway, etc.) betterment and amenity promotions (air conditioning, bus stop shelters, etc.). Most of the urban areas already have or are in the process of setting up transit districts to expand public transit service. These could result in significant patronage increases, but it is unlikely that such improvements would induce major shifts of choice riders from auto to transit without a system of concurrent disincentives for single occupancy use of the automobile.

Fringe Parking, Dial-A-Ride, Jitneys

Fringe park and ride facilities could allow suburban commuters to park their cars on the peripheries of urban areas and then take either mass transit or carpools into the central business district. To have significant impact on lowering emissions, local meterological conditions in a specific geographical area would have to be suitable. For instance, if such a facility were in a basin, the amount of pollution reduced would be diminished. Dial-a-ride and jitney service could serve as feeders to either mass transit or carpool rendezvous points, in addition to serving as a primary means of transit.

Network of Bicycle Paths and Facilities

Greater use of bicycles could be encouraged through designation and protection of bicycle lanes and incorporating bike/pedestrian paths in new developments. A recent EPA study suggested that increased use of bicycles in urban commuting could reduce auto vehicle miles traveled by as much as three percent in some areas particularly amenable to bicycle travel.

Imposition of restraints on auto usage, particularly measures like gas pricing and rationing, could be expected to encourage bicycle use. The greatest increase in bicycle ridership would probable occur for children in getting to school, recreation, etc., as parents pre-empt the car for more essential functions. Work trips by bicycle could be encouraged by providing exclusive bike lanes in city streets and a carefully laid out bicycle grid system.

Free or Lower Transit Fares

Lowering the fare is one of the more effective means of improving the competitive position of transit vis a vis the automobile, particularly for intercity travel. However, very little travel diversion from auto could be expected from short trips, or from longer trips where time is valued over price (see TRW and DOT travel demand elasticities models).

Accompanied by auto use time penalty strategies or mass transit time savings measures, lower fares could play a more important role in reducing VMT.

Tax Disincentives

A "pollution" tax could be charged in direct ratio to the emission rate and mileage of each motor vehicle or to increase the tax on gasoline (consumption varies directly to mileage). Schemes to reduce vehicle mileage through gasoline pricing may be very effective if prices are set high enough. If imposed indiscriminately on all segments of society, the largest impact is felt by limited income groups.

Various taxes on automobiles have been proposed. Low fees are not effective in reducing VMT and high fees are extremely regressive. Substantial registration fees on second or third family autos might provide reductions in VMT and still avoid some of the more regressive elements of this type of taxation.

Tolls

The imposition of tolls on freeways is a potential method of regulating road use. It is possible, however, that a high percentage of those priced off the freeways by tolls may drive on surface streets rather than shifting to car pools or transit. This could produce increased emissions as a result of reduced travel speed and idling on surface streets. Tolls also tend to be regressive since many of those priced off the roads will be low income persons.

Gasoline Limitation

Recent increasing fuel demands and the predicted fuel shortages may cause some gas rationing in the near future, and therefore result in a VMT reduction. However, this would be a by-product, and not a TCP stragegy. Administrator Train recently announced a decision not to use gasoline limitation as a TCP strategy, if possible. Studies have been done evaluating the impact of schemes to raise the price of gasoline and thus reduce consumption. The use of gasoline is inelastic in lower price ranges and more elastic with higher prices with increased effects if accompanied by a range of other VMT reduction incentives. Experience in European countries shows that even when a gallon of gasoline is priced as high as $1.50 a gallon, VMT rates continue to grow. TRW [Ref. 1] estimates that it would take two years to evaluate the effects of raising the price of gasoline. However, a gas tax accompanied by other pricing penalties on private use of the automobile - parking surcharge, tolls, high registration fees on second and third cars, emission taxes - would help decrease VMT as well as contribute funds to mass transit.

II. ANALYTIC BASIS OF VMT REDUCTION ESTIMATES

To evaluate the relative effectiveness of various VMT reduction strategies, it is necessary to have analytical methodology which can predict the potential transit ridership of average automobile occupancy rates for a set of critical variables. Unfortunately, it is very difficult to quantitate the factors people use to rate the attractiveness of car pools relative to driving alone or riding in a bus. Many of the measures EPA and the local task forces have designed to reduce VMT are untried. EPA has gathered the available data and studies that analyze the range of VMT reductions possible from various transportation controls. Analysis has included surveys to measure public attitude and anticipated behavior, pilot studies conducted in specific areas to gain better understanding of carpool modal splits, and modeling to estimate the proportion of total trips between two geographical locations that will be made via mass transit (see Appendix 1 for listing of studies).

A Federal Department of Transportation draft report indicated some important relationships between increased use of mass transit and total auto travel.[1] The following quotes from that study illustrate the difficulties in achieving shifts away from personal use of the car by only providing improved transit incentives:

> "(a) The price elasticity of demand for transit work trips is only -0.19. This means that a one percent change in price will only result in .19 percent change in demand for transit work trips. Therefore, a 20 percent decrease in transit fares would only increase transit ridership by 3.8 percent."
>
> "(b) The price elasticity or demand for transit shopping trips is only -.323. Therefore, a 20 percent reduction in price will result in an increase in shopping trip ridership of 6.5 percent."

1/Alternative Transportation Investments and/or Controls for Reduction of Air Pollution in Major Metropolitan Areas, U. S. Department of Transportation, 1972, page 10.

"(c) The time elasticity of demand for transit work trips is -.709. Therefore, a 20 percent decrease in travel time will increase the work trip ridership by 14 percent. (Note that time elasticity of demand is about 3.7 times the price elasticity.)"

"(d) The time elasticity of demand for transit shopping trips is -.593. Therefore, a 20 percent reduction in transit time will increase ridership by about 12 percent. (Note that time elasticity of demand for shopping is about twice as responsive to changes in travel time as it is to changes in fare: -.593 compared to -.323.)"

In addition, the cross elasticity for mass transit may be low without accompanying disincentives and penalties on personal use of the automobile.

EPA has funded studies to assess the possible impact of a range of incentives and disincentives to achieve VMT reductions in five of the California AQCR's. TRW has conducted studies for the Los Angeles Basin, San Francisco Bay Area, San Joaquin and Sacramento Valley. A joint IREM/Rand project [Ref. 12, 14] studied San Diego. Each region's transportation patterns can be applied to a model that can reasonably estimate the proportion of total trips between two geographical locations that will be made via alternate means other than private automobile when different incentives or disincentives are applied (Appendix 2 displays the various models and calculations used to arrive at the VMT reduction estimates). The model that has been applied to most of the California transportation studies was developed by Alan M. Voorhees and Associates (San Francisco).

The Voorhees Model

1. A "marginal utility" function is calculated for a typical trip between the two sub-areas between which projections are being made. "Marginal utility" is defined as a measure of the advantages of the private automobile over public transit. Therefore, higher marginal utilities will result in lower levels of transit ridership and vice versa.

2. Diversion curves are developed empirically for each regional area, which specifically relate transit ridership to marginal utility.

3. The diversion curves are used to predict the expected transit ridership for any calculated marginal utility. It is important to remember that the utility curves were derived empirically, and hence subject to uncertainties. It would be a mistake to view the model as an absolute predictor. Since the model has inherent uncertainties, any values calculated have the same uncertainties plus the additional uncertainties associated with various assumptions made.

There are a number of variables which can be used to measure the relative advantage the private auto has over public transit. Voorhees related marginal utility to nine variables, which fall into two classes - time and money. Within the group of nine variables used to formulate the marginal utility function, certain variables are more susceptible to change than others. Variables which are susceptible to change in the direction of decreasing marginal utility are the ones which hold most potential for decreasing VMT. Appendix 2 includes tables of the nine parameters and some implications associated with changing their marginal utility.

Theoretically, some or all of the nine parameters can be modified in hopes of affecting increases in transit ridership. Application of the model invariably shows that demand for public transit will increase if the marginal utility of the automobile is decreased.

4. Transit ridership estimates are extrapolated for different marginal utilities. They reflect three levels of optimism for what transit ridership might become under rather ideal conditions. The patronage level of forecast used depends on the transportation characteristics of the region in which the model is applied.

5. Within the defined patronage level of a region, the Voorhees curves are drawn for three different levels of income. Various income groups will exhibit different responses to, or perceive differing marginal utility changes to a uniform change in actual conditions. This is explained by the differing values placed on time and money within each economic class. Low income drivers will probably divert to public transit more rapidly than middle income drivers in the event a substantially increased cost penalty is associated with driving. However, since more low income people ride transit now, the percentage increase in transit ridership within each income level could be about the same. Appendix 2 shows the expected changes in transit ridership for various parameters as a function of three income levels.

For each region in which the model is used data is collected and typical values assumed for each parameter needed to simulate conditions experienced during a commute type trip. Using the assumed values and the variables curves can be generated for estimating the percent transit ridership as a function of each of the variables. Marginal utility is determined by holding all but one of the variables constant as one is allowed to change.

