AIR QUALITY IMPLEMENTATION PLAN DEVELOPMENT

FOR

CRITICAL CALIFORNIA REGIONS:

SAN FRANCISCO BAY INTRASTATE AQCR

PREPARED FOR

ENVIRONMENTAL PROTECTION AGENCY

JULY 1973

TRW / TRANSPORTATION & ENVIRONMENTAL OPERATIONS

AIR QUALITY IMPLEMENTATION PLAN DEVELOPMENT
FOR
CRITICAL CALIFORNIA REGIONS:
SAN FRANCISCO BAY INTRASTATE AQCR

TASK ORDER 19

CONTRACT NO. 68-02-0048

August 1973

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Redondo Beach, California

For The

Environmental Protection Agency
Office of Land Use Planning
Research Triangle Park, North Carolina

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1.0 SUMMARY

This report presents the results of an in-depth analysis of air pollution control measures potentially applicable to the San Francisco Bay Intrastate Air Quality Control Region (AQCR). The study was directed at identifying measures which would allow attainment of the National Ambient Air Quality Standards (NAAQS) promulgated pursuant to the Clean Air Act of 1970. Target date for attainment of the standards is as soon after 1975 as possible and no later than 1977.

The acceptability of the revised state implementation plans will be more critically evaluated than the original plans (submitted January 31, 1972), largely because of the decision of the Court of Appeals for the District of Columbia Circuit in NRDC versus EPA, Case No. 72-1522 (January 31, 1973). This decision holds that an adopted state implementation plan must contain measures which, if implemented, would achieve the NAAQS by May 31, 1975. The question of whether or not two-year extensions will be granted will be more strictly interpreted and based in part on more detailed technical support justification demonstrating such need. Portions of this report are intended to provide such technical support.

This document is an attempt to assess air pollution trends and control requirements for achieving the NAAQS in the San Francisco Bay Area. The pollutants of most concern are carbon monoxide, nitrogen dioxide, and photochemical oxidants. Of these, the most severe problems have come from photochemical oxidants, primarily ozone. In fact, it is inconceivable over the next decade at least, that oxidants will <u>not</u> be the limiting constraint for the region being able to achieve the NAAQS. Since ozone is a secondary pollutant (i.e., it is not a directly emitted contaminant), its control depends on eliminating the reactive hydrocarbons and nitrogen oxides which lead to its formation.

A major conclusion of the present study is that, in view of the severe air pollution in the San Francisco Bay Area and the extensive control measures which would be necessary to meet the NAAQS, a two year extension for reaching the oxidant standard is clearly justified. Any

attempts to achieve this standard sooner would result in a major social and economic disruption of the region. As currently projected controls eliminate major sources of pollution, the alternatives are putting additional controls onto already well controlled sources and/or controlling heretofore uncontrolled, minor sources. The former is frequently technology-limited, while the latter is very costly since the sources are many and relatively diffuse. Superimposed on the technical and economic constraints are social, institutional, and legal considerations. The impacts associated with more stringent controls will doubtlessly encounter obstacles on these fronts as well.

1.1 FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

The following sections summarize the major findings, conclusions, and recommendations that have emerged as a result of this study.

1.1.1 Findings

- Although air quality trends in the San Francisco Bay Area show improvement, recent air monitoring data for photochemical oxidants are still significantly above the NAAQS. Violations of the oxidant standard are both widespread throughout the Bay Area and fairly frequent, especially during the summer months.

- The topography and climate of the Bay Area are conducive to high oxidant levels being formed, especially in certain inland areas such as Livermore, Fremont, and San Leandro.

- Mobile emission sources (in particular, light duty motor vehicles) are and will continue to be the major contributors to the air pollution problem. However, because of projected controls, their relative contribution is slowly decreasing.

- Aircraft, motorcycle, heavy duty vehicle, and stationary source emissions are significant, minor sources of pollution; these sources become more significant as the target dates for compliance to air quality standards near.

- Existing and projected public transit services can handle modest increases in ridership over the short term.

- The present transportation planning efforts to meet transportation needs of the Bay Area's residents is long range in scope and geared to shaping land use patterns as well as transportation systems.

- The present life styles of the Bay Area appear incompatible with the established air quality goals; any foreseeable solution (if it exists) will have a major impact on the socio-economic fiber of the region.

- A multiplicity of agencies and organizations would be involved and/or affected by attempts to implement certain control measures; it appears that funding and institutional constraints will be very significant for many of the measures evaluated.

- The required enabling legislation to allow for several high priority control measures (e.g., mandatory inspection/maintenance and catalytic converter retrofit) will be difficult to obtain during the 1973 legislative session.

1.1.2 Conclusions

- Presently planned stationary and mobile source controls are inadequate for achieving the ambient air quality goals; therefore, additional control measures are clearly indicated.

- In 1977, attainment of the air quality standards through additional light duty vehicle controls would require their almost complete elimination.

- Controls on motorcycles, aircraft, heavy duty vehicles, and stationary sources could result in significant reductions by 1975 to 1977.

- Annual inspection/maintenance is necessary to obtain the full benefit of federal and state vehicle emission control programs.

- Catalytic converter retrofits offer major emission reduction potential. However, questions regarding the availability of lead free fuel and the widespread applicability of the devices remain unanswered.

- Presently planned transportation improvement programs will result in very minor air quality improvements.

- Control measure evaluations for vehicular miles of travel (VMT) reduction offer only modest gains towards the air quality objectives. Adequate alternative means of transportation available in the Bay Area are limited, more so in outlying regions than the areas close to downtown San Francisco.

- VMT reduction measures which offer the greatest potential generally affect areas utilizing public transit the most; therefore, issues of equity are raised.

1.1.3 Recommendations (see Chapter 8)

It is recommended that the Phase I control measures be implemented as quickly as possible. The continuation of the State's ongoing motor vehicle control program plus these measures should result in a significant improvement of the air quality by 1975 to 1977. The final decision regarding the implementation of the Phase II measures should be deferred until a careful analysis is made of the impact of such measures upon the residents of the region. Many issues noted in the report remain to be resolved. One critical issue which must be resolved is a possible conflict between the short term requirements being imposed by the Clean Air Act of 1970 and the long range transportation planning goals of the Bay Area. It is unclear if the short range measures being considered are consistent and compatible with the long range transportation system envisioned for the 1980's. If, through careful land use and transportation planning, the Bay Area can be directed toward less automobile dependence (an explicit goal of the region), every effort should be made to allow for this with a smooth transition. Short term controls which may be counterproductive to a smooth transition to long range goals will have to be carefully weighed before full implementation. This is especially critical in light of available funding for a limited number of of short and long term options.

1.2 LIMITATIONS OF THE ANALYSIS

The process of developing a demonstrably effective control strategy is fraught with many analytical difficulties and uncertainties. The severity and extent of specific uncertainties vary widely. Overall, many simplifying assumptions are made because data are either unavailable or limited in nature. In some cases, the errors resulting from certain simplifying assumptions tend to be offset by other assumptions; at other times, the errors from certain assumptions tend to be compounded.

The proposed control strategy represents the compilations, analysis, and interpretation of a large data base to arrive at the best estimates of the existing air pollution situation as well as requirements and methods for attaining the promulgated air quality standards. The nature

of the analytical methodologies and assumptions used for strategy development tend to result in propagation of errors. Therefore, the end result is likely to contain a significant degree of uncertainty.

Many issues which were identified as deserving closer scrutiny would not be examined in detail because of time and budgeting constraints. It is therefore highly recommended that as more comprehensive and accurate data become available, they be used to reevaluate the air pollution situation. This is especially important for regions, such as San Francisco, requiring large reductions in emissions to achieve the air quality goals.

To be acceptable, an air pollution control strategy must reduce emission levels sufficiently to allow for the attainment and maintenance of NAAQS. In addition, an implementable control strategy must consider the economic factors associated with its adoption as well as the social and political changes necessary to accommodate each specific control measure. Unfortunately, in many instances, these goals are diametrically opposed to each other. Strategies which are reasonably acceptable and potentially implementable are relatively ineffective. Conversely, strategies which are effective at reducing emissions sufficiently are also the least likely to be implemented and result in major socio-economic impacts. Although they are difficult to quantify, an attempt has been made in this study to discuss the socio-economic impacts and political aspects of the various measures.

The complexion of the air pollution problem centers around the assumptions made for the emission sources and the possible controls. A summary is presented below of several key assumptions made here, their limitations, and their impact on the overall problem.

1.2.1 Emission Factors

The mobile source emission estimates presented in this study are based on the latest available Environmental Protection Agency (EPA) emission factors. These emission factors are continually being revised in light of in-use and new vehicle testing programs being conducted by the EPA and others. It is highly recommended that newer and more reliable

emission factors be utilized as they become available to recompute the severity of the motor vehicle emissions.

Preliminary data indicate that emissions generated during the first few minutes of vehicle operation represent a large portion of the total emissions during any individual trip. This implies the reduction of total vehicle trips may be more important than reducing the vehicle miles traveled. Wendell, et.al. (1-1) have presented some preliminary data which illustrates the disproportionate share of emissions which are emitted when the engine is cold (Figure 1-1).

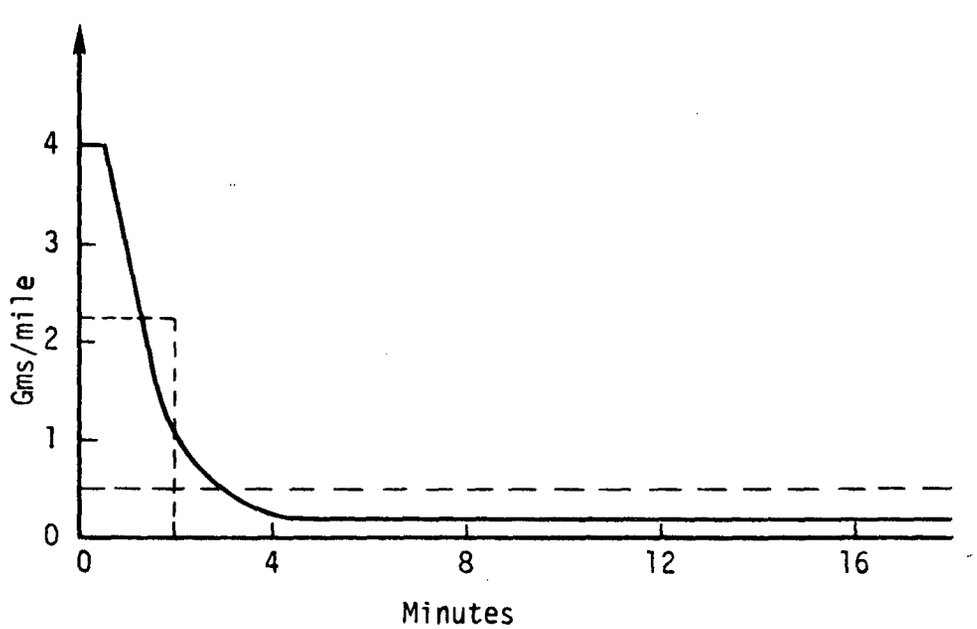

Figure 1-1. 1975 Carbon Monoxide Emissions
Based on the General Motors Report to the
Environmental Protection Agency (Reference 1-1)

Table 1-1 shows the percentage of carbon monoxide (CO) emissions which occur during the first two minutes of a "typical" trip. Also shown in Table 1-1 is the increasing importance of cold start emissions as motor vehicles become less polluting (increasing model year). The situation for hydrocarbon emissions is similar, with 80 percent from a typical trip occurring during the first two minutes.

Table 1-1. Cold Start CO Emissions for Various Model Year Vehicles

Model Year	% Emissions During First 2 Minutes
1960-1967	45
1968-1970	55
1971	62
1972	69
1973	76
1974	83
1975-1980	90

It is very apparent that with the advent of effective catalytic converters, the cold start emissions become the largest part of the vehicular emissions. This, of course, is because of the warm up times necessary for the catalysts to reach optimal operating conditions.

Cold start emissions, defined as the emissions emitted after a vehicle has not been in operation during the previous eight or twelve hours, occur primarily during the early morning as commuters start their

home-to-work trip. These starts are spatially well distributed because of the typical residential land use patterns.

The relative importance of cold start emissions is different for CO and photochemical oxidant problems. CO problems generally arise when the pollutant emission density builds up, e.g., congested central business district (CBD) traffic. The problem is dominated by short term diffusion and transport and can be alleviated with either a temporal or spatial redistribution of the pollutant loading. Because cold start emissions are spatially well dispersed, they do not play as important a role in CO problems as low speeds or stop and go traffic emissions.

On the other hand, cold start emissions do play a significant role in the severity of photochemical oxidant problems. Because of the reaction time needed to initiate and build up ozone levels, oxidant pollution has a more regional character. The most effective control strategy is to eliminate the total amount of reactants which can lead to ozone formation. Redistributing the emissions will only transfer the problem in time and/or space and not significantly reduce the severity of total oxidant levels. Since cold start emissions form a great part of total hydrocarbon emissions, strategies aimed at eliminating total trips, e.g., by substituting communication links to fulfill trip purpose, should be more important for oxidant control than measures which simply reduce total VMT.

Due to time and budgetary constraints, the impact of hot versus cold starts on total emissions and on the distribution pattern of pollutants, as well as the subsequent effect on air quality, was not analyzed in this study. It has been shown in Los Angeles that cold start emissions do play an important role in the nature of the oxidant problem (1-2, 1-3). It is therefore recommended that in future studies, which do employ more advanced modeling techniques, evaluation of the effect of hot versus cold start emissions be considered in control strategy development.

1.2.2 Traffic Data Projection

Historically, traffic data projections have not been collected with the intent of using them for estimating motor vehicle emissions. The

data, including vehicle flow speeds and model mixes, had to be reworked into a format appropriate for emission calculations. Potential inaccuracies were introduced by this process.

Projections of motor vehicle growth and VMT have been prepared by several different agencies, and little unaminity has been found concerning appropriate growth rates. Changes in traffic patterns and transit usage should be closely monitored between now and 1977 so that deviations can be determined and appropriate adjustment made in the control strategy.

1.2.3 Hydrocarbon Reactivity Assumptions

The limiting constraint for attaining the NAAQS in the San Francisco Bay Area is the photochemical oxidant standard. This implies that the most stringent controls are needed for reactive hydrocarbons (RHC) [and to a lesser degree the nitrogen oxides (NO_x)] which lead to oxidant formation.

Rollback calculations, which assume that normal oxidant concentrations are proportional to total RHC emissions, require certain assumptions regarding which components of the hydrocarbon emission inventory are to be considered reactive. To date, there have been numerous definitions of "reactive," many of which are inconsistent with one another. Most of these data have been based on smog chamber results which attempt to simulate certain atmospheric conditions. They are intended to show which hydrocarbon species will result in oxidant formation and under what conditions oxidants can be formed.

One frequently voiced objection to these types of results is their applicability to the "real world" situation. Even if the various scientific teams could agree on smog chamber results, the issue of the validity of the results in an urban environment with a wide range of particulate loadings, solar intensities, humidities, temperatures, and inversions, remains unresolved.

The reactivity assumptions used in this study have been provided by either the EPA or the California Air Resources Board (ARB). In several cases, significant differences of opinion exist on reactivity of certain

emission categories. The impact of different reactivity assumptions is very significant and can substantially affect the complexion of the problem. Using rollback calculations, higher reactivity assumptions, in and of themselves, do not make attainment of the standards more difficult. The key issue is the relative reactivity of different source types. If sources that are more easily controlled are considered to be more highly reactive, standard attainment actually becomes easier to demonstrate in strategy analysis.

Because of marked difference in control method effectiveness because of different reactivity assumptions, it is highly recommended that additional studies be initiated to clarify many of the uncertainties which presently exist regarding the definition of hydrocarbon reactivity. These studies should be aimed at resolving the inconsistencies which now exist among various industries and governmental agencies. More important, these studies could advance our knowledge of hydrocarbon reactivity as it pertains to oxidant formation in our urban environments.

1.2.4 The Rollback Method

A key calculation in control measure assessment centers on the relationship between projected emission levels and expected ambient air quality. Because of time and contractual constraints, it was not possible to utilize sophisticated modeling techniques in this study to develop this relationship. Rather, control strategy reductions were based on simple rollback assumptions which relate emissions and air quality on a proportional basis.

For oxidant, the simplistic linear rollback calculation actually understates the requirements for attaining clean air. That is, if a linear rollback model is used, the strategies which are developed will be more lenient than those which would be required according to either a statistical model or an analytical model which incorporates the photochemistry. This is documented by several studies(1-4 to 1-7) in which nonlinear models are used. These studies demonstrate that linear rollback calculations can greatly understate required RHC emission reductions for attaining the oxidant air quality standard.

The implications of this are clear. Even though the proposed control strategies evaluated are likely to result in substantial socio-economic impact, it appears that even with their successful implementation, there is no guarantee that the oxidant standard can be achieved by the required date. In fact, it is very probable that the standard will not be reached.

In view of the shortcomings of the linear rollback method, it is recommended that more rigorous modeling techniques, i.e., statistical and analytical, be used as they become available to reassess the impact of the recommended control strategy. These calculations should be repeated between now and 1977 as more recent air quality and emission inventory information become available.

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2.0 INTRODUCTION

This report presents the results of a study to evaluate potential control measures which will allow for attainment of the NAAQS between 1975 to 1977 in California's San Francisco Bay Intrastate AQCR. The control measure evaluation includes an assessment of technical effectiveness and economic impact as well as institutional, political, and social feasibility. The study was conducted by the Transportation and Environmental Operations of TRW, Inc., in conjunction with the DeLeuw, Cather and Company organization, a fully-owned subsidiary.

This chapter is intended to provide the reader with some background information on the air pollution problem in the San Francisco Bay Area. The objectives of the study as well as a regional description and a problem definition are presented. Chapter 3 discusses the baseline data to be used in control strategy development. Air quality data is first analyzed in order to select a base year. A baseline emission inventory is then organized. Finally, the transportation data base is assembled.