Conclusions From Applied Model

In comparison to transit variables, controls aimed at penalizing the automobile, are more effective. Theoretically, if the penalty placed on the auto is severe enough, high transit ridership and therefore, large VMT reductions are possible. However, the measures necessary to achieve large VMT reductions have to be very drastic.

A fairly consistent finding is that the private auto user is more affected by time loss and inconvenience than by monetary considerations. To achieve large VMT reduction by economic means alone would necessitate severe economic penalties for private auto use. The impact would be very inequitable affecting the lower classes the most.

An example from the TRW study for the L.A. Basin shows the degree of impedence necessary in money or time to achieve a VMT reduction response. Assuming no transit operation improvement, the combined vehicle operating and parking cost would have to be raised to approximately $4.00 per day ($2.00 per trip), an increase of 14 cents per mile in order to get to the saddle-point of the curve that separates the flat portion from the steeper, more responsive section. Similarly, if varied alone, the automobile travel time would have to be lengthened to more than 80 minutes (an average speed of approximately eight miles per hour) or the parking terminal time lengthened to 30 minutes to reach the same saddle point (present commute time is 23 minutes).

Unfortunately, attempts to use time to penalize the private auto are often counterproductive to reducing pollution. It has been shown that cars tend to emit less hydrocarbons and carbon monoxide at higher levels of speed than when idling or crawling in congested traffic. Therefore, the closest alternative is to implement measures that achieve great time savings for modes of travel (bus or carpool) other than the auto. Even this incentive does not achieve the same level of possible VMT reduction that a direct private auto time penalty would achieve.

To lenghten the parking terminal time implies the need to eliminate present parking spaces, a measure that is considered infeasible in light of public testimony and comment received.* However, parking management will control the growth of available spaces and impose time penalties if there is a growth in private car VMT.

A combination of adequately severe economic disincentives and of improved mass transit incentives has been promulgated for the regions in California requiring VMT reduction measures. Estimates of the expected VMT reductions achievable have been made based on the best available data and its application to the Voorhees model, or, in the case of San Francisco, to a modified BATSC/MTC** model.

* Periphery parking cannot be expected to cause significant increases in parking terminal time, since one would be able to take advantage of improved local transit or minibus to get into the CBD.

**Model designed by Bay Area Transportation Study Commission (BATSC) to estimate transportation modal choice in Bay Area. The Metropolitan Transit Commission (MTC) updated this modal to reflect recent conditions in the Bay Area.

III. ESTIMATED IMPACT OF VMT REDUCTION MEASURES

C. San Diego AQCR

A study has recently been completed in the San Diego Region to determine strategies for meeting the national ambient air quality standards. The study was conducted by Rand Corporation of Santa Monica, California, and was part of the San Diego Clean Air Project, "Regional Analysis for Meeting Air Quality Standards", being performed by the Integrated Environmental Development Agency under contract number 6704-0270-E. The Clean Air Project is supported by a grant to San Diego County from the Environmental Protection Agency and by a matching contribution from local sources. The preliminary results of this study were presented at the EPA public hearing on the San Diego plan and were carefully evaluated in developing the promulgation of the final EPA plan for the San Diego Region. Table C shows the VMT reduction control measures that are to be implemented, and their expected achievable reductions. Appendix 2 contains a sample of the model the Rand/Irem project used to project the expected VMT reductions for the region.

The proposal to require a bus/car pool computer matching and promotion system by March 1974 has been modified to require that such a system be initially established at the U.S. Navy Electronics Laboratory and the U.S. Navy Underwater Systems Center in San Diego. Upon evaluation, the system will likely be expanded to cover major private employers and governmental agencies. The Cal/Trans task force estimates a 4.2 percent reduction in VMT by 1977 if one half of the employees use the three-phase volunteer car pool system. Total cost of implementing this measure is $175,000. Finally, approximately 10 miles of freeway will be given preferential bus/car pool treatment through ramp metering with bus/car pool bypass lanes, and a major downtown San Diego street, Broadway, will be converted to exclusive bus usage as the first phase of a program to examine preferential treatment for mass transit.

Locally Implemented Proposals--

Major improvements to the mass transit system in San Diego have occurred during the past year and are expected to be expanded as additional funds become available for these purposes. San Diego Transit initiated a 25¢, all destinations, fare in August 1972 and bus ridership has doubled since that time. Three express bus routes to outlying areas of the metropolitan area were established in the past year and at least six more will be in operation by the end of 1977. This part of the system will require at least 125 new buses with an additional 175 feeder and local, off-peak buses to serve the express routes. Also, it is planned that 30 buses be added to the North County system. Fringe parking lots will be established along these routes as well as at major regional shopping centers. Approximately 20 fringe parking lots are planned to serve the expanded mass transit system with a pilot project planned at Miramar for 1975. There are plans to place bicycle protection facilities at these fringe parking lots to allow nearby residents to bicycle to the bus stops. Ridership incentive programs are being planned through an extensive public information program. Dial-A-Bus and subscription bus service will also be carefully examined. The Cal/Trans task force estimates a 5 percent reduction in VMT by 1977 through implementation of these measures.

The City of San Diego has a $125,000 regional bikeway plan under consideration, consisting of 30 local bikepath proposals. Additionally, Cal/Trans is examining at least two bike routes to parallel portions of proposed freeway improvements.

Various traffic flow improvement programs are either underway or proposed for the next 4 years in the San Diego Region. These include a major synchronized traffic signal system for major arterials, easing of traffic bottlenecks, and additional ramp metering. City officials are examining the possibility of fringe parking facilities on the perimeter of the central business district with a system of people-movers and automobile bans in the same area.

A final measure that will likely be the subject of further consideration and experimentation in the next few years will be the variation of the work week to four 10-hour days and other combinations to determine the effects of such variations on air quality and VMT. Governmental agencies will likely be early candidates for this program.

TABLE C

SAN DIEGO - VMT REDUCTION MEASURES

	Control Measures	Promulgated by EPA	Proposed by Local	Estimated Percent Reduction in Daily Vehicle Miles Traveled - DVMT: IREM/Rand Project with Cooperation from ARB, & San Diego Air Pollution Control Task Force	EPA-Voorhees Study for DOT	County Staff and Local
1.	Exclusive Bus/Car Pool Lanes	X	X (Bus only Ltd. use)	2-4	6-10	8-10
2.	Bus/Car Pool Matching (not additive with measure 1)	X	X 1/	4.2		8-10
3.	Parking Supply Management	X			1-2 3/	
4.	Mass Transit Incentives for Employees	X	X		1-2 3/	
5.	Parking Surcharge	X	X	4-10		
6.	VMT/Air Quality Improvement Monitoring Program	X	X			
7.	Gasoline Limitations	X			4/	
8.	Bus System Improvements		X 2/	5		
9.	Bikeways and Bike Lanes		X	1		1-2
10.	4-Day Work Week		X	0-2.5		
11.	Taxation and Pricing Measures (includes parking surcharge)	X				

1/ - Car pool matching programs accompanied by employer promotional incentive and disincentive programs are aimed at achieving a fifty percent rate of employee car pools.

2/ - In addition to more new buses, better scheduling, fare reductions and express bus routes, the local plan includes selective exclusive bus bypass projects, express bus stops at freeway ramp on Route 15 with fringe parking which are part of the "Improved Road Systems" strategy proposed by the local task force. An improved road systems plan that eases congestion is not included in the VMT reduction because reduction of traffic congestion may encourage the latent demand for use of the automobile, and thereby increase VMT counteracting whatever gains had been anticipated by easing congestion and thus any emissions reduction achieved.

3/ - Estimate by EPA, Region IX

4/ - Amount necessary to meet air quality standards in 1977.

APPENDIX I

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2. TRW, Transportation Control Strategy Development for Sacramento Valley

3. TRW, for San Joaquin

4. TRW, for San Francisco

5. TRW, Air Quality Implementation Plan Development for Central California Regions: Summary Report July 1973

6. State of California, Department of Public Works, for Air Resources Board, Can Vehicle Travel Be Reduced 20% in South Air Basin? January 1973.

7. California Institute of Technology, EQL, SMOG: A Report to the People of the South Coast Air Basin, January 1972

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9. Alan M. Voorhees and Associates, for Department of Transportation(DOT), Summary Report: Feasibility and Evaluation Study of Reserved Freeway Lanes for Buses and Car Pools, January 1971.

10. MTC, Proposed Regional Transportation Plan and Revisions: Improvement Proposals, June 1973.

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13. San Diego Air Pollution Control Task Force, Evaluation of EPA's Proposed Air Pollution Control Plan with Alternatives

14. Rand Corporation, A Policy Oriented Urban Transportation Model: Notes on the Rand Approvals, March 9, 1973.

15. TRW, Report on the IREM/RAND Clean Air Project.

16. EPA Region IX, Technical Support Document for LA Basin, July 31, 1973

17. Federal Register, Proposed Regulations for California Air Quality Control Districts, Vol. 38, No. 126, Monday, July 2, 1973

18. Federal Register, Promulgation for Transportation Control Plans for California, Vol. 38, No. 217, Part I, November 12, 1973

APPENDIX 2a

VOORHEES MODEL

Marginal utility = $U = 2.5\ (Ta + Tw) + Tr - (2.5\ At + Ar) + \frac{F - (Ao + Ap)}{0.251}$ (1)

Where : Ta = transit access time in minutes (i.e. the time to walk to the bus stop)

Tw = transit wait time in minutes

Tr = transit riding time in minutes

At = automobile parking access time in minutes (i.e., the time necessary to find parking and walk to destination)

Ar = automobile riding time in minutes

F = transit fare in cents

Ao = automobile operating costs in cents (excluding depreciation and insurance)

Ap = automobile parking cost in cents (averaged over the round trip)

I = mean income of the home based zoned in cents per minute

TABLE 7.4

Control of Marginal Utility Parameters

Marginal Utility Parameter [a]	Potential for Control	Example(s) of Control Aimed at Decreasing Marginal Utility
Ta	Low	More bus stops and/or routes
Tw	Medium	Improved frequency of service
Tr	Medium	Exclusive busways for freeway lanes
At	Low	Peripheral parking, auto free zones
Ar	High	Ramp metering
F	High	Lowered fares
Ao	High	Gasoline tax, "smog" tax, tolls
Ap	Medium	Increased parking costs
I	Very low	Lower personal income levels

a - see Equation 1

TABLE 7.5

ASSUMED VALUES OF MARGINAL UTILITY PARAMETERS

FOR A TYPICAL COMMUTE TRIP

Variable	Assumed Value	Source
Trip Length	10.5 miles	Table 5.4 (EPA publication APTD-1372)
Ta	5 minutes	Generally accepted value
Tw	7 minutes	15 minute headway, no transfer
Tr	48 minutes	LARTS, 1971 Travel Time Study
F	38 cents	30¢ basic fare + 8¢ for one additional zone
Ao	50 cents	4.8¢ per mile - assumed by Voorhees
Ap	2.5 cents	90¢ per day for estimated 5.8 percent who pay See Table 7.7.
I	8.3 cents/minute	$10,000 per year
At	2 minutes	A. M. Voorhees & Associates
Ar	23 minutes	Table 5.4 (EPA publication No. APTD-1372)

TABLE 7.6

MARGINAL UTILITY PARAMETER COMBINATIONS

Marginal Utility Variables	Symbol	Potential for Control	Relative Effectiveness
Transit fare (one way)	F	High	Low
Transit access and waiting time	T_a+T_w	Medium	Medium
Transit riding time	T_r	Medium	High
Auto operating and parking cost (one way)	A_o+A_p	Medium	High
Auto riding time	A_r	Medium	Low
Auto terminal time	A_t	Low	Low

NOTE: Income is considered a constant throughout, primarily because it is virtually impossible to control.

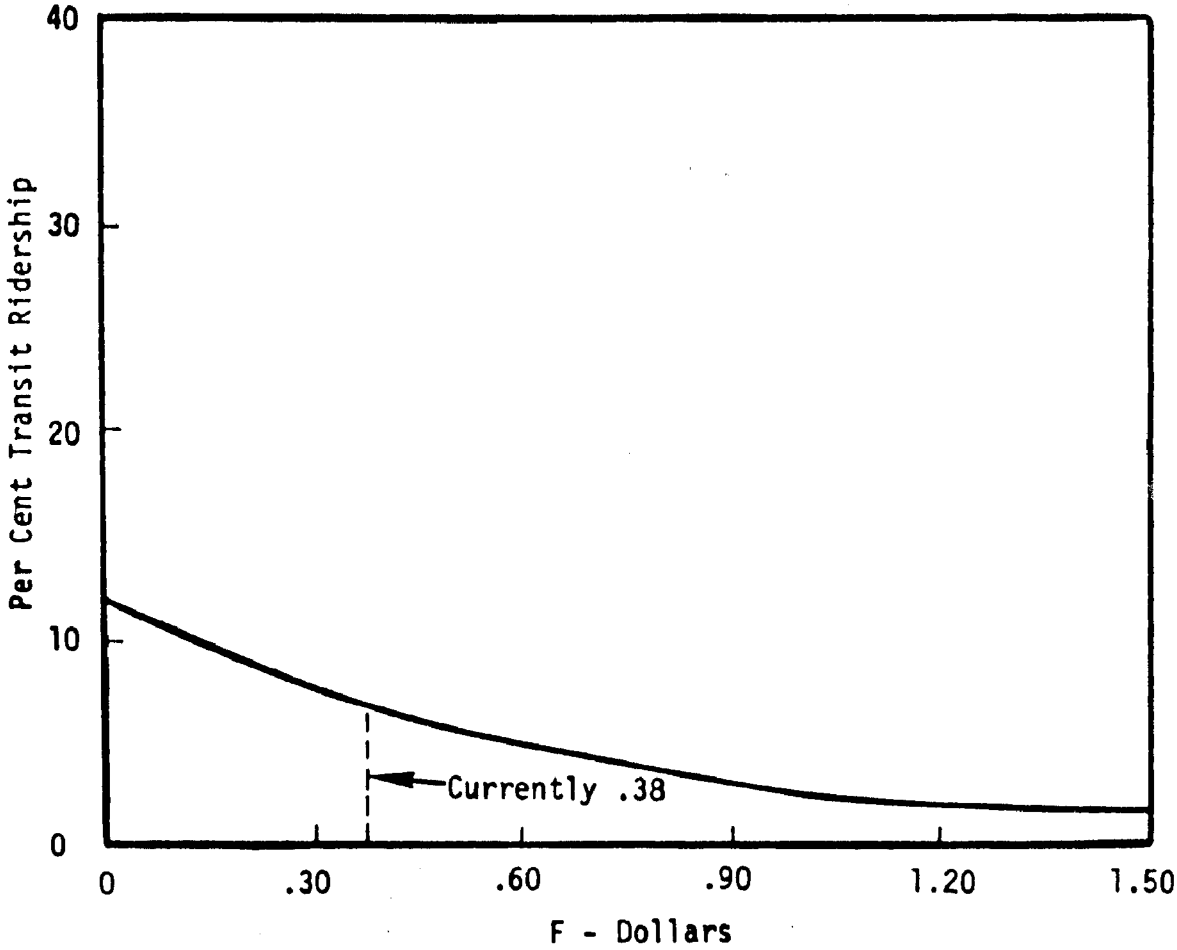


Figure 7.3. Transit Fare (One Way) vs. Per Cent Transit Ridership.

Source: Developed from the Los Angeles Metropolitan Area Mode Choice Model.