Chapter 4 develops the proposed control strategy. A menu of alternative control measures is first presented. Each control technique is briefly discussed. This information along with the baseline data of Chapter 3, allows a critique of the California ARB Implementation Plan. Finally, a proposed control strategy is presented. The strategy is divided into two phases. The first phase is highly recommended and should be instituted as soon as possible to achieve maximum effectiveness. The second phase measures appear to be necessary to achieve the desired air quality goals, and while there is no question they would result in cleaner air, the associated impact of these measures is so overwhelming, they are <u>not</u> recommended for implementation.

Following the proposed control strategy, Chapter 5 discusses the economic impact of the controls. Chapter 6 examines social impacts which are closely related to the institutional and political feasibility of the proposed measures and which dictate what measures will ultimately be imposed upon the region. Chapter 7 focuses on the government organizations

involved with transportation in the San Francisco Bay Area and on the transportation funding mechanisms which are available.

Finally, Chapters 8 and 9 deal with control strategy implementation. The discussion includes the regulating agencies involved, time scheduling, legal considerations, and means for monitoring implementation progress. Potential obstacles to implementation are highlighted. These chapters also point out the dichotomy of the regions' desire for clean air and its apparent unwillingness to give up the private auto for most transportation requirements. Controls for reducing air pollution are acceptable only up to a point, the point being when the controls infringe on present life styles. An important question is how severely restrictive measures are to be implemented and enforced and whether or not the anticipated impact on the public are warranted.

Following the main body of the report are a series of appendices which contain related, additional support information. Time was too limited to undertake a detailed analysis of all the reports available on the subject. The most important information sources which have been used in preparing this document have been included in the reference lists following each chapter.

2.1 STUDY OBJECTIVES

The purpose of this study is to develop control strategies which demonstrate attainment of the carbon monoxide (CO), oxidant, and nitrogen dioxide (NO_2) air quality standards in the San Francisco Bay Intrastate AQCR as soon after 1975 as possible but no later than 1977. In doing so, this work is an extension of other EPA studies to develop transportation control strategies for critical AQCR's across the country -- the Six Cities Study (2-1) and the Fourteen Cities Study (2-2). This report will follow up on much of the work initiated in that study, extend it to the San Francisco situation, and update much of the applicable California information which has changed since that study was released.

The majority of EPA studies have centered on the development of control strategies for <u>transportation</u> sources only in order to meet the NAAQS. The severity of air pollution in San Francisco and the emission

reduction requirements necessary to achieve the air quality goals, require an evaluation of all sources. As in the Los Angeles situation, transportation controls in and of themselves, are insufficient for reducing emissions to the required levels. The anticipated reduction in motor vehicle emissions which will result from the federal new car standards will mean that, towards the end of this decade, the percentage contribution from motor vehicles to the total pollution load will be significantly reduced. Additional controls imposed on motor vehicles will become less effective overall. Other sources will be very important, and they must be controlled to achieve the NAAQS.

Of the pollutants cited above, only CO and photochemical oxidants presently exceed the promulgated standards. Annual NO_2 averages are currently below the national standard and are projected to stay below the limits established. Like Los Angeles and many other California areas, by far the most difficult standard to attain in the Bay Area is the 0.08 ppm one-hour average for photochemical oxidants. In the near future, the oxidant standard will certainly be the limiting constraint.

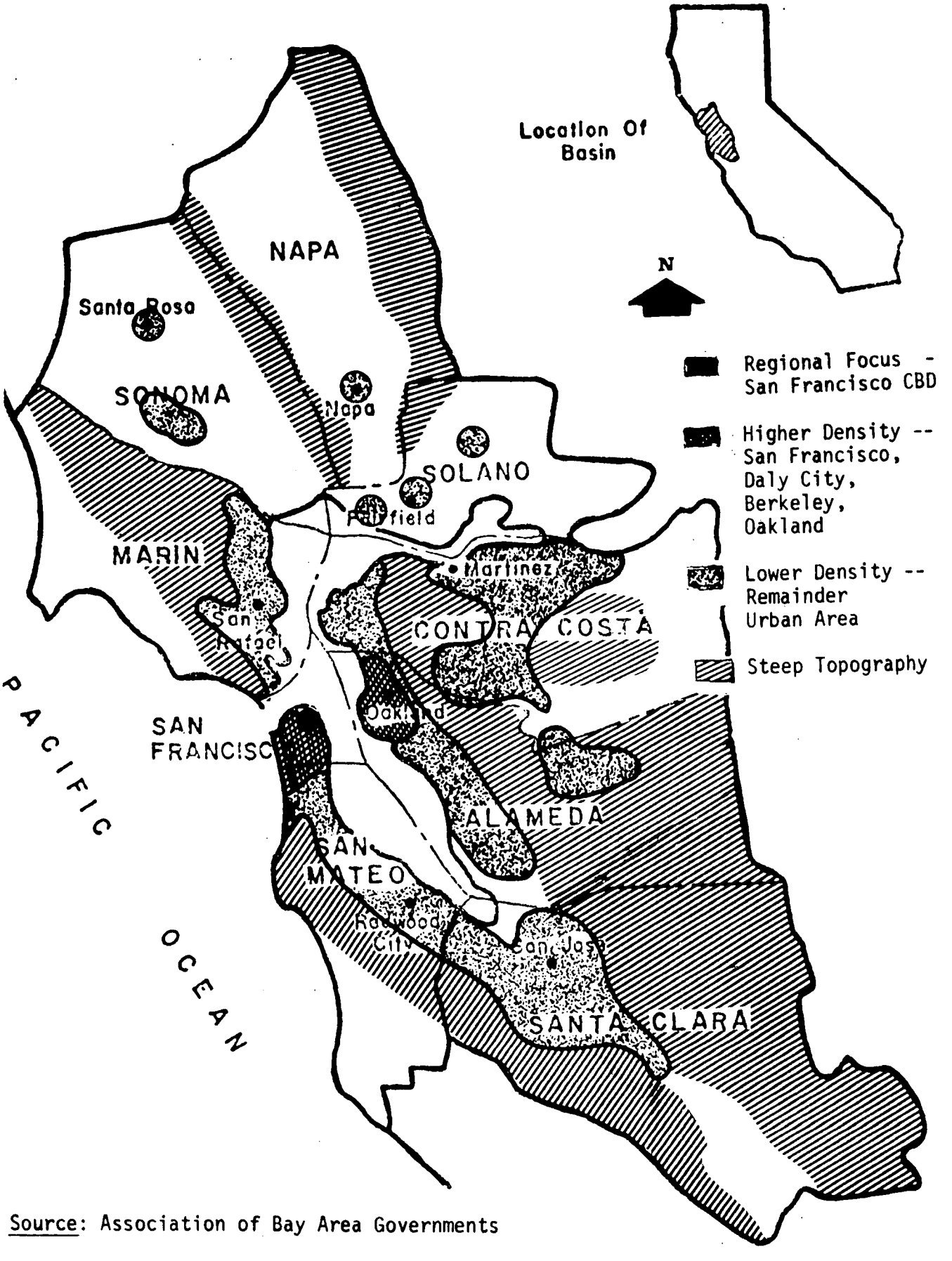
2.2 REGIONAL DESCRIPTION

The San Francisco Bay Area Intrastate AQCR, also known as the San Francisco Bay Area Air Basin, consists of all of seven counties -- namely, Alameda, Contra Costa, Marin, San Francisco, San Mateo, Santa Clara, and Napa -- and portions of two others -- southwestern Solano and southern Sonoma.

2.2.1 Physiography

Topographically, it resembles a shallow bowl with a low central bay area, rimlike mountains, and connecting valleys. The region covers more than 5,000 square miles and includes some 4.6 million people and 2.7 million motor vehicles. Figure 2-1 presents a map of the region including its development pattern and illustrates its location within California.

Table 2-1 illustrates the vast differences in the intensity of human activity over the nine county region. San Francisco County has more than 15 percent of the region's population but less than 1 percent of its land area. Included portions of Napa, Sonoma and Solano Counties together



Source: Association of Bay Area Governments

Figure 2-1. San Francisco Bay Intrastate AQCR

Table 2-1. San Francisco Bay Area Air Basin Population and Land Area

County	County's Population in Basin - 1970		% of County's Population in Basin	Area in Basin (Mi^2)		Population Density ($Persons/Mi^2$)
Alameda	1,063,800	23.5	100	733	13.2	1451
Contra Costa	558,100	12.3	100	733	13.2	761
Marin	203,300	44.5	100	520	9.4	391
Napa	79,400	1.8	100	787	14.2	101
San Francisco	699,200	15.4	100	45	0.8	15,338
San Mateo	556,000	12.3	100	447	8.1	447
Santa Clara	1,070,000	23.6	100	1300	23.4	823
Solano	124,500	2.7+	79.7	358	6.5	348
Sonoma	178,900	3.9+	87.2	620	11.2	289
	4,533,200	100.0		5,543	100.0	818

Source: State of California, The Resources Agency, Air Resources Board, The State of California Implementation Plan for Achieving and Maintaining the National Ambient Air Quality Standards, January 30, 1972. Based on information supplied by the State Department of Finance.

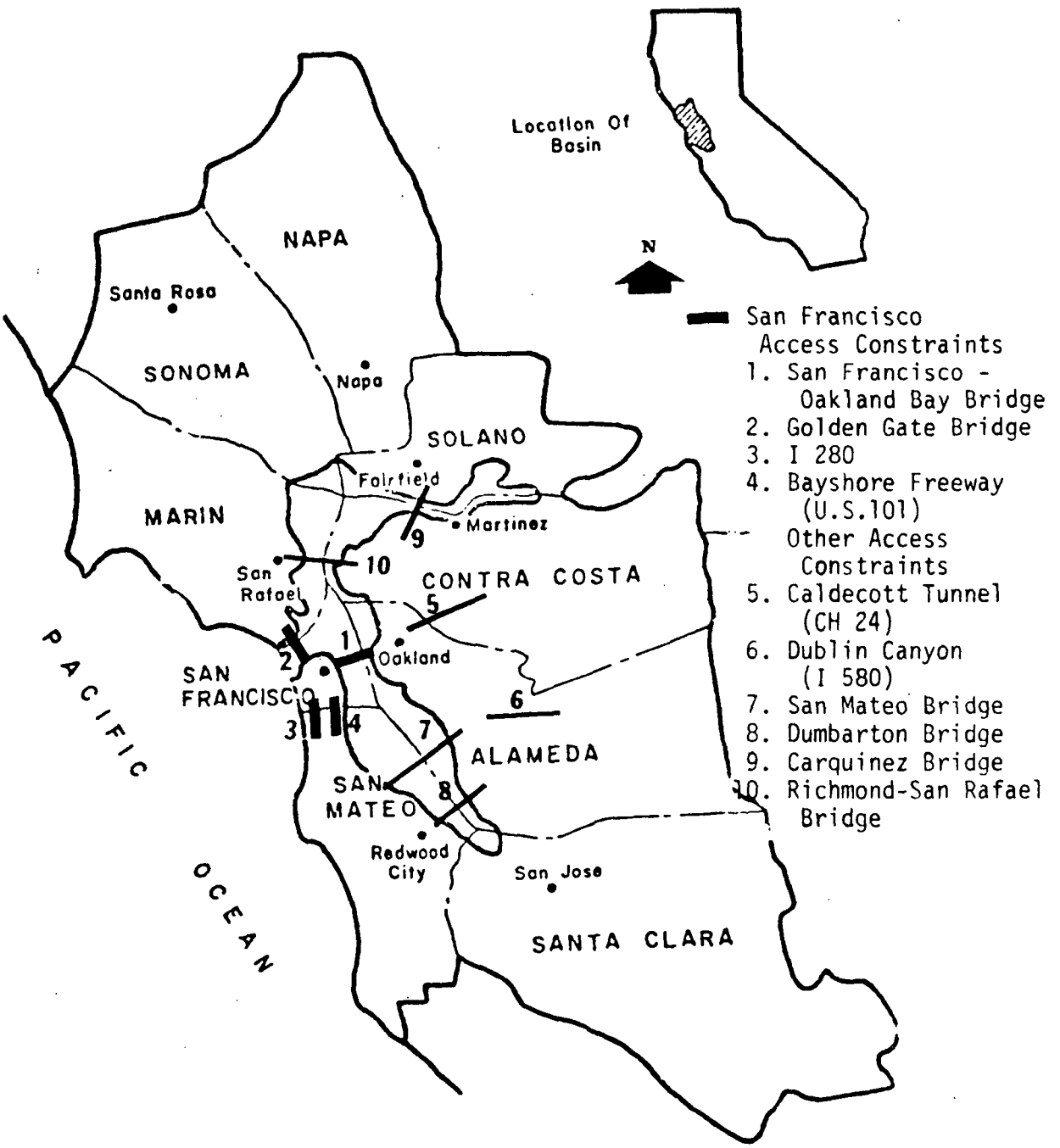
hold less than 9 percent of the region's population but 32 percent of its land area. A narrow bayside plain extends for a distance of 100 miles along the central and southern portions of the bay, containing almost uninterrupted urban development. This strip, comprising only some 10 percent of the region's land area, holds 80 percent of the regional population and some 90 percent of its employment. The lineal pattern of development has maintained a strong regional focus on the San Francisco CBD with a surrounding concentration of higher density development in the remainder of San Francisco, Daly City, and older low-lying sections of Oakland and Berkeley. The remainder of the Bay Area is of lower density and highly auto-oriented, not unlike development in other cities in the Western United States. In 1980 about three-quarters of Bay Area residents are expected to live in what the Bay Area Transportation Study (2-3) termed low density areas -- zones with less than 10 dwelling units per net residential acre.

The region's urban corridors are linked together by a limited number of bridges, tunnels, and freeway facilities. Often only one critical link exists across a topographic barrier, forming a natural constriction on vehicular flow (Figure 2-2), a factor which contributes to relatively high transit usage in commuting. About 55 percent of the commuting to the San Francisco CBD is by transit while roughly 20 percent of all Bay Area employees traveling over 10 miles prefer bus or rail over the automobile (2-4).

2.2.2 Meteorology

The climate of the San Francisco Bay Area is typical of California coastal zones. Late fall and winter are cool and windy and experience the greatest part of the region's moderate rainfall. Spring weather is variable. Most summer days are dry and sunny.

Wind patterns in the basin vary as a function of location and as a function of both time of day and season. The most frequent daylight pattern is a moderate sea breeze radiating from the coast and central Bay Area. In the evenings, the wind direction frequently reverses to a land breeze. Air movement and stability are usually dominated by the



Source: Metropolitan Transportation Commission

Figure 2-2. Key Access Constraints Within the Bay Area

Pacific high pressure zone and the associated subsidence temperature inversion. The inversion is strongest during the summer and early fall, varying daily from 1,000 to 3,000 feet.

Winds normally provide adequate ventilation to the Bay Area. However, during the summer and early fall, the persistent temperature inversion is sometimes accompanied by nearly stagnant wind conditions. This situation leads to an excessive accumulation of pollutants. Since such days are associated with moderate to high temperature and solar radiation, a photochemical smog problem results.

2.3 PROBLEM DEFINITION

Air quality measurements taken in the San Francisco region show air pollution to be a severe problem. The severity is indicated by several indices -- the geographical extent of the problem, the number of days per year various standards are violated, and the magnitude by which standards are exceeded. The extent of the problem is summarized in Table 2-2 which shows the highest readings and number of days certain levels were exceeded at various sites throughout the basin. As shown, maximum oxidant readings often exceed the air quality standard by more than fourfold. Due to moderately favorable climatology, the frequency of violations at any given station is at most, about one day in seven.

It is interesting to note that many of the Los Angeles regional characteristics are also prevalent in the San Francisco Bay Area. Overall, the population density in the San Francisco Bay Area is <u>less</u> than in the Los Angeles region. Only San Francisco County has a high population density, (15,338 persons/square mile), compared to the regional 818 persons/square mile.

The severest air pollution does not occur in the active, high density central area, but rather downwind of that area. In the South Coast Air Basin, the most critical problem areas are places like Riverside, Indio, and Banning -- areas east of central Los Angeles. In the San Francisco region, severe problems exist in San Leandro, Fremont, and Livermore -- all regions downwind of the more populous, urban areas. Even the outskirts of the airshed experience pollution, and it has

Table 2-2. Air Pollution in the Bay Area
(1971-1972)

Location of Stations	OXIDANT				CARBON MONOXIDE				NITROGEN DIOXIDE
	1971		1972		1971		1972		1971
	Maximum[1]	Violations[2]	Maximum	Violations	Maximum[3]	Violations[4]	Maximum	Violations	Annual Average
San Francisco	.15	2	.08	0	11	3	11.7	1	.027
San Rafael	.18	9	.17	5	8	0	7.7	0	.024
Richmond	.28	7	.12	7	13	1	9.1	0	.021
Pittsburg	.20	23	.19	25	6	0	5.1	0	.022
Walnut Creek	.23	36	.17	30	-	-	-	-	-
Oakland	.31	10	.12	1	11	2	7.2	0	.040
San Leandro	.36	21	.17	15	-	-	-	-	-
Fremont	.33	45	.34	44	9	0	6.5	0	-
Livermore	.23	52	.22	27	8	0	6.5	0	.025
San Jose	.15	14	.20	19	17	12	13.8	11	.034
Redwood City	.28	17	.28	17	7	0	9.2	0	.030
Burlingame	.17	5	.14	8	10	1	9.9	0	-
Petaluma	.12	6	.07	0	-	-	-	-	.013
Napa	.14	9	.18	20	9	0	7.4	0	
Vallejo	.19	11	.26	15	13	6	12.1	5	.018
Fairfield	.18	12	.13	4	-	-	-	-	-
Los Gatos	-	-	.21	15	-	-	-	-	-
Mountain View	-	-	.19	10	-	-	-	-	-
Santa Rosa	-	-	-	-	-	-	-	-	.020

[1] Highest hourly average in ppm

[2] Number of days one hour average of 0.10 ppm was exceeded

[3] Highest 12-hour average in ppm

[4] Number of days 12-hour average of 10 ppm was exceeded

Source: Bay Area Air Pollution Control District

frequently been suggested that pollution from the Bay Area spills over into adjacent regions, e.g., the Sacramento Valley Air Basin. This is analogous to transport of pollutants in the Southeast Desert from the South Coast Air Basin.

As indicated by Figure 2-3, recent trends for the Bay Area show a significant improvement in air quality. The majority of monitoring stations show improvements, with only a couple of sites experiencing more adverse conditions. Appendix A presents a more complete description of recent air quality throughout the Bay Area as well as a map of the monitoring stations.