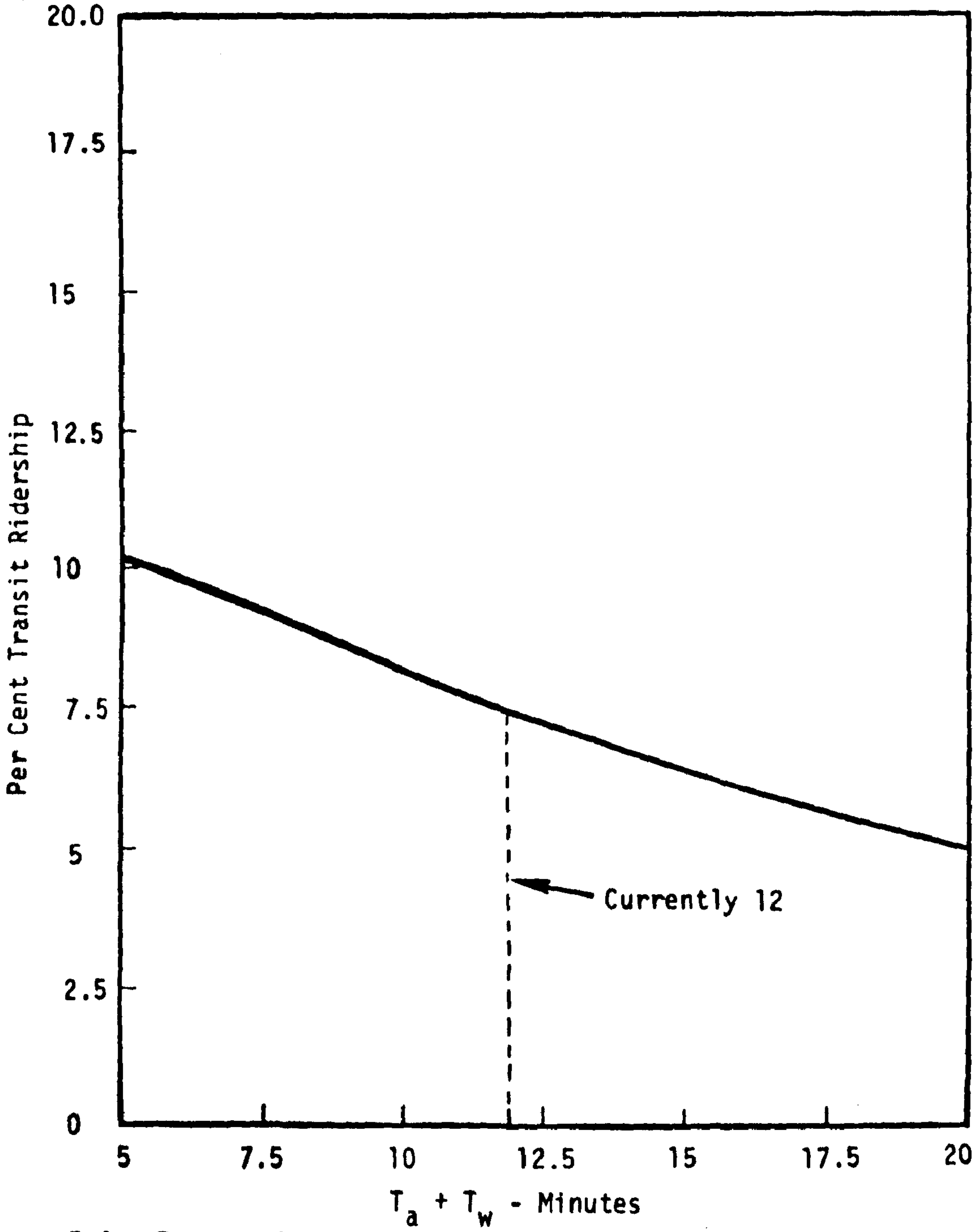


Figure 7.4. Transit Access and Waiting Time vs. Per Cent Transit Ridership.

<u>Source</u>: Developed from the Los Angeles Metropolitan Area Mode Choice Model.

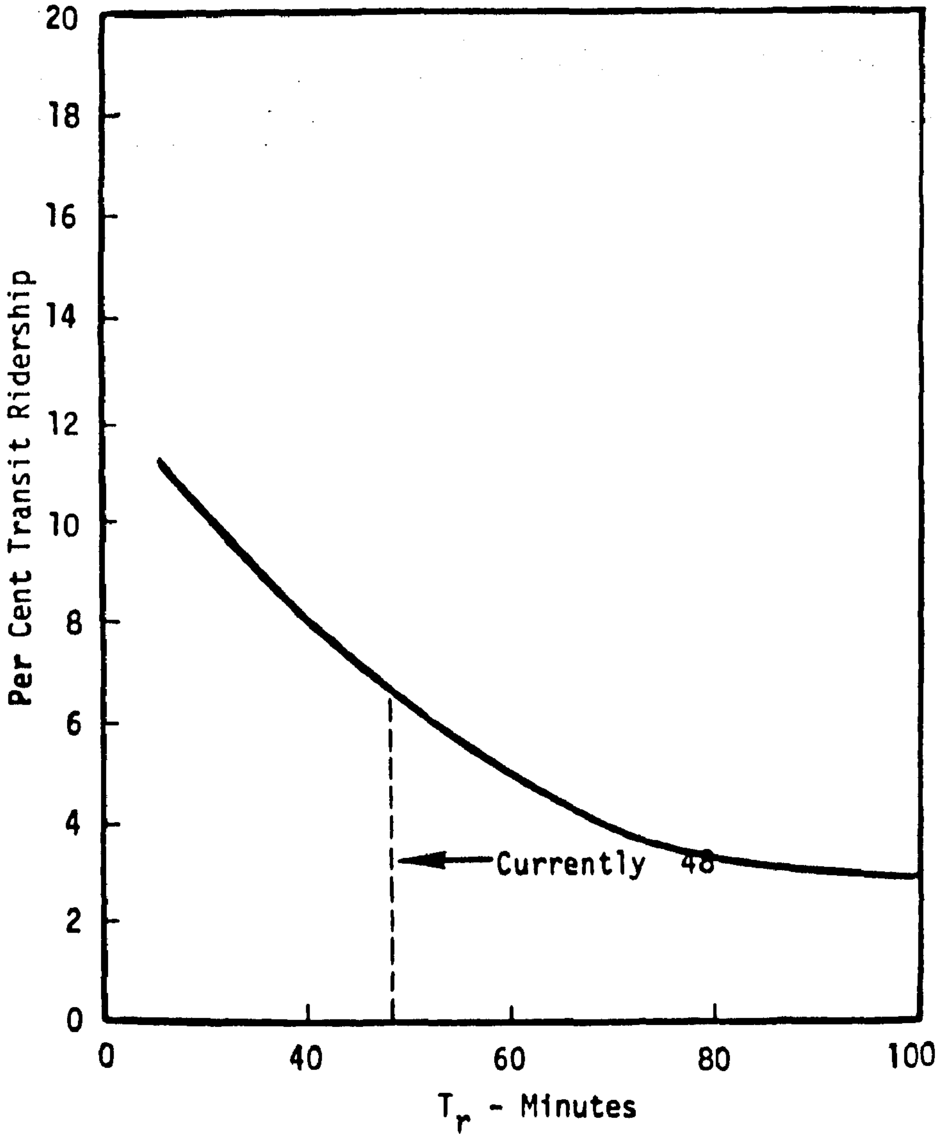


Figure 7.5. Transit Riding Time vs. Per Cent Transit Ridership.

Source: Developed from the Los Angeles Metropolitan Area Mode Choice Model.

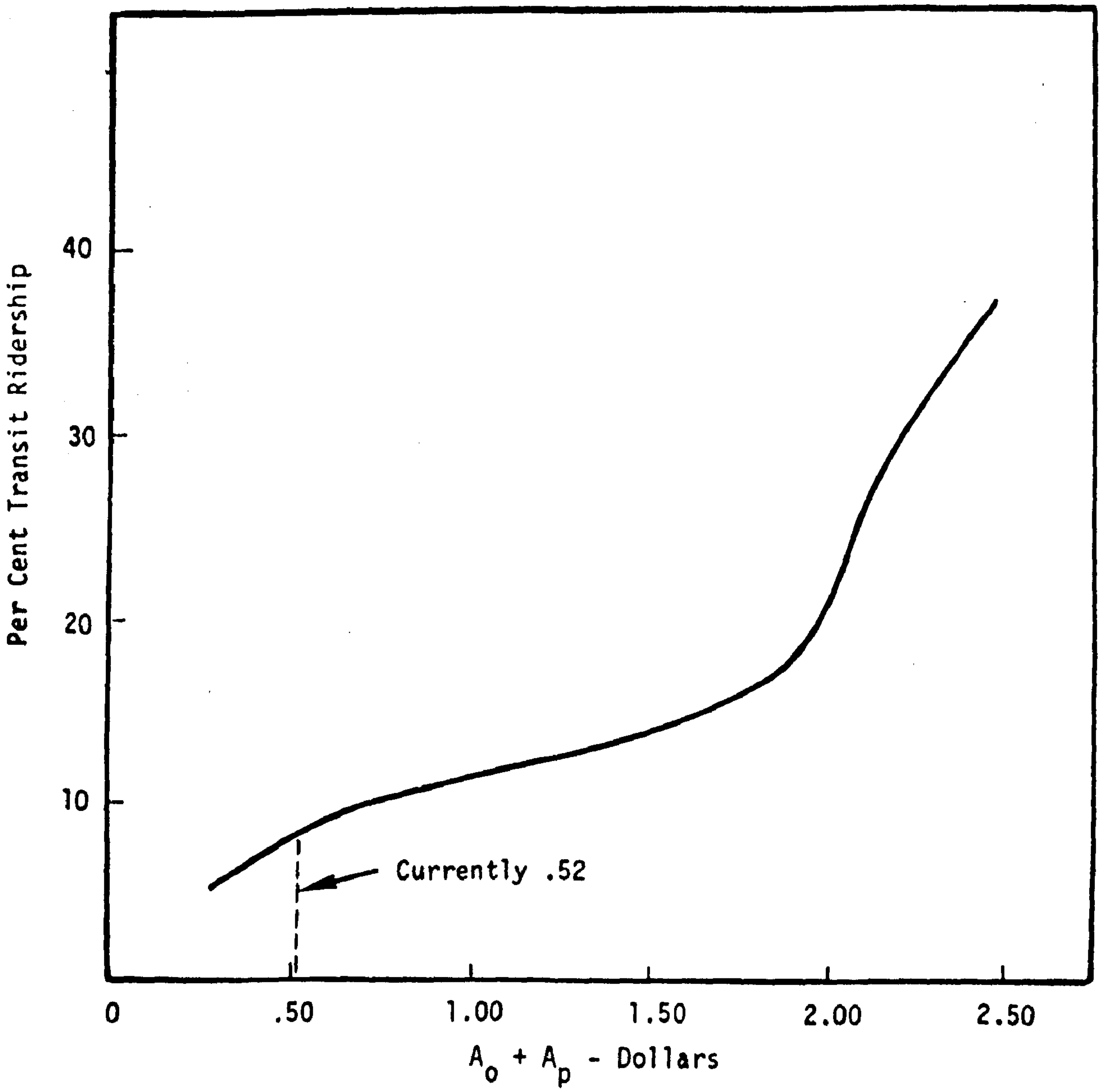


Figure 7.6. Automobile Operating and Parking Cost (One Way) vs. Per Cent Transit Ridership.

__Source__: Developed from the Los Angeles Metropolitan Area Mode Choice Model.

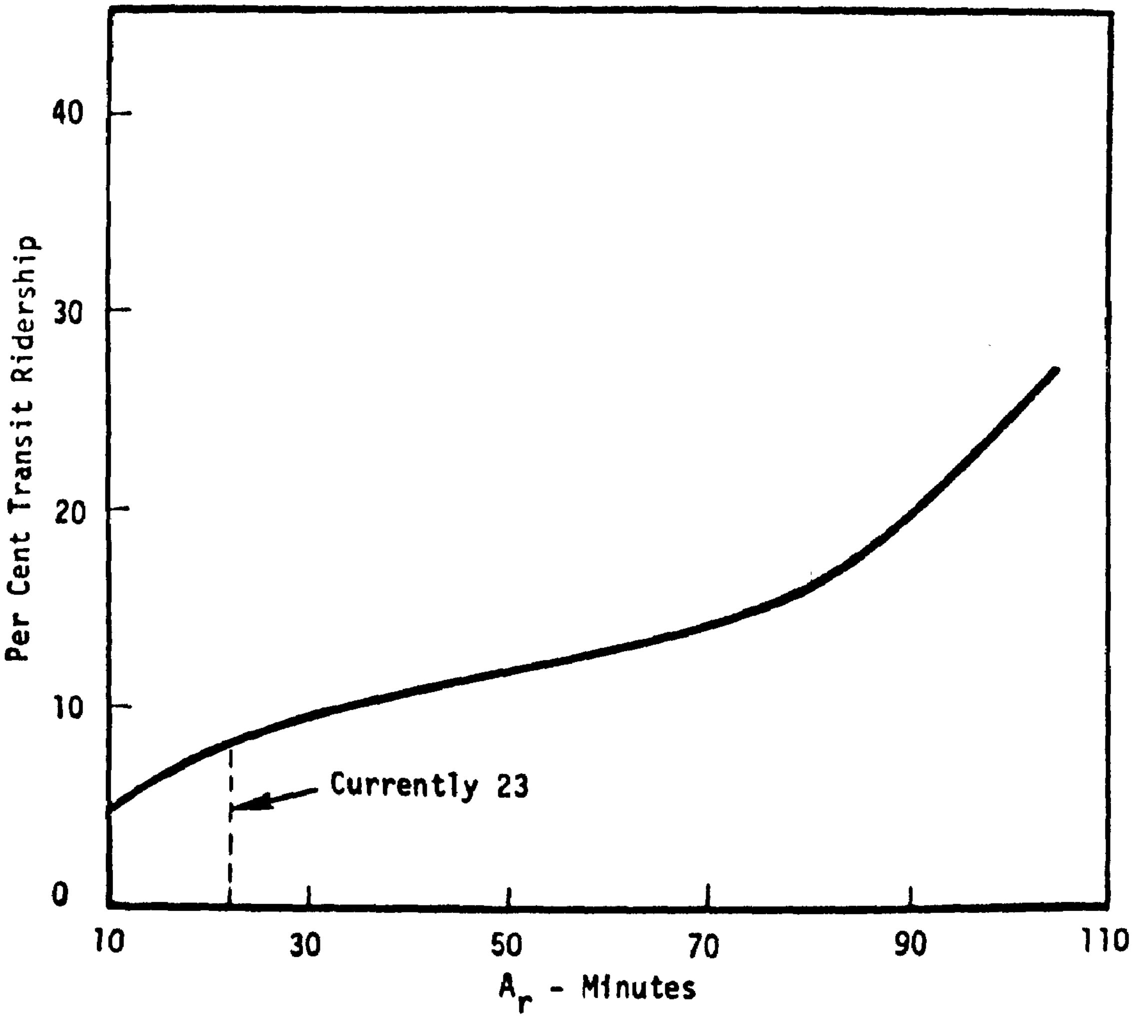


Figure 7.7. Automobile Riding Time vs. Per Cent Transit Ridership.

Source: Developed from the Los Angeles Metropolitan Area Mode Choice Model

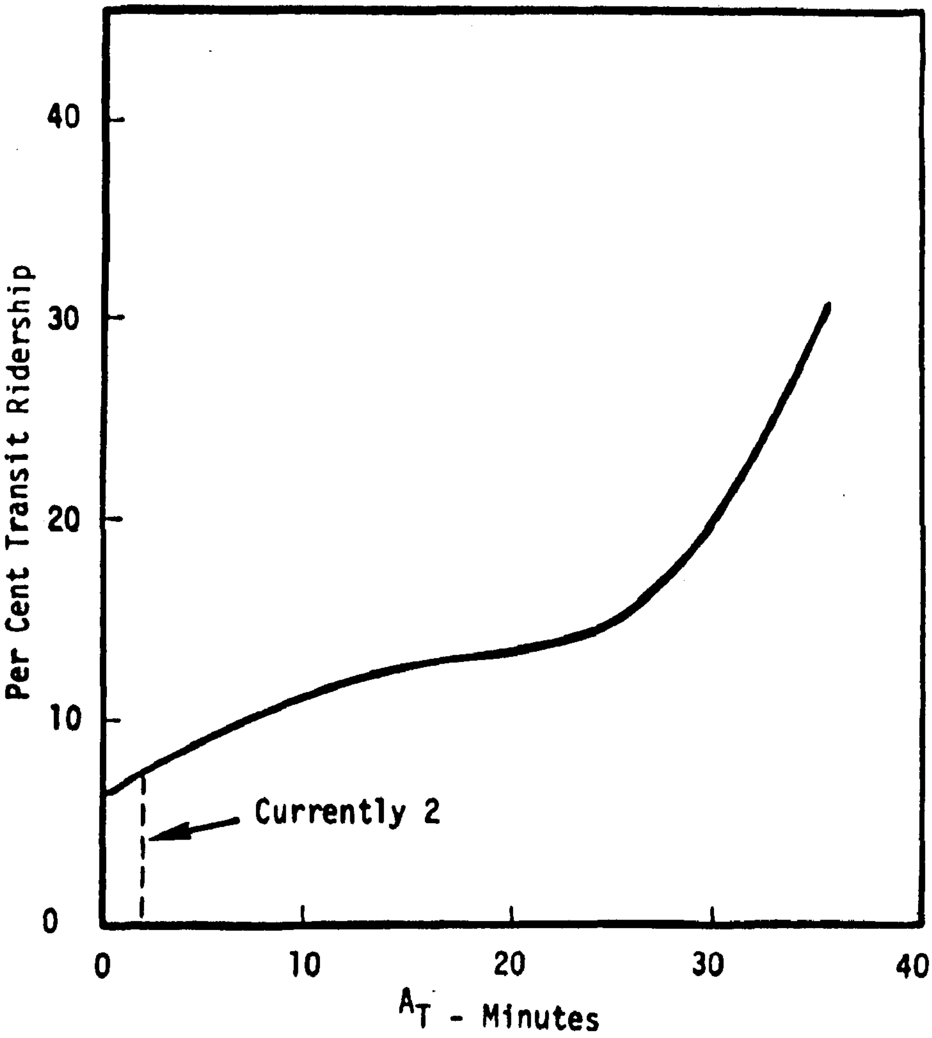


Figure 7.8. Automobile Terminal Parking Time vs. Per Cent Transit Ridership.

Source: Developed from the Los Angeles Metropolitan Area Mode Choice Model.

Sample Calculation #9

Impact of Exclusive Bus-Carpool Lane

Assumptions:

	Source
1) Trip length = 10.1 miles	See Appendix G, Table G-8. (Trip to freeway is excluded.)
2) 20 minute travel time advantage for users of the lane	San Bernardino Busway will have 18 minute advantage; Shirley Highway Busway has 30 minute advantage.
3) Values of Voorhees parameters	
T_a = 2 minutes	Assumed
T_w = 3 minutes	5 minute headway for correct bus
F = 46¢	Basic 30¢ fare + 2 zones
A_o = 48¢ (or 78¢)	4.8¢ per mile (+3¢ per mile "tax")
A_p = 2.5¢	Assumed
A_t = 2 minutes	See Reference E-5
T_r-A_r = 20 minutes	20 minute time advantage
I = 8.3¢/minute	$10,000 per year

$$U = 2.5\,(T_a+T_w) + T_r - (2.5A_t+A_r) + \frac{F - (A_o+A_p)}{0.25\ I}$$

U = -15 (-29 with 3¢ per mile "tax")

Based on the above assumptions and Figure 7.2, the estimated transit patronage is approximately 15 percent without the tax and 20 percent with the tax.