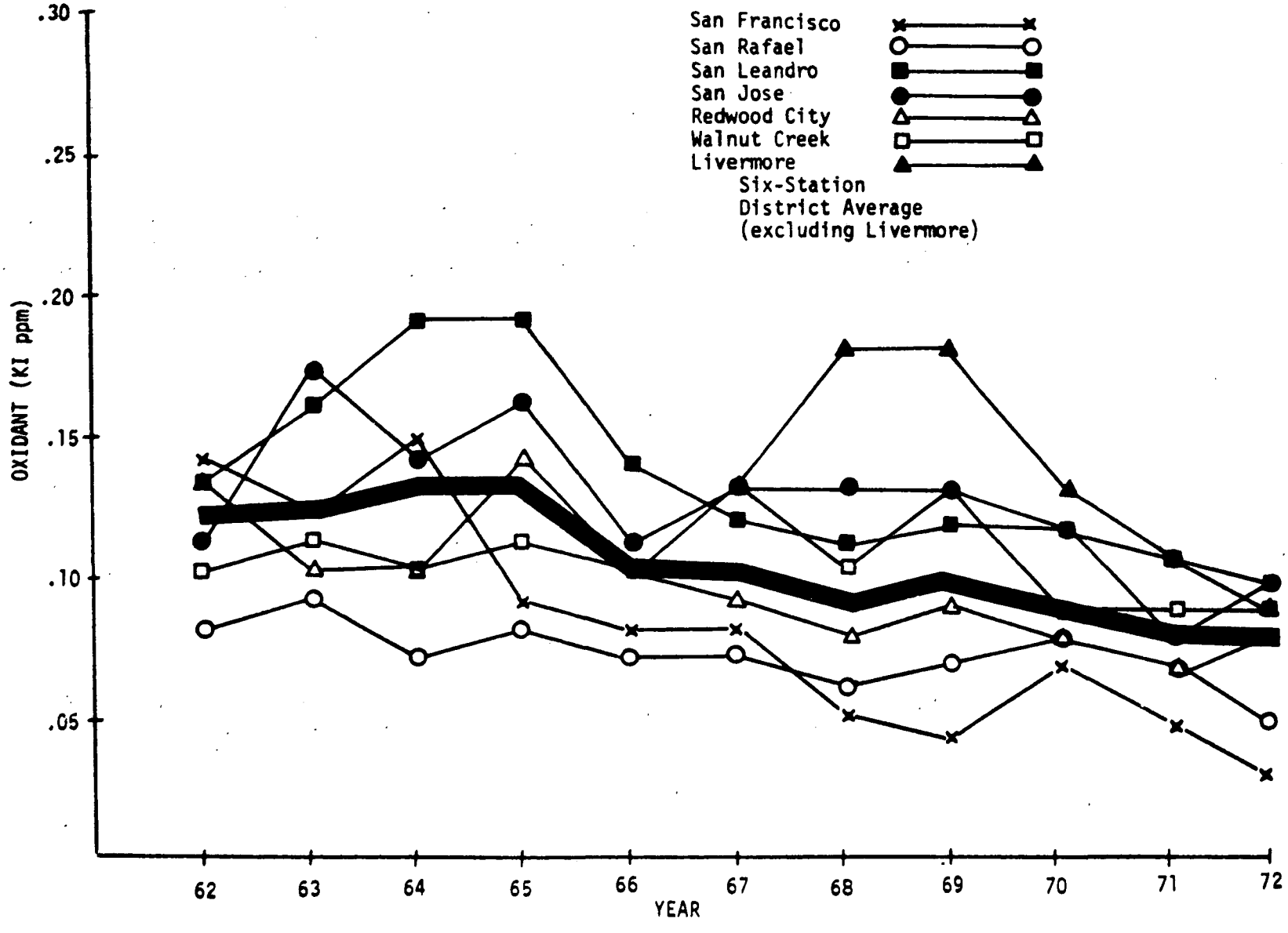


Figure 2-3. Trend of Average High-Hour Oxidant Concentrations for Days with Comparable Temperature and Inversion Conditions (April through October Photochemical Oxidant Seasons, 1962-1971)

2.4 REFERENCES

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3.0 BASELINE DATA

Before a meaninful air pollution control strategy can be developed, the base conditions of the pollution problem must be thoroughly determined. Air quality levels must be examined so that overall emission level reductions required to meet air quality standards can be calculated. For the present study, this task specifically involves choosing a "base year," finding air quality for that year, and calculating "rollback" percentages needed to meet the standard. In addition, an emissions inventory must be organized for the base year and projected to the years of interest in the future. This baseline inventory, in conjunction with the "rollback" calculations, will determine "allowable emissions" for each pollutant. The inventory will also serve as the basis for examining the effect of alternate emission control strategies. Finally, since motor vehicles turn out to be the major source of air pollution, a transportation base data is needed. This data will help to determine the effect of various motor vehicle control strategies, including reduction in vehicle miles.

Section 3.1 discusses base year selection, base year air quality, and rollback calculations. Section 3.2 develops the baseline emission inventory, (base year inventory plus projections according to a "nominal control strategy"). Section 3.3 describes the transporation base data for the San Francisco Bay Area AQCR.

3.1 AIR QUALITY DATA AND BASE YEAR SELECTION

Section 2.3 emphasized that the San Francisco Bay Area AQCR has a severe air pollution problem. This severity is reflected in the geographic extent of the pollution, in the frequency with which standards are violated, and by the magnitude of standard violations on the most polluted days. In formulating a control plan for this problem, existing air quality must be studied to determine what overall emission reductions factors are needed to attain the federal air quality standards.

According to federal regulations, an adequate control plan must include sufficient emission reductions to meet the federal air quality standards even during the most adverse meteorological circumstances.

To help assure this goal, it is necessary to design the control plan around the most difficult set of conditions, i.e., the year with the most blatant violation of the federal air quality standards. This is referred to as the "base year." Because of guidelines provided by the EPA, the base year was selected from the 1970 to 1972 range.

3.1.1 Base Year Selection

An examination of air monitoring data from 19 stations in the San Francisco Bay Area AQCR for the years 1970 to 1972 yields the following conclusions:

- The maximal one-hour average oxidant in the region during 1970 to 1972 was .36 ppm at San Leandro on September 13, 1971.
- The maximal eight-hour average CO in the region during 1970 to 1972 was 17 ppm at San Jose on November 4, 1971.
- The maximal annual mean NO_2 in the region during 1970 to 1972 was .048 ppm at San Francisco in 1970, the second highest was .04 ppm at Oakland in 1971.

The federal standards for oxidant (.08 ppm - 1 hour) and for CO (9 ppm - 1 hour) were considerably exceeded. The standard for NO_2 (.05 ppm - annual mean) was not exceeded. Also, the NO_2 standard should not be exceeded in the future because total NO_x emissions will decrease considerably as new car NO_x controls take effect.

The two pollutants which exceed the standard and require control plans both attain maximal violations in 1971. 1971 is therefore the appropriate choice as "base year" for the San Francisco Bay Area.

3.1.2 Rollback Requirements

Table 3-1 gives the maximal air pollution levels for 1971 in San Francisco and compares them to the federal standards. The percentage "roll-back" in RHC emissions (assumed proportional to maximal oxidant) and in CO emissions to attain the standards is also presented. The base

year emission levels for RHC and CO, (calculated in the next section), are given here also so that "allowable emission levels" can be computed from the rollback percentages.

Table 3-1. Rollback Calculations and Allowable Emission Levels

Pollutant	1971 Air Pollution Level	Federal Air Quality Standard	Rollback Required	1971 Emission Level	Allowable Emission Level
Oxidant (RHC)	.36 ppm - 1 hour	.08 ppm 1 hour	78%	567	125
Carbon Monoxide	17 ppm - 8 hours	9 ppm 8 hours	47%	2573	1364

3.2 BASELINE EMISSION INVENTORY

Table 3-2 presents the baseline emission inventory for the San Francisco Bay Area AQCR. Average tons per day emissions are given for total hydrocarbons (THC), RHC, NO_x, and CO. Subdivisions are made according to source class (stationary, aircraft, and motor vehicle) and within source class according to specific source type.

The baseline consists of the base year (1971) and projections through 1975, 1977, and 1980 for a "nominal control strategy." An unambiguous definition of "nominal control strategy" is not readily apparent; control regulations are in a state of rapid flux. The decision as to what controls enter the baseline inventory is thus somewhat arbitrary. The important point in constructing the baseline is to carefully delineate the assumed, nominal controls. In the present study, the baseline case assumes the following control strategy:

a) For stationary sources, the baseline control is the degree of control existing in the base year (1971).

b) For aircraft, the baseline is the present federal control program (burner-can retrofit and emission standards for future new engines).

c) For heavy duty motor vehicles and diesels, the baseline consists of the present federal control program. Motorcycles have no controls. For light duty vehicles, the

present California/federal new car controls and the present California ARB retrofit program [positive crankcase ventilation (PCV) valve and exhaust devices for 1955 to 1965 and 1966 to 1970 vehicles] are assumed.

To emphasize the relative significance of the two or three major sources of air pollution in San Francisco, pie charts have been constructed for the 1971 base year inventory. These charts, shown in Figure 3-1, give the percent of base year emissions attributable to each source category. Figure 3-1 also indicates that for each pollutant, motor vehicles (light duty, heavy duty, diesels, and motorcycles) were the major contributors in 1971. Other significant sources of RHC were petroleum marketing, organic solvent use, and aircraft. Fuel combustion in the petroleum, power, and residential - commercial sectors are also significant contributors of NO_x.

Table 3-2 indicates that the relative importance of various sources changes considerably in the 1970's under the assumed baseline controls. The new car and retrofit control programs greatly reduce emissions from light duty motor vehicles (LDM). For this decade, the present federal control strategy essentially just "holds the line" on aircraft, heavy duty motor vehicles (HDMV), and diesel emissions. With no further control assumed in the baseline, stationary source emissions continue to expand as activity in the region grows.

The specific assumptions and calculations used to construct the baseline inventory are presented in Sections 3.3.1, 3.3.2, and 3.3.3 below. These deal with the stationary source, aircraft, and motor vehicle source classes respectively and present the details on base year data, reactivity assumptions, nominal controls, and projection techniques. The limitations of the assumptions and analysis are also thoroughly discussed.

3.2.1 Stationary Sources

3.2.1.1 Baseline Stationary Source Inventory

The base year, San Francisco Base Area, stationary source inventory for THC, NO_x, and CO is derived from 1971 San Francisco Bay Area APCD data(3-1). For most categories, with a slight adjustment for growth,

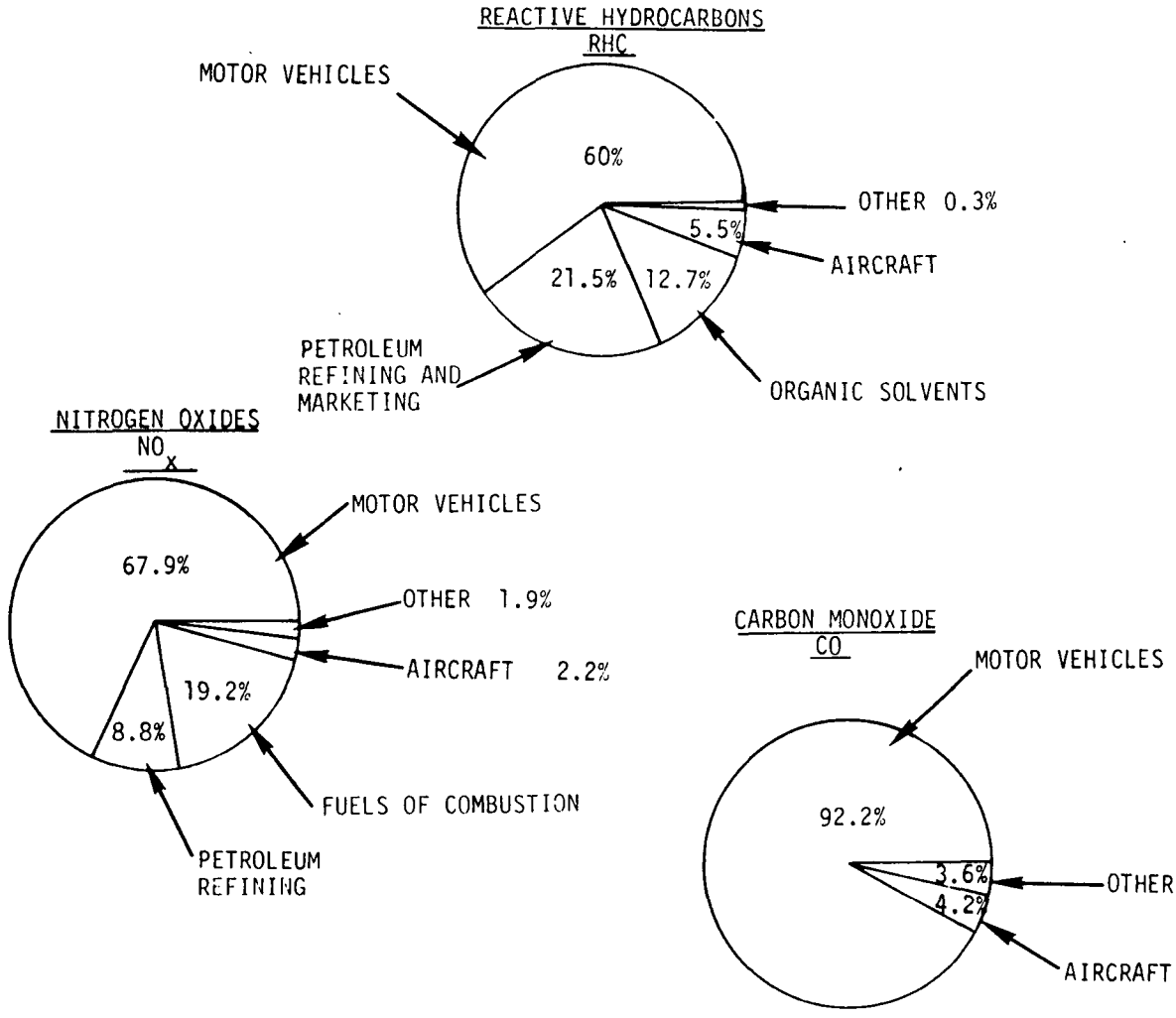


Figure 3-1. San Francisco Bay Area AQCR Major Contributors 1971 Base Year Emission Inventory

Table 3-2. San Francisco Bay Area AQCR Baseline Emission Inventory, 1971, 1975, 1977, and 1980

SOURCE	1971				1975				1977				1980			
	THC	RHC	NOX	CO	THC	RHC	NOX	CO	THC	RHC	NOX	CO	THC	RHC	NOX	CO
Stationary Sources																
Petroleum Refining	54	5	55	9	61	6	55	9	64	6	55	9	71	7	55	9
Petroleum Marketing	126	117	-	-	142	132	-	-	150	140	-	-	166	152	-	-
Organic Solvents:																
Surface Coating	210	42	-	-	222	44	-	-	229	46	-	-	246	49	---	-
Dry Cleaning	24	5	-	-	25	5	-	-	26	5	-	-	28	6	-	-
Degreasing	46	9	-	-	49	10	-	-	51	10	-	-	54	11	-	-
Other	80	16	-	-	85	17	-	-	88	18	-	-	94	19	-	-
Chemical Industries	21	-	3	27	25	-	3	32	27	-	4	34	30	-	4	38
Incineration and Agricultural Burning	8	1	-	25	8	1	-	25	8	1	-	25	8	1	-	25
Fuel Combustion:																
Steam Power Plants	1	-	58	-	1	-	61	-	1	-	63	-	1	-	68	-
Residential, Commercial, and Industrial	2	-	62	21	2	-	66	-	2	-	68	-	2	-	73	-
Other:																
Mineral, Food, Lumber, and Metallurgical	17	-	8	10	20	-	10	12	22	-	11	13	24	-	12	15
Subtotal — Stationary	589	195	186	92	642	215	195	78	670	225	201	81	726	245	212	87
Aircraft	34	31	14	110	38	34	21	152	38	34	25	177	37	33	33	192
Motor Vehicles																
Light Duty Motor Vehicles	362	301	326	2137	209	170	273	1301	154	123	213	933	94	73	137	522
Heavy Duty Motor Vehicles	23	19	20	131	23	19	22	149	22	18	21	154	19	16	19	163
Diesels	9	9	78	54	10	10	103	62	10	10	96	56	9	9	87	46
Motorcycles	13	12	-	49	17	15	-	60	19	17	-	69	22	20	-	81
Total	1030	567	624	2573	939	463	614	1802	913	428	556	1470	907	396	488	1091

this data is equivalent to the 1970 ARB inventory for stationary sources in San Francisco(3-2). Major differences occur only in the agricultural, incineration, and lumber burning categories, reflecting the assumed effects of burn-no-burn regulations and other burning regulations established by 1971.

Table 3-3 presents the hydrocarbon reactivity assumptions used in the stationary source inventory. For each stationary source except petroleum marketing, 1970 ARB assumptions on hydrocarbon reactivity are used. These in turn are based on Los Angeles County APCD reactivity figures. According to recent EPA specifications (3-3), petroleum marketing emissions were taken as 93 percent reactive, (whereas the ARB uses a 45 percent reactivity). Hydrocarbon reactivity assumptions are very critical to oxidant control strategies. Unfortunately, they are among the least reliable values used here. The reactivity assumptions will be discussed in more detail in Section 3.2.1.2.

Table 3-3. Reactivity Assumptions for Stationary Sources

Stationary Source	Reactivity (%)	Reference
Petroleum Refining	10	3-2
Petroleum Marketing	93	3-3
Organic Solvents		
--Surface Coating	20	3-2
--Dry Cleaning	20	3-2
--Degreasing	20	3-2
--Other	10	3-2
Burning: (Incineration, Agricultural, Lumber)	10	3-2
Other:	0	3-2

To complete the baseline stationary source inventory, the 1971 inventory is projected to 1975, 1977, and 1980 with the basic assumption that the degree of emission control existing in 1971 is preserved. The 1971 control level results from Regulations 1, 2, and 3 of the San Francisco Bay Area APCD. These baseline controls are outlined in Table 3-4.