Sample Calculation #9 (Cont'd)

$$\% \text{ VMT Reduction} = 100\text{-}100 \left\{ \frac{OCB(1-F_T) + OCA(F_T)}{OCB(1-F_{T_o}) + OCA(F_{T_o})} \right\}$$ (Eq. (7), Sample Calculation #1)

The percentage of total commute VMT which is travelled on the freeway system in the Basin is approximately 17 percent (see Appendix G, Table G-8); therefore,

$$\% \text{ VMT Reduction} = .17 \left\{ 100\text{-}100 \left[\frac{OCB(1-F_T) + OCA(F_T)}{OCB(1-F_{T_o}) + OCA(F_{T_o})} \right] \right\}$$

Assume:

1) OCB = 50 persons per bus
2) OCA = 1.1 persons per car
3) F_{T_o} = negligible on freeways presently
4) F_T = .15 (.20 with "tax")

% VMT Reduction = 2.5 (or 3.2 with "tax")

To achieve an occupancy of 1.5

Assume:

1) During commute periods, average volume per lane of traffic of 1500 vehicles per hour
2) Carpool is three or more people per automobile
3) Negligible carpooling on the freeway presently
4) Eight lane freeway (four in each direction)
5) Capacity of freeway lanes is 1800 vehicles per hour
6) No diversion to transit
7) Total person trips on freeway is constant

Sample Calculation #9 (Cont'd)

Let N = Number of cars in carpool lane (three persons per car) when all other lanes are at capacity and the resultant average automobile occupancy is 1.5 persons per vehicle.

Then $$\frac{(3)(1800 \text{ veh./ln-hr})(1.1 \text{ persons/veh.}) + N(3 \text{ persons/veh.})}{(3)(1800) + N \text{ veh./ln-hr}} = 1.5$$

$\rightarrow$ N = 1440 veh./ln-hr

Persons diverting to carpools = 1440 x 3 = 4320

Total number of person trips = (3)(1800)(1.1) + (1440)(3) = 11,340

% of freeway commuters shifting to car pools = $\frac{4,320}{11,340}$ = 38%

Impact of Shifts in Carpools

Assume occupancy can be increased to 1.5 persons per vehicle.

From Sample Calculation #2 for commute periods periods,

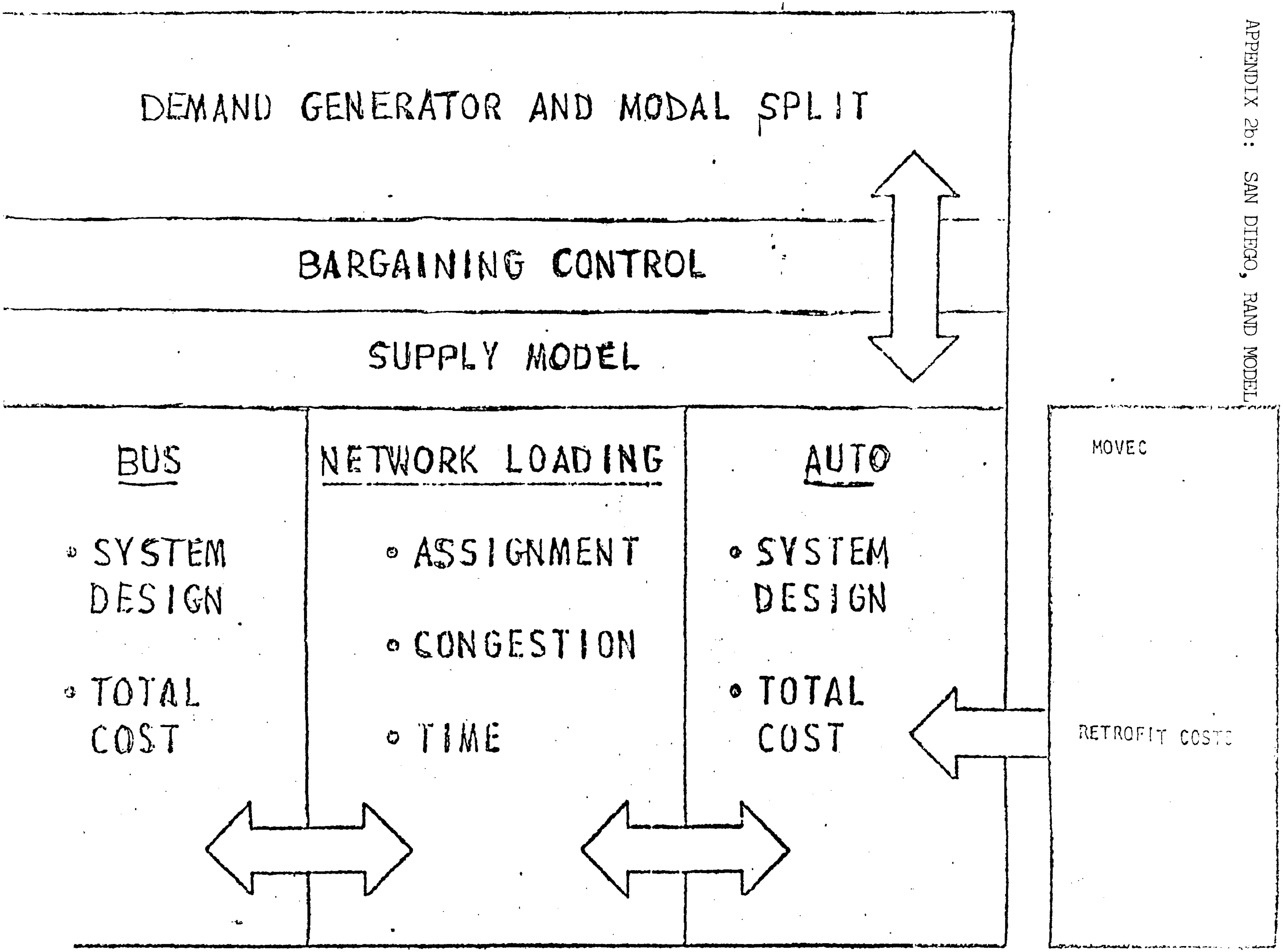
$$\% \text{ VMT Reduction} = 32.4 \left(1 - \frac{1.21}{OCA}\right)$$

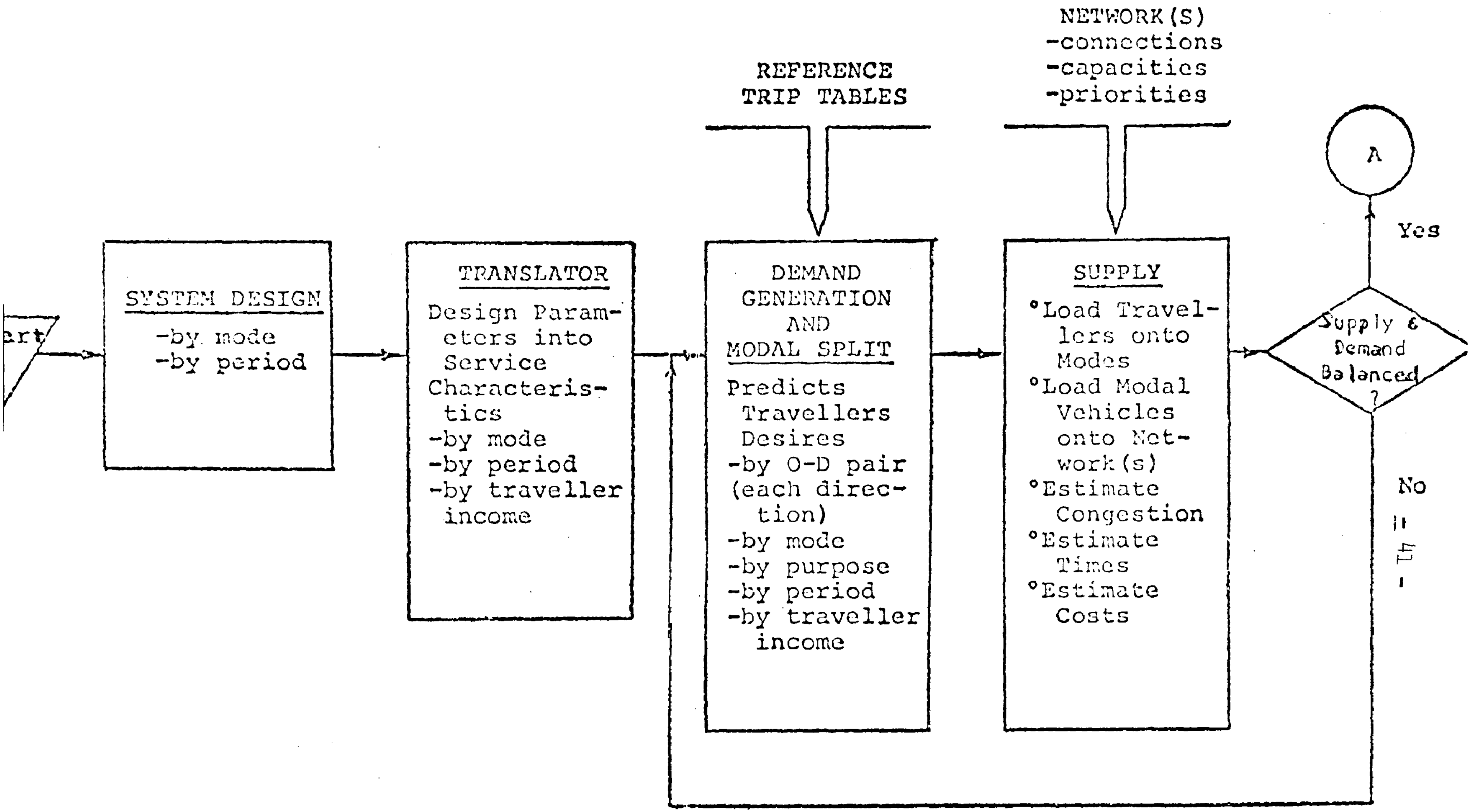
This strategy impacts 72.5 percent of the commute VMT (see Appendix G, Table G-8).