The effects of these controls are as calculated by the San Francisco APCD and the California ARB with one exception. It is assumed here that burn-no-burn regulations are 90 percent effective in limiting emissions on days when air quality standard violations occur. (No allowance for this is made by the APCD or ARB.)

Table 3-4. Baseline Stationary Source Controls of Hydrocarbon, RHC, CO, and NO_x for the San Francisco Bay Area AQCR (Reference 3-4)

Source	Control
Petroleum Refining	Floating roofs and other systems to prevent vapor losses.
Petroleum Marketing	Submerged fill pipes at gas stations Some systems at bulk terminals.
Organic Solvents	Rule 66 type regulation limiting reactive hydrocarbon emissions.
Incineration and Agricultural Burning	No backyard burning. Other open burning restrictions. Agricultural burn-no-burn regulations.* Limits on organic emissions from incinerators.
Other: Lumber	Burn-no-burn regulations of certain types of lumber burning.*

*It is assumed that burn-no-burn regulations are 90 percent effective in limiting emissions on days when air quality standard violations occur. All of agricultural burning and about 1/2 of lumber burning is covered by burn-no-burn rules.

The growth rate assumptions in the baseline inventory varied from source to source. They are summarized in Table 3-5. For most sources projected growth was assumed proportional to population growth. For certain industries which are expanding at rates significantly different from population growth rates, emissions were projected according to expected growth in constant dollar earnings for those industries. The choice of constant dollar earnings as a growth indicator was arbitrary. Emissions for these industries could also have been taken as proportional to production. However, production type projections make no allowance for technological improvements. Constant dollar earnings grow more

slowly than production and thus have the right sign to allow for technological process changes. A third type of assumption was used for petroleum marketing emissions. Growth was taken as proportional to growth in gallons sold. The technical aspects of the problem indicate that, for a given degree of control, this should be a very realistic assumption.

Table 3-5. Growth Assumptions for Stationary Source Emissions

Source	Growth Assumption
Petroleum Refining	THC and RHC as earnings (Reference 3-4) NO_x and CO - no growth (Reference 3-5)
Petroleum Marketing	Growth according to projected gasoline sales (Reference 3-6)
Organic Solvents	
--Surface Coating	Growth as population (Reference 3-7)
--Dry Cleaning	Growth as population (Reference 3-7)
--Degreasing	Growth as manufacturing (Reference 3-4)
--Other	Growth as population (Reference 3-7)
Chemical Industry	Growth as earnings (Reference 3-4)
Incineration and Agricultural Burning	No growth
Fuel Combustions - Steam Power Plants	Growth as population (Reference 3-7)
Fuel Combustion - Residential, Commercial, and Industrial	Growth as population (Reference 3-7)
Other: Mineral, Food, Lumber and Metallurgy	Growth as industry specific earnings (Reference 3-4)

3.2.1.2 Limitations of the Analysis

Since the 1971 San Francisco APCD inventory served as the foundation for the stationary source 1971 base year emission estimates in this study, the results presented here are subject to the limitation of that inventory. These limitations concern the approximations inherent in emission factors, source usage data, and source number estimates. There is insufficient time in the TRW project to review in detail all of these approximations. Suffice it to note that for THC, NO_x and CO emissions from stationary sources, none of the APCD inventory figures deviated way out of line from what would be expected by comparison with other regions, and no major inconsistencies appeared.

The least reliable aspects of the base year and projected baseline stationary source inventories are the hydrocarbon reactivity assumptions. Hydrocarbon reactivity is an extremely complex and difficult issue. Hydrocarbon mixtures can be ranked in reactivity according to the percent of the mixture that can possibly react, or alternatively, according to some scale which assigns weights to individual compounds. This ranking can be based on hydrocarbon consumption rate, NO_2 formation rate, ozone levels, or eye irritation production. The ranking depends on the time allowed for reactions to occur as well as on ratios of the input reactants (hydrocarbon and NO_x).

As was noted in Table 3-3, the present study has used the 1970 California ARB emission inventory reactivity assumptions for all stationary sources except petroleum marketing. For petroleum marketing (as well as mobile sources), recent EPA reactivity results were employed. The ARB reactivity scale is founded upon Los Angeles County APCD smog chamber experiments. The EPA scale is based on experiments and conclusions by Altshuller (3-8). These two scales yield very different estimates of reactivity. For instance, diesel exhaust, considered unreactive according to the ARB, is 99 percent reactive according to the EPA. Evaporated gasoline, considered 45 percent reactive by the ARB, is 93 percent reactive according to EPA. It is a troublesome inconsistency in this study that ARB estimates are used for all but one stationary source,

(yielding an average reactivity of less than 20 percent for these sources), while EPA assumptions are used for petroleum marketing, (93 percent reactivity), and mobile sources (all of high reactivity). This has been done, however, so as to include the most recent data (EPA reactivity figures), even though corresponding data were unavailable for most stationary sources.

All illustration of how confusing and arbitrary reactivity assumptions can be is provided by past inconsistencies in the treatment of organic solvent reactivity. In the 1970 ARB inventory and the original California Implementation Plan(3-2), the ARB assumed a 20 percent reactivity for each major class of solvent use (surface coating, dry cleaning, degreasing, and "other") and for each county in the San Francisco, Sacramento, and San Joaquin regional areas. This reactivity was based on Los Angeles County APCD estimates for "post-rule 66" emissions. However, although San Francisco had implemented such a rule by 1970, certain other counties had not. Thus, 20 percent reactivity was used whether or not a county had adopted Rule 66. Fortunately, this may not be an extremely bad assumption. For surface coatings, meeting Rule 66 for the Los Angeles and San Francisco regions has meant, in practice, that it is met for other California regions [nearly all surface coatings supplied to these regions are the same as supplied to Los Angeles and San Francisco(3-9)]. Reactivities of other organic solvents should also be somewhat uniform throughout California.

It was learned, late in the present study, that organic solvent reactivity assumptions were changed for the San Francisco region in the April 20, 1973 ARB plan.* Instead of relying on their previous inventory, the ARB used the reactivity assumptions of recent, unpublished, San Francisco APCD work. These reactivity differences, for the 1971 base year, are outlined in Table 3-6. Surface coating and "other" reactivities are the same. Dry cleaning reactivity has decreased (the 1973 plan assumes 20 percent of petroleum based cleaner is reactive while

*This information cannot be obtained from the April 1973 ARB plan directly because emissions are not broken down source by source.

the 1972 plan assumes it is all reactive). Degreasing reactivity has greatly increased, (the 1973 plan assumes TCE degreaser is 100 percent reactive, while the 1973 plan either mis-estimates TCE use or assumes a lower percent reactivity). In each of the above discrepancies, arguments can be made for either assumption. Because of this inconclusiveness and because reactivity assumptions can vary so drastically, hydrocarbon reactivity values constitute the greatest limitations in the stationary source analysis.

The projected growth assumptions made here are also subject to some question. Certain stationary source emissions were assumed to grow as population, others were assumed to grow as industry specific earnings, and petroleum marketing emissions were assumed to grow as gasoline sales. None of these is likely to be exactly right. However, petroleum marketing is the dominant stationary source for the most significant pollutant, (RHC), and the growth assumption (as sales) for that source should be fairly accurate. Other growth assumptions, though less exact, apply to less significant sources, and control strategy conclusions should be insensitive to errors in those assumptions.

Table 3-6. ARB Organic Solvent Reactivity Assumptions for San Francisco (January 1972 Implementation Plan Versus April 1973 Revisions)

Source	THC	RHC	
		January 1972 Plan	April 1973 Plan
Organic Solvents:			
--Surface Coating	210	42	42
--Dry Cleaning	24	5	1
--Degreasing	46	9	38
--Other	80	16	16
Total	360	72	97

3.2.2 Aircraft

Table 3-7 summarizes aircraft emissions in the San Francisco Bay Area for the base year 1971 and projected emission levels for 1975, 1977 and 1980. Emissions are divided into two categories -- civilian airports and military air bases. THC emissions are shown to increase in 1975 but decrease slightly in 1977 and again in 1980. CO and NO_x emissions increase in every projected year.

Table 3-7. Aircraft Baseline Emissions in the San Francisco Bay Area by Airport Type

	THC (Tons/Day)				CO (Tons/Day)				NO_x (Tons/Day)			
	1971	1975	1977	1980	1971	1975	1977	1980	1971	1975	1977	1980
Civilian Airports*	29.91	33.65	33.21	32.90	102.80	144.30	170.00	184.10	10.88	17.84	22.30	30.34
Military Air Bases	4.63	4.53	4.53	4.53	7.48	7.41	7.41	7.41	2.91	2.91	2.91	2.91
Total Emissions	34.54	38.18	37.74	37.43	110.28	151.71	177.41	191.51	13.79	20.75	25.21	33.25

*Includes commercial air carrier, air taxi, and general aviation

RHC's are estimated to comprise 90 percent of THC emitted by aircraft (both turbine-powered and piston-powered) and are as shown in Table 3-8.

Table 3-8. RHC Emissions From Aircraft in the San Francisco Bay Area

Year	1971	1975	1977	1980
Emissions (tons/day)	31.09	38.18	37.74	37.43

The values in Table 3-7 were developed with the use of aircraft operations data (both historical and projected) published in a report by the Bay Area APCD (3-10). The operations data was translated into emission estimates with the use of emission factors published by the EPA (3-11). These calculations are discussed in detail in Appendix E.

The analysis and prediction of aircraft emissions is limited in two important areas. The first limitation involves the projection of aircraft activity up to ten years in the future. Normally significant errors occur in such predictions because of unforeseeable fluctuations in the economy and the labor market. In fact, no estimates are made for long-term changes in aircraft operations at military air bases since trends in these operations are almost totally related to unpredictable circumstances.

The second limitation of the analysis involves the use of the aircraft emission factors. These factors were derived by EPA from test data describing the emission rates of particular types of aircraft engines at thrust settings typical of each mode of the Landing Takeoff (LTO) Cycle. In cases where the average time-in-mode for each aircraft engine type is known for an airport, this data can be used directly to estimate yearly emissions. Unfortunately, the time-in-mode is not known for any airport in this study. Anticipating such situations, EPA assumed a particular set of times-in-mode as typical of the worst-case condition at a large metropolitan airport and assumed an engine type typical of each aircraft class -- Jumbo Jet, Long-range Jet, Medium-range Jet, etc. Emission factors were then calculated as an emission rate per LTO for each class. Although this is the best one can do considering the poor availability of data, this method has several inherent weaknesses:

1) The worst-case time-in-mode is not truly representative of the yearly average operation cycles at any airport.

2) The worst-case time-in-mode is not typical of most airports in the San Francisco Bay Area, since San Francisco International is perhaps the only airport which can be truly labeled a large metropolitan airport.

3) Although the engine types chosen as typical of particular aircraft classes may be used on the majority of craft within the class, the actual emission rates can vary significantly, just as in the case of motor vehicles, both within the engine type chosen for each class and between this engine type and others used on similar aircraft in the class.

The EPA emission factors have been compared to the factors used by the Bay Area APCD (3-10) and have been found to differ significantly for

some classes. The THC emissions predicted for 1975 using the EPA method is approximately 20 percent higher than the Bay Area APCD value.

3.2.3 Motor Vehicles

Motor vehicles constitute the most substantial source of air contaminants in the San Francisco Air Basin. As such, the development and assessment of transportation control plans depends heavily on the ability to quantify air pollutants arising from motor vehicle operations. Section 3.2.3.1 provides a discussion of the motor vehicle baseline emission inventory, quantified for the base year and projected years, under the applicable baseline control conditions. Section 3.2.3.2 is a discussion of limitations and constraints inherent in the current state of the art for motor vehicle emission inventory determinations.

3.2.3.1 Baseline Motor Vehicle Inventory

Environmental pollution resulting from motor vehicle emissions was investigated by considering separately the contributions from: light-duty vehicles, heavy-duty gasoline-powered vehicles, heavy-duty diesel vehicles, and motorcycles. Emissions from these vehicle types were estimated by determining the annual mileage by model distribution of the region's vehicle population, the overall mileage and average speed of vehicles in the region, and then applying appropriate emission and reactivity factors which are attributable to the various vehicle age classifications.

Characterization of the San Francisco Air Basin vehicle population into the pertinent classes was accomplished by manipulation of data obtained from the State Department of Motor Vehicles, the California Highway Patrol, the State Air Resources Board, and the Division of Highways. Hydrocarbon, CO, and NO_x emission factors were obtained from Reference 3-12 and from direct communication with the EPA Region Office 9.

The quantification of RHC assumes foremost importance in the total emission inventory and in the development of prospective pollution control plans. It is assumed there is a one-to-one relationship between the quantity of RHC emissions and atmospheric oxidant concentration. The

required 78 percent oxidant rollback being sought for the Sacramento Regional Area is accomplished by a 78 percent rollback in RHC emissions.

The ranking of hydrocarbon reactivity is a controversial issue and has been the subject of several studies which when compared, differ widely in their resultant conclusions. In resolving the difficulties presented in selecting reactivity factors for this study, TRW was provided with guidelines from the EPA. The reactivity values, in terms of the emitter type, are as follows:

Gasoline evaporative emissions (for all vehicles)	.93
Light-duty vehicle exhaust	.77
Heavy-duty gasoline vehicle exhaust	.79
Heavy-duty diesel vehicle exhaust	.99
Motorcycles (2-stroke)	.96
Motorcycles (4-stroke)	.86

The numerical calculations required for estimation of motor vehicle emissions are carried out with the use of a computer program. The methodology for these calculations is discussed in Appendix D.

Baseline motor vehicle emission estimates for RHC are shown in Table 3-9.

Table 3-9. Baseline Motor Vehicle RHC Emissions - San Francisco Air Basin

Type of Vehicle	RHC (Tons/Day) 1971	1975	1977	1980
Light Duty	301	170	122	73
Heavy Duty (Gasoline)	19	19	18	16
Heavy Duty (Diesel)	9	10	10	9
Motorcycle (2-stroke)	8.4	10.3	11.8	13.9
Motorcycle (4-stroke)	3.5	4.3	4.9	5.8
TOTAL	340.9	213.6	166.7	117.7
Percent Reduction (Fraction of base year)		37.3	51.1	65.4

Because of federal automobile standards imposed in 1975 and specific vehicle controls required under the California Auto Emission Standards, vehicle emissions are expected to decrease in future years. By 1975, motor vehicle RHC emissions will have decreased by 37 percent, and by 1980, the expected reduction is 65 percent. Since motor vehicle emissions constitute the main source of air pollution, it appears evident that additional vehicle controls will be required to attain the total 78 percent emission rollback and the 1975 federal air quality standards. While the enforcement of 1975 federal vehicle emission standards will result in substantial reductions of atmospheric pollution, the full benefit of this control is mitigated by the growth of the vehicle population and the associated increase in total VMT. Projections for motor vehicle registrations in future years were made, utilizing a linear multiple regression analysis (see Appendix B). In this mathematical procedure, vehicle registration is determined by its relationship to socio-economic variables (population and per capita income) for which future growth has already been analyzed by other reliable methods. Projections for daily vehicle miles driven in the San Francisco Bay Area were available from transportation studies (3-13). Figure 3-2 shows the projections for light and heavy duty motor vehicles and for total light duty and heavy duty vehicle miles traveled in the San Francisco Bay Area. The projections, devised independently, show very similar trends. Because of the anticipated growth rate of 37 percent in vehicle VMT and 27 percent in vehicles from the base year to 1980, total vehicle emission reduction goals are more difficult to attain.

Another factor mitigating the control of motor vehicle emissions is the fact that heavy duty vehicles, and particularly motorcycles, are not controlled to the same degree as light duty vehicles. From Figure 3-3 it can be seen that there is a substantial shift in the relative contribution of the various vehicle types to the degradation of air quality in future years. For example, motorcycle emissions in 1972 constituted 3.5 percent of all motor vehicle emissions; while by 1980, they are expected (with present strategy control plans) to account for 17 percent of all motor vehicle RHC emissions. The increasing prominence of the motorcycle in the overall projected pollution problem is enhanced

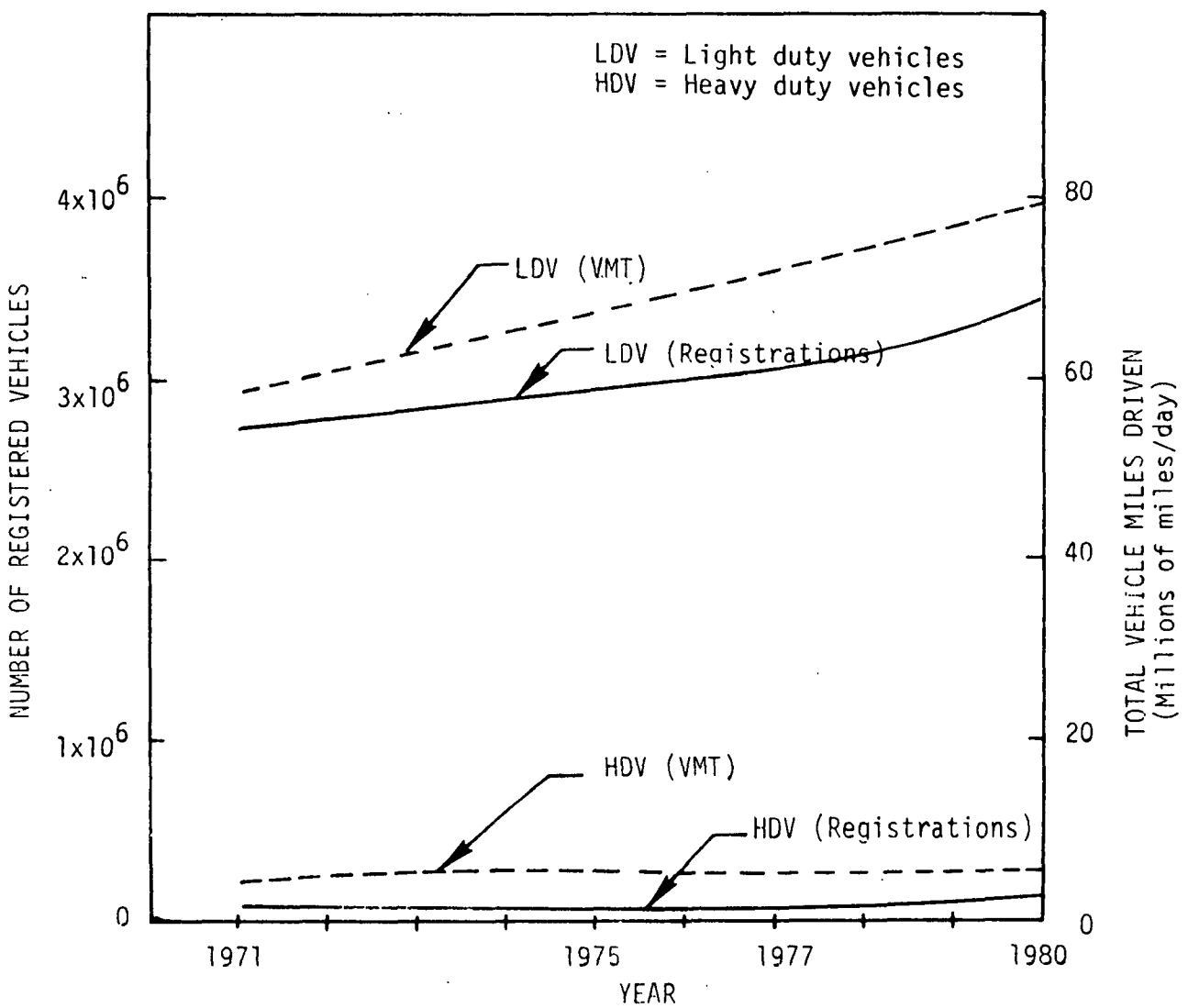


Figure 3-2. Projected VMT and Vehicle Registrations for San Francisco Bay Air Basin