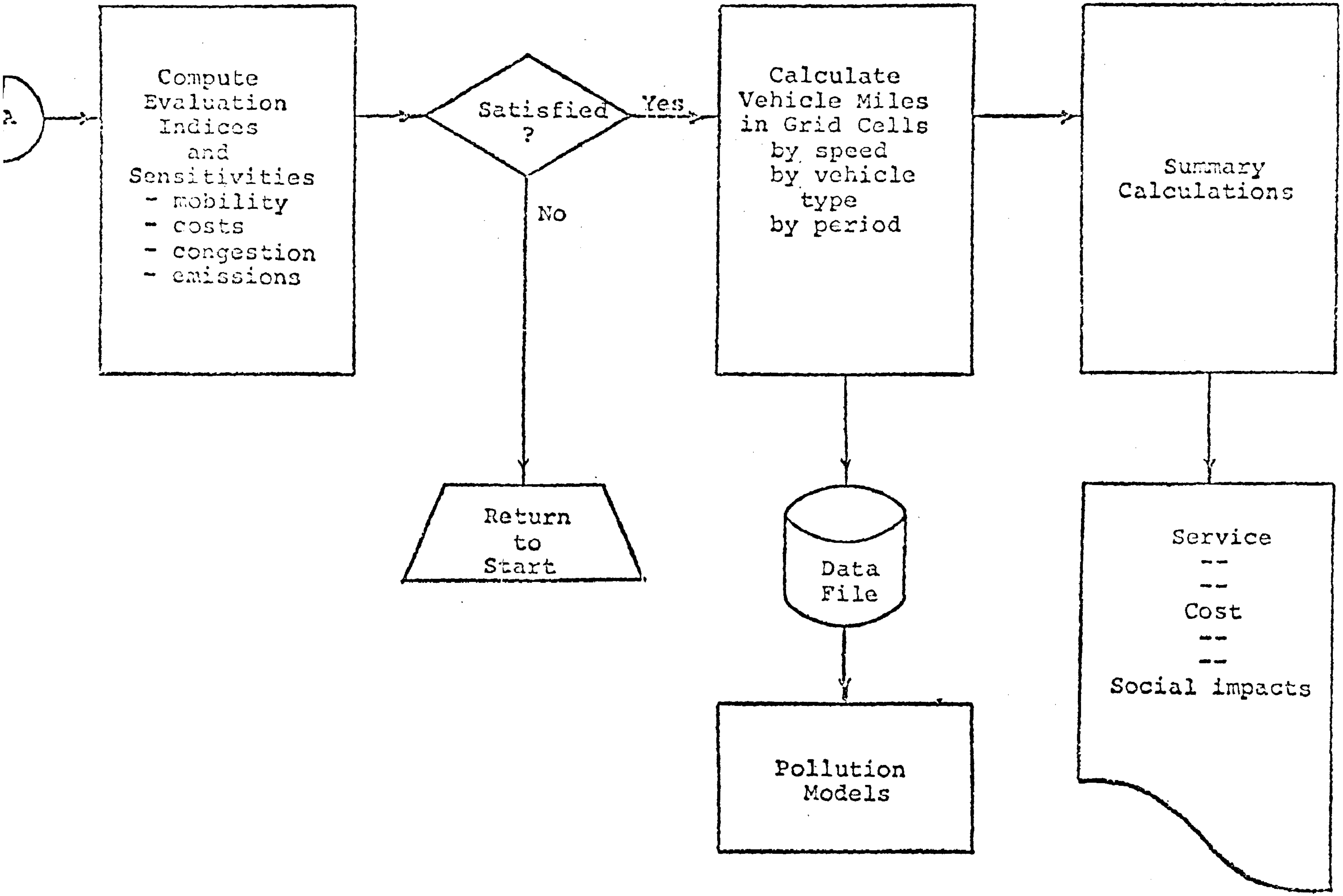
$$\begin{aligned} \% \text{ VMT Reduction} &= .725(32.4)\left(1 - \frac{1.21}{OCA}\right) \\ &= 23.5 \left(1 - \frac{1.21}{1.5}\right) \\ &= 4.4\% \end{aligned}$$

Figure 1

TRANSPORTATION MODEL




art
SYSTEM DESIGN
-by mode
-by period
TRANSLATOR
Design Parameters into Service Characteristics
-by mode
-by period
-by traveller income
REFERENCE TRIP TABLES
DEMAND GENERATION AND MODAL SPLIT
Predicts Travellers Desires
-by O-D pair (each direction)
-by mode
-by purpose
-by period
-by traveller income
NETWORK(S)
-connections
-capacities
-priorities
SUPPLY
°Load Travellers onto Modes
°Load Modal Vehicles onto Network(s)
°Estimate Congestion
°Estimate Times
°Estimate Costs
Supply & Demand Balanced ?
Yes
No
A


A
Compute Evaluation Indices and Sensitivities
- mobility
- costs
- congestion
- emissions
Satisfied ?
Yes
No
Return to Start
Calculate Vehicle Miles in Grid Cells by speed by vehicle type by period
Data File
Pollution Models
Summary Calculations
Service
--
--
Cost
--
--
Social impacts

EXAMPLES OF TRANSLATOR OPERATION

- Describe Policies in Natural Terms
  - -- Parking availability and cost, by area
  - -- Motor Vehicle Emission Control Device Policy
  - -- Specify O-D pairs with *direct* bus service
  - -- Specify headways
  - -- Priority and nonpriority capacities by link
  - -- Minimum priority-eligible carpool size
  - -- Taxes, license fees, parking fees

- Special Models Translate Policy to Service Characteristics
  - -- Parking availability implies delay
  - -- Motor Vehicle Emission Controls contribute to auto operating cost
  - -- Headways, direct bus service specification influences bus service characteristics

DEMAND GENERATION AND MODAL SPLIT

- USES EXISTING OR FORECAST TRIP TABLES AS STARTER
  - e.g., 1970 actual
  - e.g., 1975 San Diego forecast from California Highway Department
- PERTURBS THESE TO ESTIMATE DEMAND
- INCLUDES INDUCED DEMAND FROM SERVICE IMPROVEMENTS
  - predicts upper and lower bound as well as intermediate value
- USES MODIFIED VERSION OF EXISTING, CALIBRATED SAN DIEGO MODAL SPLIT MODEL
  - considers service characteristics for each mode
  - considers income distribution of travelers
- SERVICE CHARACTERISTICS CONSIDERED INCLUDE:
  - in-vehicle time
  - excess time (wait, walk, etc.)
  - user cost

  Service characteristics may differ with income group
- DEMAND IS DISTINGUISHED
  - by mode
  - by purpose
  - by period of day (AM-peak, PM-peak, off-peak)
  - by direction between an O-D pair.

SUPPLY: LOADING THE MODES

- AUTOMOBILE MODES INCLUDE: personal auto, car pool auto
- BUSSES INCLUDE: regular, mini, or dial-a-bus
- BUS COVERAGE: line-haul, low- or high-density area coverage
- BUS ROUTE: fixed or demand responsive (dial-a-bus)
- BUS ACCESS/EGRESS: walking, bus, auto park--or kiss-and-ride
- SEPARATE SUPPLY MODELS FOR EACH MODE
- GIVEN BUS DEMAND, AMONG ORIGINS AND DESTINATIONS ITERATIVELY DETERMINE LEAST COSTLY ROUTE STRUCTURE
- LOAD TRAVELERS INTO MODAL VEHICLES, BY PERIOD

SUPPLY: LOADING THE NETWORK(S)

- USES DETAILED, REALISTIC NETWORK
  - e.g., Division of Highways: 7000 links, 2300 nodes
- CONSIDERS ACTUAL LINK CAPACITIES
- PRIORITIES MAY BE SPECIFIED BY LINK, BY MODE, BY PERIOD
  - Link A for bus only
  - Link B for bus and car pools (e.g., 3 or more people)
- LOADS NETWORKS WITH VEHICLES, CONSIDERING PRIORITY AND CAPACITY
- CALCULATES CONGESTION - BY LINK, BY PERIOD
- CALCULATES TRAVEL TIMES AND COSTS BY O-D PAIR AND DIRECTION, MODE, PERIOD, PURPOSE
- ITERATIVELY RE-LOADS NETWORK(S) TO IMPROVE SERVICE.