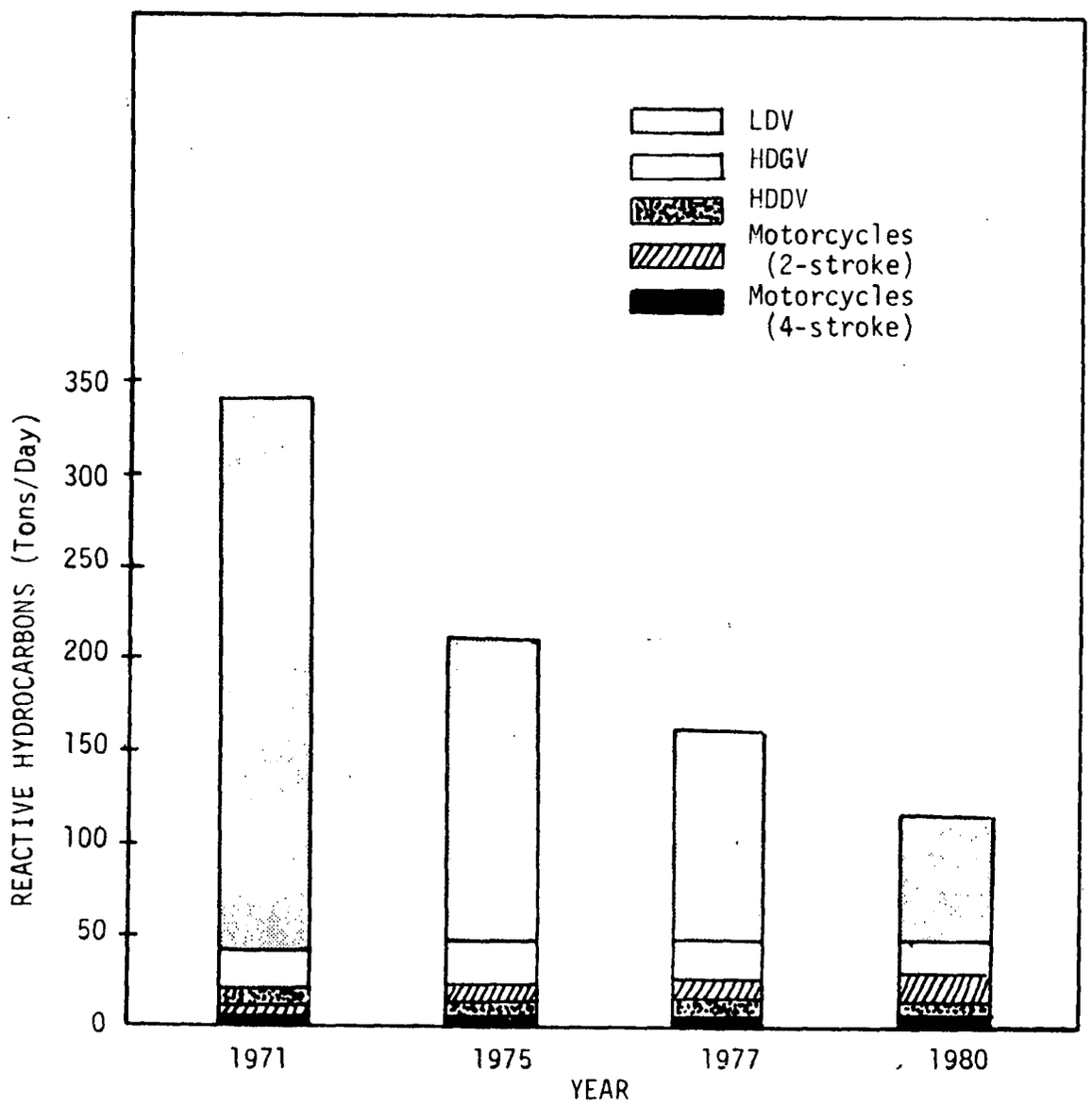


Figure 3-3. Relative Baseline RHC Emissions from the Vehicle Types in the San Francisco Air Basin

further by the rapid growth rate (64 percent by 1980) expected for this vehicle type (see Figure 3-3).

Figure 3-4 demonstrates the relative hydrocarbon emission control trends expected between the various vehicle types. It can be seen that motorcycles are the heaviest polluters per mile of travel and that their emissions are uncontrolled in the baseline projections. The effect of exhaust control deterioration for older model vehicles, and traffic flow patterns (speed adjustment factor) in the overall vehicle emission totals is shown dramatically by comparison of the projected 1980 baseline total hydrocarbon emissions per VMT value with the future (1976 and after) federal exhaust emission standards for new vehicles.

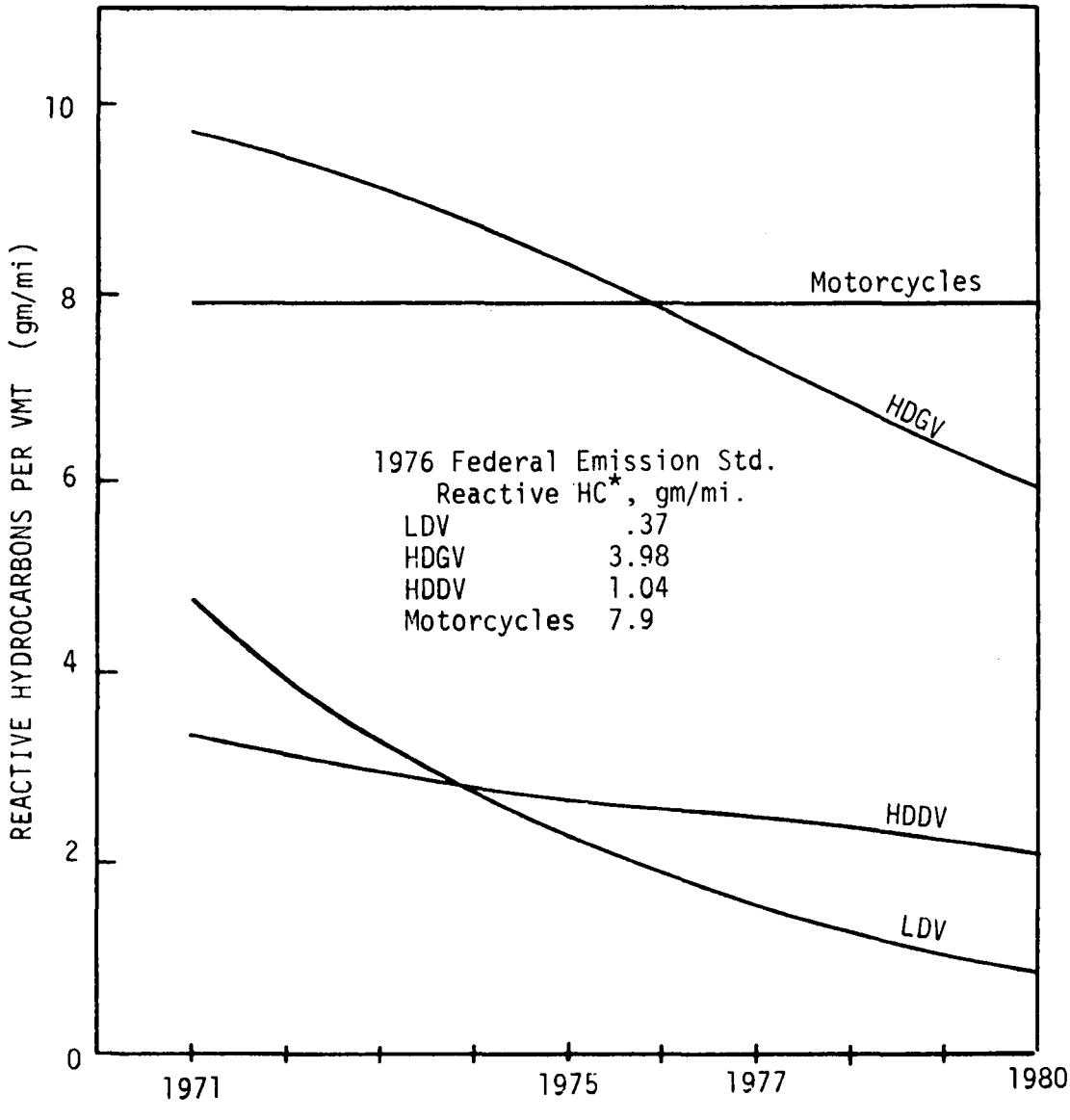


Figure 3-4. Degree of Baseline Control for Various Vehicle Types in the San Francisco Air Basin

Baseline motor vehicle emission estimates for CO and NO_x are shown in Table 3-10. The table shows that baseline control plans account for reductions in CO emissions which are nearly equal to the reductions obtained for RHC's. These reductions will result in the attainment of the federal air quality standards for CO. NO_x emissions do not pose an air quality problem in either the baseline projections or the base year itself.

Table 3-10. Baseline Motor Vehicle Emissions in the San Francisco Air Basin

CO EMISSIONS Type of Vehicle	1971 (Base Year)	1975	1977	1980
Light Duty	2137	1301	933	522
Heavy Duty (Gasoline)	131	149	154	163
Heavy Duty (Diesel)	54	62	56	46
Motorcycle (2-Stroke)	14.2	17.5	20.1	23.6
Motorcycle (4-Stroke)	34.7	42.6	48.5	57.4
Total	2370.9	1572.1	1211.6	812
% Reduction (Fraction of Base Year)		33.69	48.9	65.7
NO_x EMISSIONS				
Light Duty	326	273	213	137
Heavy Duty (Gasoline)	20	22	21	19
Heavy Duty (Diesel)	78	103	96	87
Motorcycle (2-Stroke)	-	-	-	-
Motorcycle (4-Stroke)	-	-	-	-
Total	424	398	330	243
% Reduction (Fraction of Base Year)		6.13	22.17	42.69

3.2.3.2 Limitations in the Analysis

The quantification of air contaminants generated by motor vehicles in a specific region depends substantially on the availability of empirical data characterizing emission rates as a function of various aspects of the regional vehicle population and transportation patterns. Because vehicle emission rates depend on such a great variety of factors (i.e., type of vehicle, condition of vehicle, driver habits, traffic flow, climate, vehicle load, etc.), an accurate functional determination of these rates is extremely involved, if not impossible. Consequently, the notion of overall, or "average" emission rate values, becomes a necessary expedient in the quantification of motor vehicle air contaminants. In the light of this analytical compromise, average emission data by vehicle model year have been generated for a "representative" nationwide driving pattern termed the 1972 Federal Certification Test Procedure, and a limited number of "region specific" adjustment factors have been determined for application to the basic emission factors when specific regional data (average speed, altitude of region, gross weight of vehicle) is available to permit this adjustment.

Substantial effort was exercised to obtain specific motor vehicle information characterizing the San Francisco Air Basin such that a maximum number of "region specific" adjustments could be made. Despite these adjustments, it was recognized that the final determination of total motor vehicle emissions involved a procedure containing several inherent limitations which could cause misrepresentation of region-specific characteristics.

The least reliable aspect of the base year and projected baseline motor vehicle pollutant source inventory concerns hydrocarbon reactivity assumptions. Hydrocarbon reactivity is an extremely difficult and complex issue. Hydrocarbon mixtures can be ranked in reactivity according to the rate at which they react, the mixture that is potentially reactive, or the products of reaction. The criterion for the ranking of hydrocarbon reactivity is a controversial issue. The ARB reactivity scale is based on experiments performed in the Los Angeles APCD smog chamber experiments. The EPA utilizes a reactivity scale based on experiments by

Altshuller (3-8). The two scales are highly discrepant. For instance, diesel exhaust, considered unreactive according to the ARB, is 99 percent reactive according to the EPA. Evaporated gasoline, considered 50 percent reactive by the ARB, is 93 percent reactive according to the EPA. Since the conventional oxidant rollback procedure centers on the reduction of the reactive element of the THC inventory, the uncertainty surrounding the reactivity scale is probably the most significant limitation mitigating the calculation of a meaningful air contaminant inventory.

The determination of total VMT within a specified region is best determined by transportation studies conducted in the field. VMT may also be calculated based on vehicle registration and annual vehicle mileage data for the region of study (the approach used by State Air Resources Board), or based on total regional gas consumption and vehicle gas mileage data. The latter approaches for calculating VMT were expected to yield results in accord with the transportation study figures, provided the regional characterization of vehicular travel used in the analysis was representative of actual travel in the region (i.e., inflow vehicle characterization equal to outflow vehicle characterization). A summary and comparison of the VMT determination is portrayed in Figure 3-5.

While there appears to be little question that transportation studies yield the most reliable estimates of overall vehicular travel in the base year, there is some question as to the accuracy of segregation of VMT in terms of heavy duty and light duty vehicles and in the projection of these values to future years. The latter estimates involve reliance on limited or conflicting data and as such have been subject to numerous judgments in the analysis. These judgments involve the selection of various conflicting studies projecting community growth parameters (population, money earnings, vehicle registrations, highway and street expansions).

Another inherent difficulty in calculating future motor vehicle pollution arises from the unpredictability of consumer preferences. A number of unforseen factors may cause considerable changes in future vehicle buyer habits. For example, it is noted that substantial increases

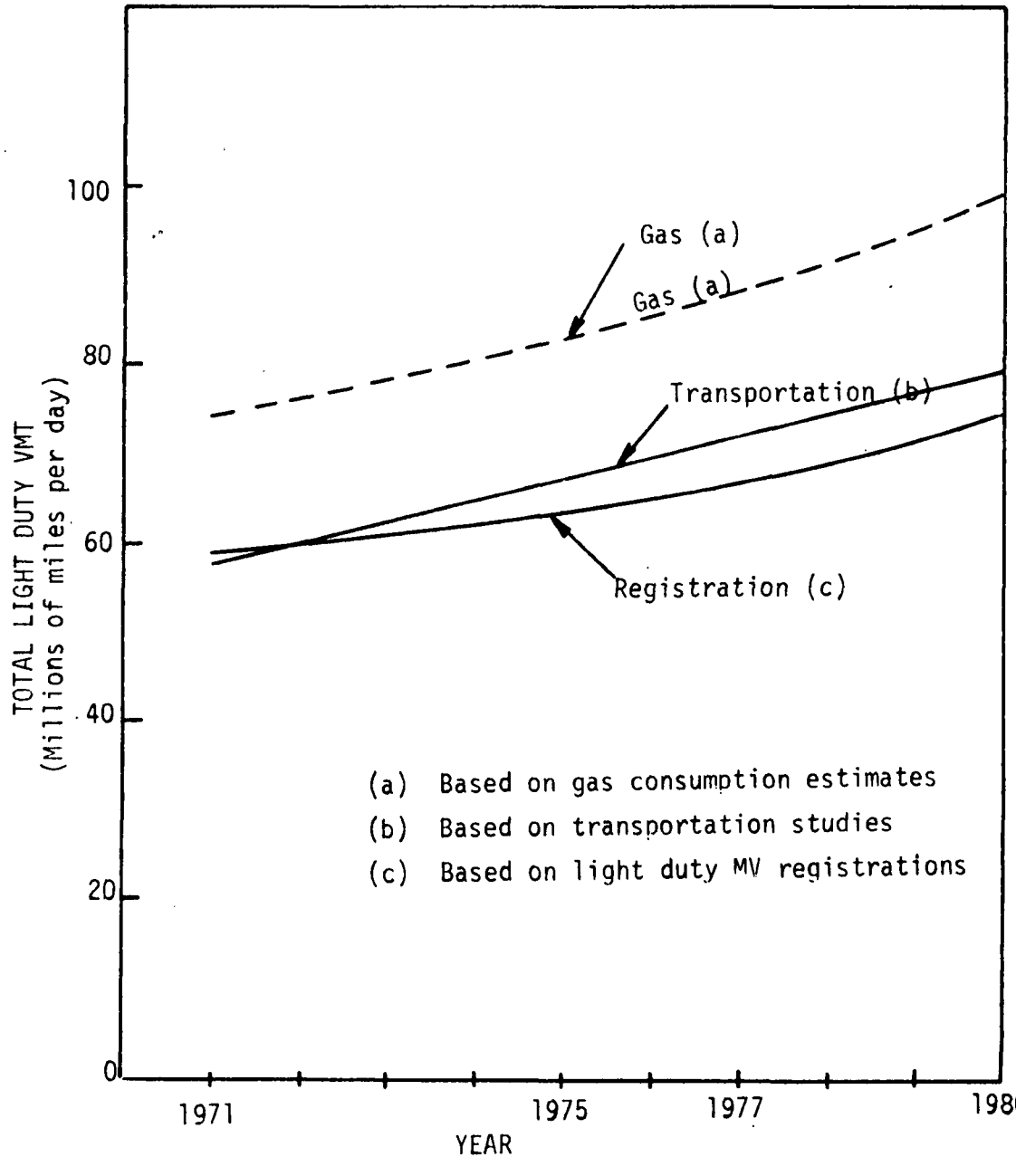


Figure 3-5. Baseline Total VMT Determinations for San Francisco Air Basin

in small car sales were recorded during the first half of 1973, quite possibly because of the rapidly rising gasoline prices and the increased emphasis on energy shortages. In view of recent air quality emphasis and the subsequent mandatory pollution control retrofit programs now being discussed, speculations are strong that new and later model car sales will increase significantly in the regions targeted for controls. For the purpose of the analysis conducted here, consumer buying habits were considered fixed, and the vehicle model year distribution and annual mileage by model distribution were assumed the same for all years in the estimates.

Another weakness in the emission inventory analysis concerns the day-by-day variability of air contaminants generated by motor vehicles. The analysis has included the assumption that pollutant emissions are discharged at a relatively uniform rate throughout the year, when actually there may be significant daily and seasonal variations which contribute to a varying atmospheric oxidant potential. The availability of data and the limited time available for this study did not permit a quantification of the parameters associated with this issue.

The methodology utilized in calculating motor vehicles (see Appendix D) emissions provides for an adjustment of the federal certification test procedure emission rates on the basis of regional average vehicular speed. The source of data for regional traffic speeds are transportation studies conducted by the Division of Highways (3-13). The average speeds are reported in terms of "weighted average speeds," and are computed by aggregating the product of VMT and arithmetic average speeds measured for the various roads and highways throughout the region. The resultant weighted average speed is therefore somewhat higher than the true arithmetic average speed. Consequently the corresponding speed adjustment factor for emissions is somewhat misleading. Because of an absence of other vehicle speed data, the weighted average speeds were incorporated in the analysis.

It is evident that the combined effect of the above limitations is a basic uncertainty in the reliability of the emission inventory. A further effect is the untenable status of pollution control strategies which rely on the analysis. The assumptions and constraints contained in the methodology are inherently unavoidable at this time. However, the analysis presented herein is fully representative of current methodology in motor vehicle emission estimation, and as such, represents the most valid inventory update available at this time. Further study is needed to qualify and improve the emission quantification procedures.

3.3 TRANSPORTATION DATA

Key to developing a transportation control strategy for the Bay Area is an understanding of the diversity of travel patterns, transportation facilities, and transportation opportunities. Travel patterns and transportation facilities and services are described in the following sections.

3.3.1 Travel Patterns

Principal transportation data source for the San Francisco Bay Area is the work of the Bay Area Transportation Study Commission (BATSC), predecessor agency to the Metropolitan Transportation Commission (MTC) which now coordinates transportation planning activities in the area. Their analyses in terms of trip purpose, origin-destination pattern, mode of travel (auto, transit, walk, etc.), distribution of vehicle miles of travel, and average vehicle speed have direct application in evaluating transportation control strategies.

3.3.1.1 Trip Purpose, Mode, Origin-Destination Pattern

Table 3-11 presents regional average weekday trip making by purpose for BATSC 1965 base year and forecast years 1980 and 1990. By interpolation, regional trip totals for the 1971 air quality base year and forecast years 1975 and 1977 are estimated at 12,366,000, 13,688,000 and 14,358,000, respectively. Work trips and non-home based trips each account for approximately one-quarter of the total trip activity.

Table 3-11. Regional Person Travel Estimates

Trip Purpose	1965 Number of Trips (000)	1965 Percent Total	1980 Number of Trips (000)	1980 Percent Total	1990 Number of Trips (000)	1990 Percent Total
Home-based						
Work	2,626	25.3	3,952	25.8	4,761	25.8
Personal business	1,248	12.0	1,710	11.2	2,059	11.1
Social	795	7.7	1,095	7.2	1,276	6.9
Recreational	535	5.2	863	5.6	1,048	5.7
Convenience shopping	1,223	11.8	1,704	11.1	2,068	11.2
Comparison shopping	409	3.9	585	3.8	708	3.8
Other home-based	1,095	10.5	1,519	9.9	1,840	10.0
Non-Home-based	2,447	23.6	3,879	25.4	4,711	25.5
Total	10,378	100.0	15,307	100.0	18,471	100.0

Source: BATSC 1965 Survey and Forecasts

Table 3-12 presents regional trip patterns for average weekday person trips. Over 20 percent of the region's 11,829,000 trips are focused on San Francisco; Santa Clara County accounts for more than 23 percent of the regional trip activity. Table 3-13, 1965 work person trip breakdowns by county, further illustrates trip focus on San Francisco. Some 29 percent of the regional work trip activity originates or is destined in San Francisco County. Table 3-14 indicates resident employees place of work, providing background to the work travel matrix.

Despite the central role of San Francisco, the majority of the region's trips remain within the county in which they are produced as illustrated in Tables 3-15 and 3-16. This limits the opportunities for public transit as trips to the dense urban concentrations are most subject to diversion from automobile to transit. It also points up the need for control strategies which have a region-wide impact rather than concentration in one subarea.

Table 3-17 presents average weekday person travel for the region by trip purpose and mode. Some 8 percent of the total travel (nearly 10 percent if walk trips are ignored) are transit trips. The high transit orientation of work, school and comparison shopping trips is also indicated. Tables 3-18 and 3-19 present total person trips by mode and county for all purposes and work purpose, respectively. The tables illustrate the high transit orientation of San Francisco trips. Of the urban counties Santa Clara stands out with only 2 percent transit. (1973 estimates indicate only 1.4 percent transit mode split in Santa Clara County.)

3.3.1.2 Vehicle Miles of Travel

Estimates of VMT, a data item of secondary importance in transportation planning, are critical inputs to pollution emission inventories and control strategy development. Some discrepancies in reported and projected VMT data for the Bay Area exist. Figures reported by BATSC run significantly lower than those reported by the California Division of Highways. The BATSC figures are reported from computerized highway

Table 3-12. All Purposes 1965 Average Weekday Person Trips by All Modes

County of Production (Residence)	County of Attraction									
	ALA	CC	MRN	NAP	SF	SM	SCL	SOL	SON	TOTAL
Alameda	2669954	67009	4966	1496	104980	18083	22637	2327	517	2891969
Contra Costa	148824	1187642	3550	1108	38621	4210	2020	10656	488	1397119
Marin	5059	1872	350070	636	57556	3448	417	1115	4299	424485
Napa	1046	674	53	146250	709	50	47	17186	1899	167914
San Francisco	44100	8323	14963	329	1840598	85122	9030	2064	1041	2005570
San Mateo	9373	1946	2133	0	199763	1145797	82702	202	936	1442852
Santa Clara	16680	1305	452	177	28199	73723	2509392	587	306	2630821
Solano	3729	7685	1480	8301	4307	288	405	345762	0	371957
Sonoma	2268	320	8838	2404	5973	712	656	2204	472876	497251
Total	2901033	1276779	386505	160701	2280706	1331433	2627306	382103	482362	11828928

Note: Entries in above table represent non-directional trips. Each entry indicates the total trips in both directions that are produced by the residents of the county of production and attracted to each county.

Source: BATSC 1965 Origin-Destination Surveys

Table 3-13. Home-Based Work Trips - 1965 Average Weekday Person Trips by All Modes

County of Production (Residence)	ALAMEDA	CC	MARIN	NAPA	SF	SM	SCL	SOL	SON	TOTAL
Alameda	544,414	19,108	1,140	632	61,690	9,606	10,606	1,189	0	648,385
Contra Costa	75,298	174,964	1.084	29	25,324	1,905	951	4,046	51	283,652
Marin	2,426	1,279	51,125	95	37,618	825	417	477	691	94,953
Napa	834	622	0	25,457	526	50	0	7,168	519	35,176
San Francisco	17,101	2,794	2,799	0	458,026	29,422	3,000	944	0	514,086
San Mateo	4,171	431	554	0	106,499	202,086	25,861	120	204	339,926
Santa Clara	6,987	173	0	0	12,937	29,219	497,333	69	0	546,718
Solano	1,390	4,349	634	2,204	2,566	128	0	62,207	0	73,478
Sonoma	387	152	4,068	76	3,412	172	0	1,534	79.860	89,661
Total	653,008	203,872	61,404	28,493	708,598	273,413	538,168	77,754	81,325	2,626,035

NOTE: Entries in above table represent non-directional trips. Each entry indicates the total trips in both directions that are produced by the residents of the county of production and attracted to each county.

Table 3-14. Resident Employees Place of Work - Percentage, 1965

County	% Work in Co. of Res.	% Work in San Francisco	High County Other than S.F. County	%	% Work all Other Places
Alameda	81	11	Contra Costa	3	5
Contra Costa	59	11	Alameda	26	4
Marin	54	39	Alameda	2	5
Napa	69	3	Solano	22	6
San Francisco	87	--	San Mateo	6	7
San Mateo	54	34	Santa Clara	8	4
Santa Clara	86	4	San Mateo	6	4
Solano	80	6	Contra Costa	6	8
Sonoma	86	5	Marin	5	4

Source: BATSC 1965 Origin-Destination Survey

Table 3-15. 1965 Average Weekday Person Trips - Comparison of Trips Within County and Adjacent Counties

County of Production	Total Trips Produced	Trips Remaining Within County		Trips Attracted To Adjacent Counties		Remainder Within Region
		Trips	%	Trips	%	%
Alameda	2,891,969	2,669,954	92.3	194,626	6.7	1.0
Contra Costa	1,397,119	1,187,642	85.0	198,101	14.2	0.8
Marin	424,475	350,070	82.5	61,855	14.6	2.9
Napa	167,914	146,250	87.1	18,085	10.8	2.1
San Francisco	2,005,570	1,840,598	91.8	144,185	7.2	1.0
San Mateo	1,442,852	1,145,797	79.4	282,465	19.6	1.0
Santa Clara	2,630,821	2,509,392	95.4	90,403	3.4	1.2
Solano	371,957	345,762	93.0	15,986	4.3	2.7
Sonoma	496,251	472,876	95.3	11,242	2.3	2.4
TOTAL	11,828,928	10,668,341	90.2	978,327	8.3	1.5

Source: BATSC 1965 Origin-Destination Survey

Table 3-16. 1965 Average Weekday Person Trips - Home-Based Work Trips
Comparison of Trips Within County and Adjacent Counties

County of Production	Total Work Trips Produced	Trips Remaining Within County		Trips Attracted To Adjacent Counties		Remainder Within Region
		Trips	%	Trips	%	%
Alameda	648,385	544,414	84.0	91,404	14.1	1.9
Contra Costa	283,652	174,964	61.7	104,668	36.9	1.4
Marin	94,953	51,125	53.8	38,309	40.3	5.9
Napa	35,176	25,457	72.4	7,687	21.9	5.7
San Francisco	514,086	458,026	89.1	49,322	9.6	1.3
San Mateo	339,926	202,086	59.4	132,360	38.9	1.7
Santa Clara	546,718	497,333	91.0	32,206	6.6	2.4
Solano	73,478	62,207	84.7	6,553	8.9	6.4
Sonoma	89,661	79,860	89.1	4,144	4.6	6.3
TOTAL	2,626,035	2,095,472	79.8	470,650	17.9	2.3

Source: BATSC 1965 Origin-Destination Survey

Table 3-17. 1965 Average Weekday Trips by Purpose and Mode

PURPOSE	MODE								
	Vehicle			Transit			Walk		
	Vehicle Driver	Passen-gers	Total Persons	% Vehi-cle	Persons	% Transit	Persons	% Walk	Total Person Trips
H.B. Work & Work Related	1,829,542	325,877	2,155,419	82.1	331,300	12.6	139,316	5.3	2,626,035
H.B. Personal Bus., Med.-Dental	725,825	300,105	1,025,930	82.2	70,722	5.7	151,214	12.1	1,247,866
H.B. School	144,541	254,034	398,575	27.5	323,659	22.4	726,152	50.1	1,448,386
H.B. Visit Friends	404,175	250,686	654,861	82.4	20,894	2.6	119,241	15.0	794,996
H.B. Eat Meal, Commercial Rec.	235,728	219,977	455,705	85.2	25,127	4.7	54,222	10.1	535,054
H.B. Conv. Shopping, Shopping Both	754,400	213,739	968,139	79.2	24,031	2.0	230,743	18.8	1,222,913
H.B. Comparison Shopping	235,308	107,962	343,270	84.0	38,622	9.5	26,688	6.5	408,580
H.B. Free Rec. Accompany Person, Other	544,523	439,161	983,684	89.8	9,424	0.9	102,230	9.3	1,095,338
Non-Home Based	1,364,318	603,342	1,967,660	80.4	89,583	3.7	390,196	15.9	2,447,439
TOTAL (all purposes)	6,238,360	2,714,883	8,953,243	75.7	933,362	7.9	1,940,002	16.4	11,826,607

Source: BATSC 1965 Origin-Destination Survey

Table 3-18. Distribution of 1965 Average Weekday Total - Person Trips by Mode

County	Percent of Trips by Mode: Vehicle (Driver & Passenger)	Transit	Walk
Alameda	78.0	6.7	15.3
Contra Costa	79.5	5.8	14.7
Marin	83.8	6.3	9.9
Napa	84.7	5.6	9.7
San Francisco	56.3	21.1	22.6
San Mateo	79.3	7.1	13.6
Santa Clara	87.7	2.0	10.3
Solano	79.3	2.6	18.1
Sonoma	80.2	8.2	11.6
Total Region	75.7	7.9	16.4

Source: BATSC 1965 Origin-Destination Survey

Table 3-19. Distribution of 1965 Average Weekday - Work Person Trips by Mode

County	Percent of Trips by Mode		
	Vehicle (Driver & Passenger)	Transit	Walk
Alameda	84.9	11.2	3.9
Contra Costa	91.9	5.5	2.6
Marin	88.9	8.3	2.8
Napa	95.3	1.4	3.3
San Francisco	59.0	33.7	7.3
San Mateo	87.6	8.9	3.5
Santa Clara	94.2	2.5	3.3
Solano	90.3	3.7	6.0
Sonoma	95.2	1.9	2.9
Total Region	82.1	12.6	5.3

Source: BATSC 1965 Origin-Destination Survey

network assignments. As a result, vehicle mileage from intrazonal trips are not reflected as these trips are not "loaded" on the network. Moreover, commercial vehicle tripmaking is not reflected in the BATSC data. Even with adjustments for these factors, significant discrepancies remain as illustrated in Figure 3-6. Curve 1 in Figure 3-6 shows linear projection of the Division of Highways VMT estimates, curve 2 is adjusted BATSC estimates, and curve 3 shows unadjusted BATSC VMT data from network assignments. Inset on the figure are VMT totals for the three critical air quality years as taken from each of the three curves. For purposes of this study, the Division of Highways based VMT estimates have been treated as upper limits in the air quality analyses. Actual calculated emissions are based on the VMT figures from adjusted BATSC estimates.

Table 3-20 illustrates the discrepancy between BATSC and Division of Highways breakdown of VMT by county. The data indicate a broad dispersion of the VMT over the region pointing up the need for control strategies which are regional in impact. Control measures aimed at reducing VMT in regions most susceptible to control (e.g. San Francisco) are likely to be relatively ineffective since these areas account for only small fractions of the total VMT and are typically areas which currently have the highest levels of transit ridership. Adding restrictive controls to the more dense activity centers raises questions of equity, i.e., those most likely to use transit penalized while offenders in low-density suburbia escape restrictions.

Table 3-21 presents statistics on VMT generation and growth for the region disaggregated by BATSC superdistricts as presented on Figure 3-7. The VMT per capita figures provide a relative measure of propensity to use the auto by subarea of the region. Estimates indicated in the table reflect VMT from BATSC 1965 O-D trips (excluding intrazonals) aggregated to the superdistricts in which trips were produced (not necessarily the one in which all the VMT was run up). Growth rates are based on 1965 to 1980 BATSC projected trip patterns.