OUTPUT OF TRANSPORTATION MODEL

- Person-Trips -- Volume, including induced
  - -- By O-D pair, purpose, mode, period of day, traveler income group, traveler residence
  - -- Highlights differences in travel behavior by different social groups
- Service Characteristics - User Time(s), Cost(s), Frequency
  - -- By O-D pair, mode, period of day, traveler income
  - -- Predicts accessibility to work, nonwork destinations
- Traffic Volumes
  - -- By network link, mode, traveler income, period of day, speed
  - -- Used with motor vehicle emission control model to obtain emissions
- To Distribute Impacts by Social Group
  - -- Predict impacts by income and residence group
  - -- Apportion the impact for a particular income-residence group among it's *component* social groups (e.g., race), based on estimators derived from census data

III. MODEL PURPOSE, METHOD OF OPERATION, AND SOURCES OF EFFICIENCY

PURPOSE

The purpose of the set of models described in this note is to predict a number of important potential impacts of a wide variety of transportation-related policies. The policies include any blend of the following:

- adjust parking price
- adjust parking availability
- priority routes for designated vehicles
- taxes and liscense fees
- fixed-route or demand responsive public transit

and many others. Impacts include:

- cost impacts
- economic impacts (e.g., employment)
- service impacts (e.g., mobility)
- environmental impacts (e.g., air quality)

The distribution of most impacts among socio-economic strata is also accomplished.

METHOD OF OPERATION--GENERAL

The straightforward method for accomplishing those purposes (and in part our method) is to follow these steps:

1. Partition the study region into a number of areas. Each area is to be treated as a single point, to and from which trips are made.
2. Specify the transportation policy, including technical and institutional factors.

3. Translate the policy variables into the transportation service characteristics perceived by the traveller.
4. On the basis of the service characteristics, predict the demand for travel from each area to every other area. Predictions are made for each mode, for various periods in the day, and for various trip purposes. Demand is also stratified by traveller characteristics (e.g., income).
5. Load the predicted demand onto the transportation systems provided. This is a process involving several steps.
   a) Put the predicted demand--i.e., person trips--in the appropriate modal vehicles. For example, put bus riders on busses following the appropriate routes.
   b) Load the modal vehicles on the appropriate networks of roadways and/or guideways.
   c) Examine the traffic flows on links of the network to determine congestion. If travel times are altered due to traffic volumes, re-load the networks. Repeat until no one can improve his service by changing his route.

d) Compare each traveller's new service characteristics with those from which demand was predicted. If there has been any significant change, return to step 4, and obtain a new prediction of demand. Otherwise (i.e., if service has not changed significantly), we say that demand and supply are "balanced," and we continue.

6. Evaluate the policy that was input at step 2. This requires certain criteria, against which one tests the policy's performance. These criteria should include:

   a) Mobility--how easily may members of different social groups get around?

   b) Costs--e.g., are there certain bus routes that cost a great deal and serve very little demand?

   c) Congestion--how much time is lost per day by travellers due to congestion?

   d) Emissions--does this policy reduce emissions as much as desired?

Also compute the sensitivities of these indices (mobility, cost, etc.) to changes in selected policy variables. If the policy is satisfactory--that is, meets all the criteria--we are finished. If not, these sensitivities will indicate what changes in policy variables must take place in order to more nearly satisfy the criteria. We then make the indicated changes, and re-enter at step 2 with our modified policy.

IV. TRANSPORTATION DEMAND AND MODAL SPLIT: THE POTENTIAL TRIPS APPROACH

In transportation modelling, one usually predicts total demand for trips first, and later apportions the trips among the different modes of travel (e.g., bus, auto). Depending on the model used, the total demand will depend on such things as population, per capita income, and amount of employment. The fraction of trips using each mode (called the modal split) will depend upon the service characteristics provided by that mode (e.g., trip time, cost, frequency of service). The function describing this dependence is called the conductance of the mode.

Clearly, this separation of a total demand prediction from the modal split operation is artificial. Moreover, for our purposes, (designing measures to reduce air pollution), it is not even approximately right. For this separation assumes that total demand is independent of the conductances, or service characteristics, of the different modes, and one possible measure for reducing emissions of air pollutants is to raise the price of travel, thus causing people to forego some trips.

On the other hand, we have no need to predict changes in total demand in response to changes in income or population. Thus we may simplify the demand prediction step, and having done so, combine it with the modal split step. We call our method the "potential trips approach".

We assume that no matter how good (within reason) the service becomes, there will still be a limit to the number of trips that will be taken. Call this limit $\overline{T}$. We also know that in the nominal case, the numbers of trips actually taken by each mode are T_A^* (for auto) and T_B^* (for bus), total T_N^*. (The superscript * will always refer to the value of a quantity in the nominal case.) Then we define the number of trips foregone in the nominal case, T_F^*, by the equation:

(1) $$T_A^* + T_B^* + T_F^* = \overline{T}.$$

One may think of T_F^* as the potential latent demand that may be realized by a sufficiently great improvement in, for example, the bus system.

We let W_A, W_B, be the conductances for auto and bus respectively, remembering that they are functions of the auto and bus service characteristics respectively. Their values in the nominal case are, of course, W_A^* and W_B^*. We take the "conductance" W_F^* of not making the trip to be the constant 1.

The conductance is defined so that, if the conductance of a mode (say auto) is changed, then the ratio of the mean number of trips by that mode to the old number of trips must be proportioned to the corresponding ratio of conductances. Thus:

(2)
$$\frac{T_A}{T_A^*} \alpha \frac{W_A}{W_A^*}$$

(3)
$$\frac{T_B}{T_B^*} \alpha \frac{W_B}{W_B^*}$$

By analogy we let:

(4)
$$\frac{T_F}{T_F^*} \alpha \frac{W_F}{W_F^*} = 1.$$

We also require that the new trips T_A, T_B and T_F sum to the maximum number of trips allowed. That is,

(5)
$$T_A + T_B + T_F = \overline{T}.$$

But equations (2) - (5) are easy to solve. We obtain

$$T_A = \frac{(T_A^* \frac{W_A}{W_A^*})\overline{T}}{T_A^* \frac{W_A}{W_A^*} + T_B^* \frac{W_B}{W_B^*} + T_F^*}$$

The two equations for T_B and T_F are similar.

Two questions remain: where does one obtain the conductances; and what is the source of $\bar{T}$? For the San Diego transportation model, the conductances are obtained directly from the San Diego Modal Split equation. This equation is:

$$W_m = \exp\left(c_m + \sum_i a_i X_{im}\right) \qquad (6)$$

where the subscript m refers to mode (bus or auto), the a_i and c_m are calibration constants, and X_{im} is the value of the i^{th} service characteristic for mode m. Service characteristics are line-travel time, excess time, and cost. (Actually, the San Diego modal split equation was originally expressed in terms of the differences in service characteristics between bus and auto, but the manipulations necessary to arrive at the equivalent equation (6) are trivial.)

Recall that $\bar{T}$ was an upper limit to the number of trips that would be taken, given the best reasonable quality of service. In San Diego, where there is virtually no congestion, no mode of travel is likely to provide better service times in the foreseeable future than auto does today. Further, for the very wealthy, the cost of travel by auto is of small importance. Thus in San Diego, we may take $\bar{T}$ to be the number of trips that the Division of Highways' demand model predicts would be taken if every household were very wealthy.

A lower bound on $\overline{T}$ is just the trips currently being made when service characteristics are the same as the nominal, then $T^*_F = T^*_F$. In this case, our potential trips model gives answers identical to the San Diego modal split model. Further, given a set of service characteristics, the potential trips model will predict the same modal split percentages among people who do travel as would the original San Diego model. But the number of trips will be different when the value chosen for $\overline{T}$ is different from the nominal number of trips taken $(T^*_A + T^*_B)$. For example, consider the following two scenarios:

(i) Auto service is degraded, and bus service held constant, until the split between the modes is equal.

(ii) Bus service is improved, and auto held constant, until the split is equal.

If $\overline{T}$ is taken to be the number of trips as if everyone were wealthy, then under scenario (i) we would predict a decrease in the total number of trips, while under scenario (ii) we would predict an increase. The San Diego model (and the potential trips model with $\overline{T} = T^*_A + T^*_B$) will predict the same total number of trips in either case.

BASIC DATA USED IN DAILY VEHICLE MILE CALCULATIONS

The data are based upon 1975 forecasts of:

1. Average auto occupancy for work trips of 1.1 persons per auto.

2. 18.8 miles per work round trip.

3. 400,000 daily vehicle work round trips.

4. 7.5 million daily vehicle work trip miles.

5. 21.0 million total daily vehicle miles.