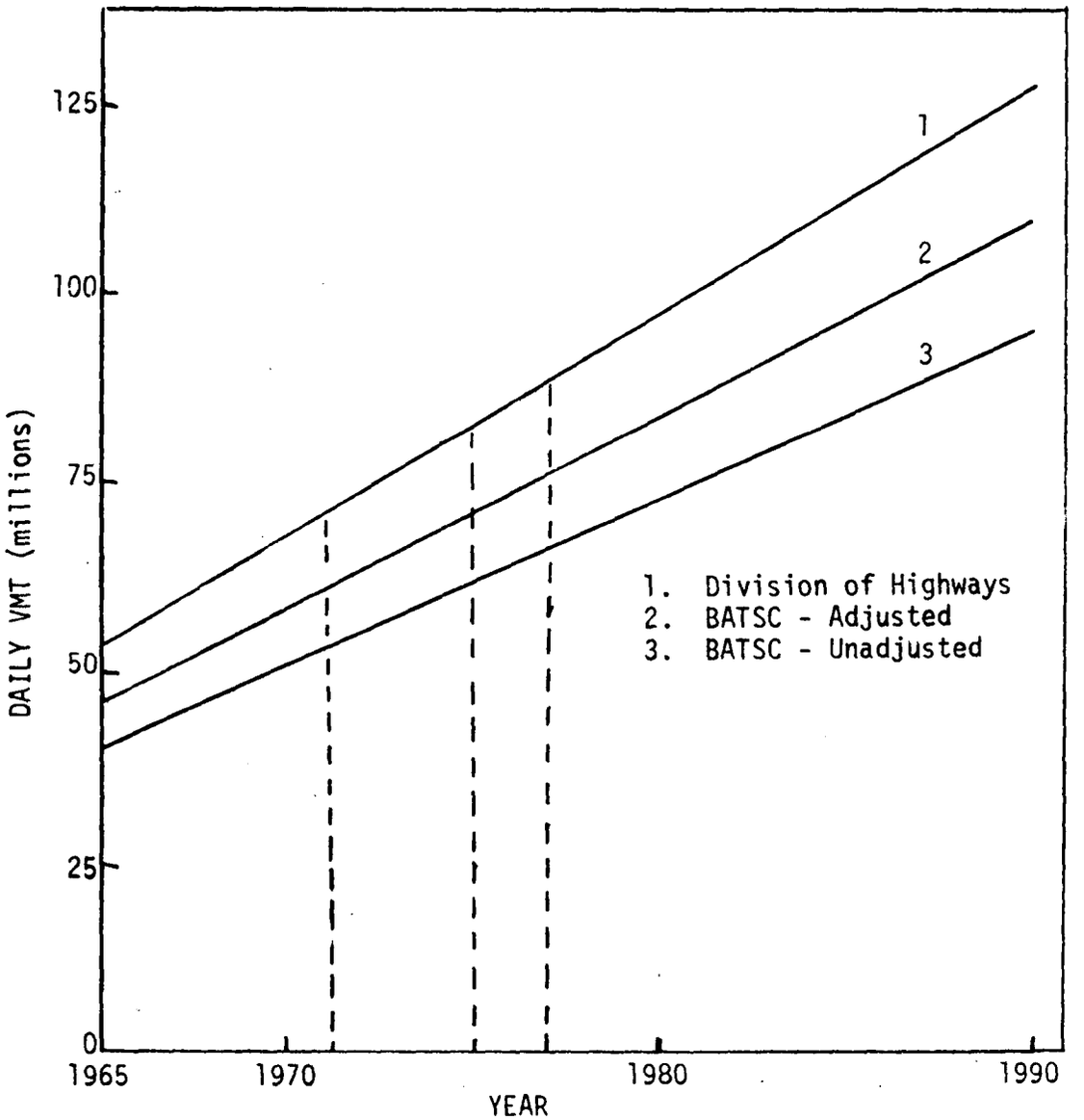
Table 3-20. VMT by County

County	% Total BATSC[1]	% Total DOH[2]
Alameda	23.7	26.3
Contra Costa	10.8	11.8
Marin	5.0	6.4
Napa	1.1	2.1
San Francisco	11.7	9.6
San Mateo	14.2	11.9
Santa Clara	23.3	18.6
Solano	4.6	6.6
Sonoma	5.6	6.7
	100.0	100.0

[1] 1965 BATSC Origin-Destination Survey

[2] 1966 Statewide Transportation Study

Note: Despite BATSC omissions of intrazonal and commercial vehicle trips, the effect on percentage VMT distribution should be minimal as these should be roughly proportional to total trip activity. Significant discrepancies in the above table pose some question.



	1971	1975	1977
1.	71,500,000	83,596,000	89,644,000
2.	61,850,000	71,990,000	77,060,000
3.	53,486,000	62,430,000	66,902,000

Figure 3-6. Estimated Daily VMT

Table 3-21. VMT Originating in each of 30 BATSC Superdistricts[1]

Superdistrict	VMT Generation Population	Projected % Regional VMT Growth 1965-80
1	5.33	.5
2	4.24	1.0
3	4.23	2.5
4	4.78	1.0
5	7.09	4.0
6	9.66	3.0
7	10.63	3.5
8	8.54	1.5
9	9.99	2.0
10	8.48	4.5
11	8.73	5.0
12	13.57	18.0
13	8.65	2.5
14	9.78	4.0
15	7.75	6.0
16	6.48	5.5
17	5.82	2.0
18	7.64	2.0
19	9.55	3.5
20	8.48	7.5
21	5.82	3.0
22	6.28	2.0
23	2.92	4.0
24	6.50	1.5
25	8.41	1.0
26	11.71	1.0
27	8.23	1.0
28	18.58	0.0
29	8.69	5.0
30	9.32	2.0

Source: BATSC 1965 Travel Data

[1]Superdistricts located in Figure 3-7

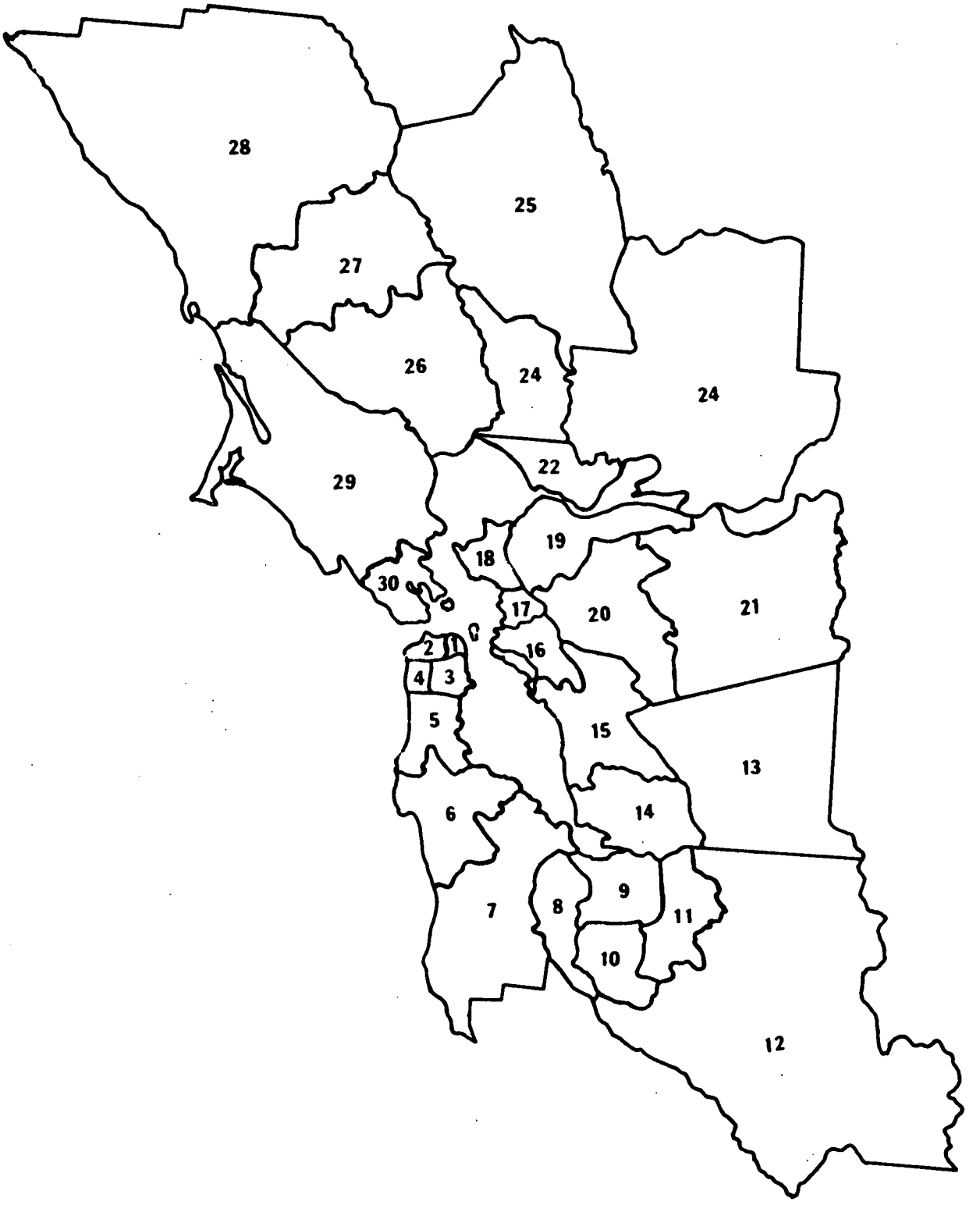


Figure 3-7. BATSC Super Districts

Inspection of Table 3-21 and Figure 3-7 reveals that in the urbanized portion of the region, VMT generation is significantly greater in the southern sector (Superdistricts 6-13). These same areas (Santa Clara County and the southern portions of San Mateo and Alameda Counties) are projected to be responsible for a large share of the region's VMT growth, some 37 percent. This points up the desirability of a control strategy which has impact in these parts of the region. Table 3-22 presents a breakdown of VMT by roadway functional classification along with statistics of roadway mileage by functional class based on Division of Highways data as reported by BATSC. It must be noted that the 1965 VMT total from which these breakdowns are reported differs significantly from the VMT total reported by the Division of Highways in the 1966 Statewide Transportation Study.

Table 3-22. VMT Breakdown by Roadway Functional Classification

	Road Miles		Daily VMT	
Class of Facility	Amount	Percent Total	Amount	Percent
Freeways and Expressways	429	2.8	17,370,000	28.8
Arterial and Collector	6,590	42.2	27,080,000	45.0
Local	8,626	55.0	15,850,000	26.2
Total	15,645	100.0	60,300,000	100.0

3.3.1.3 Average Vehicle Speed

Data on regional average travel speed, another key input to the air quality forecast process, is also somewhat tenuous. The BATSC work indicated an average network speed of 36.8 mph in 1965 and projected 42.2 mph for 1980. Linear interpolation between these values gives the following areawide average travel speeds for the air quality base and projection years:

1971 - 39.0 mph
1975 - 40.4 mph
1977 - 41.2 mph

The 1971 Statewide Transportation Study reported a somewhat higher average travel speed for the Bay Area than the above estimate - 41.9 mph. But this variation of speeds is of small significance in air quality forecasting as in this speed range hydrocarbon and carbon monoxide emissions do not change significantly. This same factor also mitigates the concern that the above speeds may be overly high because of omission of short trips on local, low speed streets. Accounting for such trips is not likely to decrease the reported average travel speed by more than 1 or 2 miles per hour.

3.3.2 Transportation Facilities and Services

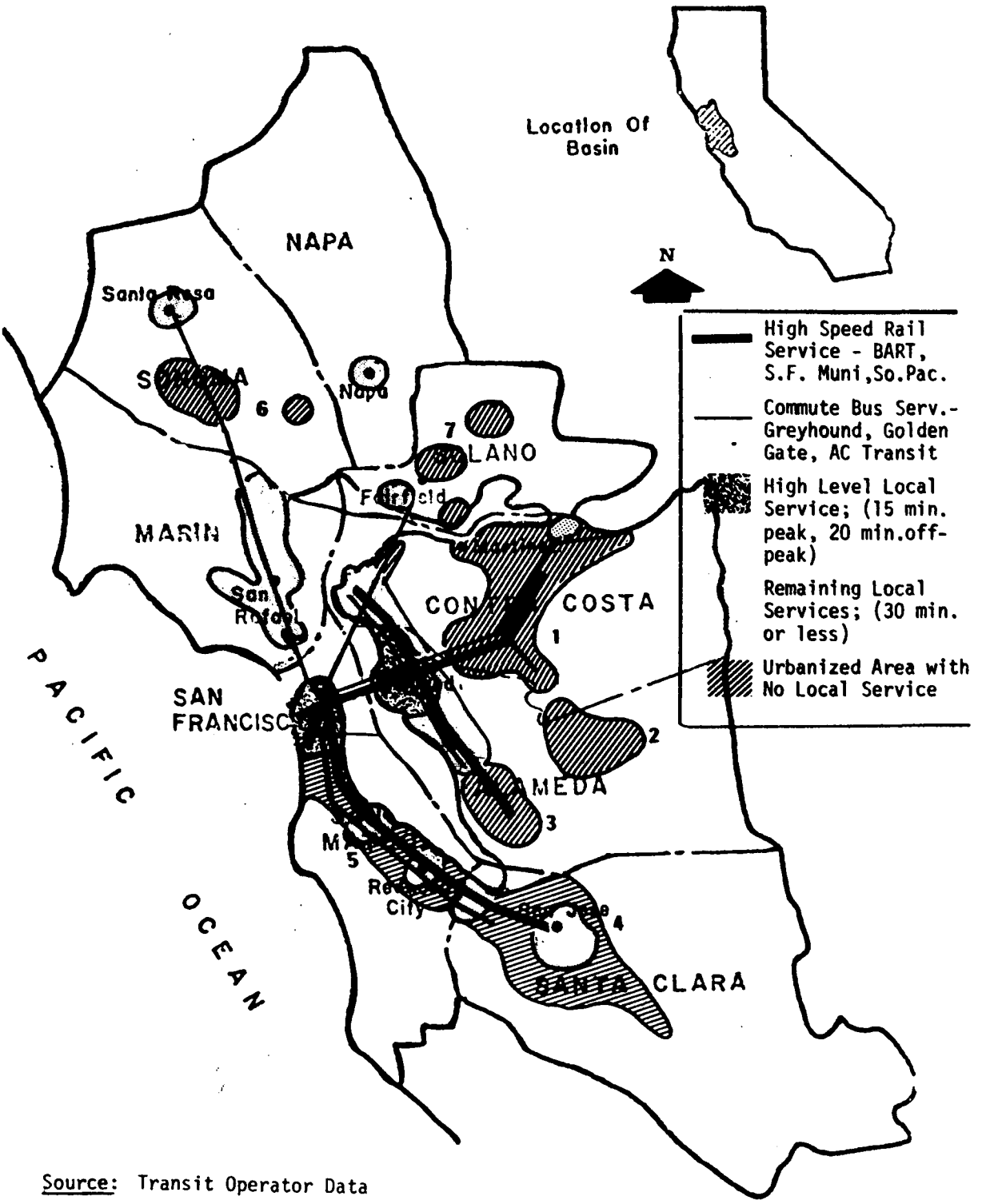
A brief description of transit services, highway facilities and parking conditions in the Bay Area is presented here as a prelude to consideration of transportation control strategies. Existing transit operations and pending improvements affect the capacity of the region to provide options to auto use as various constraints are implemented. Congestion on the existing highways in the region and pending improvements work both for and against cleaner air; increased congestion may increase vehicle emissions, but congestion usually helps make transit more competitive. Availability of parking affects the price and convenience of the auto trip which must be countered if VMT is to be reduced.

3.3.2.1 Transit Services

Table 3-23 briefly describes existing transit operations in the Bay Area. Figure 3-8 portrays current Bay Area transit coverage, including high speed rail service, commute bus service, and local bus service. The Bay Area Rapid Transit District (BART) (to be completed in the fall of 1973) Muni Subway (to be completed in 1975) and Southern Pacific Railroad plus commute bus services run by Greyhound, Golden Gate, and AC Transit form the backbone of the region's transit system. A high level of local service (at least 15 minute peak hour service, 20 minute midday) exists in San Francisco, Daly City, and low lying portions of Oakland and Berkeley. A lesser level of transit service covers about one-third of the remainder of the urbanized area, princiapally western Alameda and

Table 3-23. Bay Area Region Transit Operators

OPERATOR	SERVICE AREA	ROUTES NO.	ROUTES TYPE	HEADWAY RANGE (Min.)	ANNUAL PATRONAGE	USERS	RECENT OR POTENTIAL IMPROVEMENTS
San Francisco Municipal Railway	City/County of San Francisco	63	Local	2-40	82,000,000	General	Muni Metro & Subway
		8	Express	5-30	7,000,000	Commute	Exclusive bus lanes
Alameda-Contra Costa Transit District	Coastal area of Contra Costa & Alameda Counties from El Sobrante to Hayward	55	Local	2-60	36,300,000	General	Expanded service area
		16	Express	2-60	14,300,000	Commute	Eliminate transbay runs
Greyhound Lines-West	Peninsula-Daly City to San Jose	4	Local	10-60	6,900,000	Commute-Gen.	Establish service along I-280 corridor
		4	Express	5-15		Commute	
	Contra Costa-Orinda to Antioch	2	Local	15-60	2,900,000	Low Mobility-	BART Service to SF, East Bay & Feeder Bus
		9	Express	4-15		Commute	
	East Bay-Oakland to Vallejo	1	Local	15-60	600,000	Low Mobility-	Feed to BART at Richmond or El Cerrito
		2	Express	5-60		Commute	
Golden Gate Bridge, Highway and Transportation Dist.	Marin-Sonoma Counties from Sausalito to Santa Rosa	9	Local	15-60	1,500,000	Low Mobility- Low Income	Bus lane on US 101
		18	Express	5-15	3,900,000	Commute- Low Mobility	Busway in SF
Santa Clara County Transit District	Palo Alto, Santa Clara, San Jose, Saratoga, Los Gatos, Campbell	19	Local	10-120	5,100,000	Low Mobility- Low Income- Sr. Citizen	Expanded coverage and service area
Southern Pacific Company	SF to San Jose 8 station stops	1	Express	5-120	6,000,000	Commute	Upgrade to rapid transit
Bay Area Rapid Transit District	SF to Daly City-Fremont-Richmond-Concord	4	Express	2-15	full operation by 9-73	Commute-Gen.	Extensions to Livermore, Antioch, SF(NW), SF Airport
Northgate Transit Company	Daly City-Westlake-Colma-South SF	6	Local	20-60	400,000	Low Mobility- Low Income	Improved coverage, headway
South San Francisco Transit	South San Francisco	2	Local	30	?	Low Mobility- Low Income	Improved service
San Mateo Courteous Transit	San Mateo	2	Local	60	100,000 ?	Low Mobility- Low Income	Improved coverage, headway
Redwood City Municipal Transit	Redwood City	5	Local	30	300,000	Low Mobility- Low Income	Improved headways
Peerless Stages System	Oakland-San Jose-Santa Cruz	5	Express	45-90	300,000	General- Low Mobility	Feed to BART @ Fremont Run Fremont-San Jose
Vallejo Transit Lines	Vallejo	6	Local	40-80	500,000	Low Mobility- Low Income	Improved coverage, headways
Vaca Valley Bus Lines	Fairfield/Travis AFB	1	Local	60	200,000	Air Force personnel	Expand as part of Fairfield local system
Napa Transit Company	Napa	2	Local	60	?	Low Mobility- Low Income	Improved service
Petras Transportation Co.	Pittsburg	1	Local	90	?	Low Mobility- Low Income	Improved service
Greyhound Lines-West (Intercity)	SF to San Jose-Salinas, Los Gatos-Santa Cruz, Livermore-Stockton, Vallejo-Stockton, Vallejo-Calistoga, Sonoma-Santa Rosa & Martinez-Stockton	7	Intercity	15-120		Low Mobility	Expand service as part of region-wide trunk system
Santa Rosa Municipal Transit	Santa Rosa	3	Local	40-45	206,750	General	Subsidized private jitney operations



Source: Transit Operator Data

Figure 3-8. Bay Area Transit Coverage

Table 3-24. Key to Urbanized Areas Without Transit Service

1. Eastern Contra Costa County -- Orinda, Moraga, Lafayette, Walnut Creek, Pleasant Hill, Concord, Martinez, Antioch

2. Livermore - Amador Valley -- Dublin, San Ramon, Pleasanton, Livermore

3. Tri-Cities -- Fremont, Newark, Union City

4. Santa Clara County -- Mountain View, Santa Clara, Sunnyvale, Cupertino, Saratoga, Milpitas, Los Gatos, Campbell and portions of San Jose

5. Penninsula -- Menlo Park, Atherton, San Carlos, Belmont, Burlingame, Hillsborough, Millbrae, San Bruno, Pacifica, Brisbane, and portions of South San Francisco

6. Sonoma County -- Petaluma, Sebastopol, Cotati, Rohnert Park, Sonoma

7. Solano County -- Fairfield, Vacaville and Benecia

Contra Costa Counties and Marin County. An estimated 50 percent of Bay Area residents presently live within walking distance (1/4 mile) of local transit service (coverage applied to 1970 census data). A much lower percentage of new development, perhaps 10 percent, is within walking distance of a local transit route.

Service in the northern three counties (Napa, Solano, Sonoma) is limited to small local operations in the three largest cities, Vallejo, Napa and Santa Rosa. A limited number of private operations providing specialized services, i.e., Jitney Commute Bus to Mare Island Naval Shipyard in Vallejo and Travis Air Force Base and Golden Gate Transit Service to San Francisco from Santa Rosa, Petaluma and Rohnert Park. Because of the sparse development in these counties, opportunities for affecting air quality improvement by diverting large numbers of persons from autos to improved transit services are extremely limited. However, ongoing studies of feasibility for high speed ground transportation linkage between the Bay Area and Sacramento could result in linkage between the cities of Vallejo and Fairfield with a central part of the region. But this is an extremely long-term prospect.

In the central Bay Area, a number of transit operations provide high volume local and intercity services. Golden Gate transit operations extend north from downtown San Francisco, through Marin County and to Santa Rosa. In the less than two-year period since the Golden Gate District has taken over operation in this corridor from Greyhound Lines-West, patronage has almost doubled from 4200 daily riders to some 7600 currently. This is the result of a combination of factors, i.e., better distribution in downtown San Francisco, better neighborhood penetration at the Marin County end, an exclusive bus lane on US Route 101 at the Waldo Grade, and new, air-conditioned buses. Golden Gate also operates ferry service between Sausalito and Tiburon and downtown San Francisco. A new ferry terminal and three new ferrys are expected to be in operation in 1974 and 1975. Long range planning for separate right of way for bus or rail services in the Golden Gate corridor is under way but in the time frame of this study (through 1977) principal

opportunities appear to be incremental additions to existing operations and possible extensions of exclusive bus land provisions.

In the East Bay, the Alameda-Contra Costa Transit District provides excellent local, express, and transbay services in the western portion of the two above-named counties. As the BART operations comes into full service in September of this year, AC transbay operations will be de-emphasized and routes reoriented to BART feeder service. Coordination of service with BART is now under study as well as a potential Dial-a-Ride demonstration program.

In central Contra Costa County, studies for provision of BART feeder and local service (with special emphasis on service to low mobility groups) are ongoing. Existing Greyhound Lines-West commute service to San Francisco will be phased out as BART comes into full system operation. Studies of BART extension to Pittsburg and Antioch are ongoing. Such extensions are unlikely in the period of concern for air quality planning. However, express bus linkage to BART from these areas is anticipated in the near term.

In central Alameda County, studies have been completed for express bus linkage between the Livermore-Pleasanton area and BART at Hayward; studies for BART rail extension into this area are ongoing. However, only the bus services are likely to be operational by 1977. In southern Alameda County, the cities of Newark, Fremont and Union City are evaluating proposals for local and BART feeder transit services.

In San Francisco City and County, the San Francisco Municipal Railway provides intensive areawide transit coverage, operating streetcars, trolley buses, conventional motor coaches and cable cars. The new "Muni-Rapid" streetcar subway on Market Street is scheduled to begin operation in 1975 providing higher levels of service in the corridors now served by streetcars. Proposals for rapid transit service in the Geary corridor are now under study but these studies are of a long term nature. One unique form of service in San Francisco is the jitney operation along heavily travelled Mission Street.

The BART is completing a 75-mile rail rapid transit system serving Alameda, Contra Costa and San Francisco. The system radiates from Oakland with lines extending west across the Bay, through downtown San Francisco to Daly City north to Richmond east to Concord and south to Fremont. BART embodies the most recent rapid transit technology with automated fare collection and train control, operating speeds to 80 mph with an average system speed (including station stops) of about 50 mph. The full 75 mile system is expected to be in revenue operation by late 1973 and patronage estimates for 1975 project some 200,000 average weekday patrons -- 104,000 in the commute peaks, 96,000 in the off-peak period. While BART will have major impact in diverting motorists from their autos, caution must be exercised in viewing the above patronage figures, since many of the projected BART riders will be diverted from existing bus operations.

Principal transit operations in San Mateo County are the Southern Pacific Railroad and Greyhound Lines-West commute services to San Francisco. At present Southern Pacific operates 23 commute trains through San Mateo between San Francisco and San Jose (in Santa Clara County), transporting some 11,500 commuters. Its principal deficiency is the location of the San Francisco terminal at Third and Townsend streets, one-half to three-fourths of a mile from the CBD and remote from BART and other elements of the regional transit system. Studies for extension of BART service to the San Francisco Airport and the length of San Mateo County are ongoing. However, two similar proposals have been abandoned in the past 10 years. Within San Mateo County, local transit services are provided in the cities of Redwood City, San Mateo, South San Francisco, and Daly City.

Of the urbanized counties in the region, transit has least impact in Santa Clara County where it currently penetrates only 1.4 percent of the travel market. However, the newly formed Santa Clara County Transit District is in the process of purchasing 200 new propane propelled buses. This will immediately increase the level and quality of transit service in the county but is unlikely to have significant impact in terms of persons attracted from their autos and resultant VMT decreases. The

County Transit District, in association with MTC, is commissioning a $1.7 million study to develop a long range transportation plan. However, results of this study are likely to have effect only after 1980.

3.3.2.2 Pending Transit Improvements

The MTC staff presented a draft of a proposed regional transportation plan in February 1973 to comply with SB325 legislation mandating such a plan by July 1, 1973. The plan draft contains Table 3-25 recommendations for early implementation. No exact implementation schedule was presented in the draft, but implementation appears likely by 1977.

3.3.2.3 Capacity of Transit Service to Handle Additional Riders

Existing transit operations in the central and south-central portion of the region comprise the principal resource for effecting large scale replacement of personal motor vehicle travel in the near term future. In general, transit affords good accessibility through most of the central region although requirements for multiple transfers between routes and between systems in order to duplicate many of the trips now being made by auto makes transit usage inconvenient or even problematic on many origin-destination exchanges. In existing services capacity is generally available, both peak and off-peak, and additional capacity can be added incrementally given patronage demand and adequate funding to offset additional capital and operating costs.

As a rule of thumb, about 80 percent of all transit costs are operating expenses. Current Federal assistance is comprised only of capital grants (with the exception of limited demonstration programs). State sources provide some operating funds as a percentage of capital funds invested. The burden of transit operating expenses must be shouldered either via the farebox or through local taxation. Federal and/or additional operating subsidies would be desirable in fostering improved transit systems and reinforcing transit usage.

Table 3-25. Recommended Transit Improvements

	County	Project Description	Remarks	MTC Staff Category[1]
1.	San Francisco	Doyle Drive reconstruction (GG Bridge Approach)	Further evaluation of alternatives and impacts required, but safety considerations make resolution an urgent matter	II
2.	SF-Marin	Ferry System improvements: Present plans for ferries and terminals.	Implementation in coming year	I
3.	Marin-Sonoma	Local transit service improvements in urbanized areas of South Marin County, Novato, Petaluma, and Santa Rosa.	Improvements needed, studies now underway to define routes and costs. Should have high priority for implementation.	II
4.	SF-SM-SC	Regional trunkline transit on peninsula	Plans for BART extensions and/or express bus service and/or SP commuter service improvements, including transit access to SFO, now in progress. Some staged improvements are high priority.	II
5.	SC1	Local transit service improvements	Improved bus services under Santa Clara County Transit District sponsorship beginning implementation now	I
6.	Marin-Ala.	Richmond-San Rafael Bridge transit service	Studies underway of possible bus service within year; rapid transit as a long-range consideration	II
7.	SM-SC-Ala.	Dumbarton Bridge Corridor: Replacement of existing bridge	Replacement authorized by legislature; MTC approval not required	I

Table 3-25. Recommended Transit Improvement (Continued)

	County	Project Description	Remarks	MTC Staff Category[1]
8.	Ala.-SC	a) Express bus connections from San Jose to Fremont BART Station.	Santa Clara County Transit District prepared to implement within year. Routes, schedules, stops to be worked out.	II
9.	Ala.-CC	Local Transit Service Improvements a) Fremont-Union City-Newark Area b) AC Transit Service Areas in East Bay	Studies leading to early implementation now in progress. High priority. Study of appropriate service levels and alternatives to fixed bus route service now underway.	II II
10.	Alameda	Express bus service from Hayward BART Station.	To be implemented this year.	I
11.	CC-Ala.	Local bus service in Livermore-Pleasanton-San Ramon Valley areas.	Studies leading to early implementation needed. High priority.	II
12.	Contra Costa	Route 4 - Willow Pass-Highway improvements.	Design studies and impact studies.	I
13.	Contra Costa	Express bus service - from Concord BART Station to Pittsburg-Antioch	To be implemented this year	I
14.	Contra Costa	Local transit service in central county.	Studies leading to implementation now underway. High priority.	II

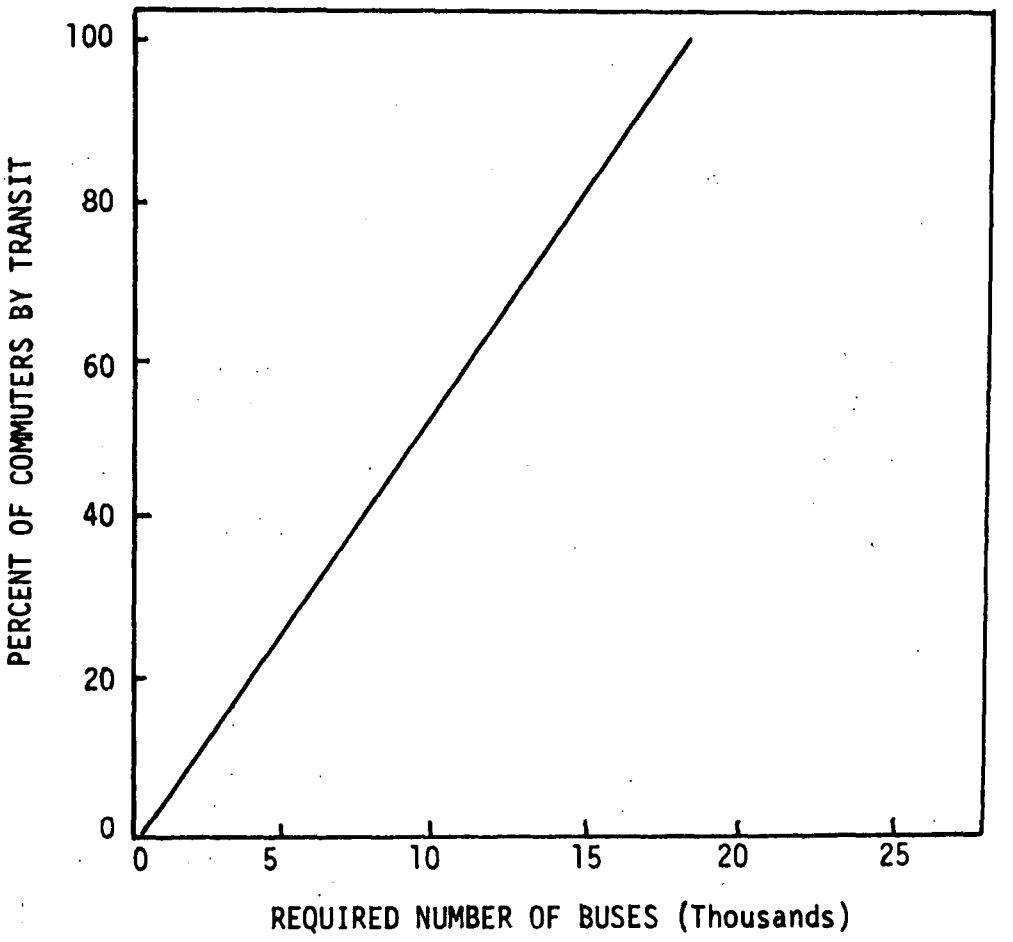
[1]Staff proposals subject to Commission review following public hearings. Category I for implementation immediately. Category II items are urgently needed, but some planning still required.

With regard to available capacity, most of the existing bus commute services operate on no-standees basis (by public choice). However, a standee capacity is available if required on an emergency basis. By 1975 to 1977 BART will be operating with some standees in peak periods, even with maximum length trains and minimum headways possible (3-15). However, substantial additional capacity is available depending on the level of "crowding" which is deemed acceptable.

Numbers of buses which might have been retired or reassigned to less productive feeder services as a result of BART opening could be retained in trunk haul commute services. About 100 motor coaches retired from San Francisco Municipal Railway service are still available. These vehicles are in poor repair but possibly could be reconditioned for service in a short range emergency program. However, despite these resources of additional capacity on existing (including BART) services and some availability of older transit vehicles, large scale rollbacks in auto use (through restrictive controls) on a regional basis and provision of substitute public transportation would necessitate purchase of buses on a massive scale. Figure 3-9 indicates a very rough dimensional estimate of the fleet size required to provide substitute transportation under various commuter leads.

The current limitations of U. S. bus production capacity have been documented in earlier reports (3-16). Recently a third manufacturer has entered the domestic bus production field. Even with this production capacity increase, in light of the fact that numerous other urban areas may be attempting to acquire large numbers of new vehicles on short delivery schedules as part of their air pollution control strategy programs, production capacity seems likely to remain a constraint. Perhaps more significant is the cost of massive transit expansion on the short term scale.

Achieving a 20 percent shift of regional work commute person trips to transit in the short-term (1977) time frame of this study would entail acquisition of some 3 to 4 thousand new buses, streetcars, or trolley coaches.



Assumptions:

Average occupancy of 40 persons per bus
Each bus makes three revenue trips
during each commute period

Figure 3-9. Theoretical Bus Requirements for Commute Transit Riderships

This would involve a capital investment (at $40,000 per vehicle) of $120-160 million (local share: $40-53 million). Annual operating expenses per bus typically range between $50 and $70 thousand per bus (depending on miles operated, labor costs and local conditions). This would entail incremental annual operating costs of between $150 and $280 million. (Note: the region's total state transit support (SB325 funds) amount to $34 million annually.) When these capital and operating costs and the anticipated quality of service rendered are compared with such opportunities as a San Mateo County BART extension (which would conceivably be operational by the early to mid-1980's at a price tag of roughly $1 billion), serious question is raised as to the advisability, even if technically possible, of pursuing an emergency transportation program to meet the 1977 air quality standards. It would seem more reasonable to allow necessary lead time for implementation of effective long-range transit services now being planned and to provide incentives and financing assistance to them. The MTC and the component jurisdictions of the region are now heavily engaged in such intermediate and long-range planning efforts. An emergency program for VMT reduction may be inconsistent with these ongoing longer-term efforts (and which are close to fruition) as well as totally drain the region's transit resources.

3.3.2.4 Highway Facilities

Figure 3-10 illustrates 1970 congestion on Bay Area freeways. Peak hour traffic congestion is most evident on critical links across topographic barriers such as the Bay and ridges. Such congestion contributes significantly to greater transit use, since drivers perceive time delay disproportionately to actual delay. Note peak hour congestion over segments of most Bay Area freeways with particular congestion on routes leading to San Francisco.

MTC staff presented a draft report on the regional transportation plan earlier this year. Table 3-26 contains highway improvements proposed for early implementation. Although no specific schedule was given, implementation by 1977 might be expected.

Table 3-26. Recommended Highway Improvements

	County	Project Description	Remarks	MTC Staff Category[1]
1.	Sonoma	Route 101 improvements to Cloverdale	Construction and final design in progress.	I
2.	San Mateo	I-380 from I-280 to Route 1 in Half Moon Bay	Relationship of coastal growth and development plans to travel needs is understood by San Mateo County, ABAG and and new Coastal Commission. Pressing safety problems at Devil's Slide.	II
3.	San Francisco	I-280 Third Street to SF Bay Bridge	Important 1/2-mile link in completion of the interstate system. Should be approved for Category I when final design problems resolved.	II
4.	San Mateo	I-380 Access to SF International Airport	Project now under construction in second of four stages.	I
5.	SCl	Route 101 Freeway - Cochran to Hellyer (Gilroy Bypass)	Important inter-regional link; should be approved for Category I when locational impact problems resolved.	II

[1] Staff proposals subject to Commission review following public hearings. Category I is for immediate implementation. Category II items are urgently needed, but some planning work still required.

3.3.2.5 Parking Conditions

Availability of parking in relation to employers, shopping centers, and other major generators is reflected in the price of parking and transit/auto choice in trip making. Reducing the supply and/or increasing the price of parking may, under certain circumstances, be able to increase transit usage.

Table 3-27 indicates daily parking rates for offstreet lots and garages in selected locations in the Bay Area. The San Francisco CBD has the single highest average rate with the San Francisco Airport having the next highest rate.

Table 3-28 breaks down the supply of parking space in the San Francisco downtown, the single largest aggregation of parking in the region. Of the 78,740 spaces available in 1965, 37 percent were on-street spaces, 36 percent were in off-street lots, and 27 percent were in off-street garages (3-17). Approximately 88 percent of the downtown parking spaces were available for public use. Supply has increased since 1965, but by an unknown amount (3-18).

It is estimated that 65 percent of the city's off-street parking lots and garages are on land owned by government -- City, State or Federal (3-19). This land is typically leased to private operators, rather than managed by the public agency itself. Revenue from lease agreements is estimated to comprise less than one percent of the City's budget. Most money taken in from lease agreements and parking meter revenues finds its way back into parking facilities, via the City's off-street parking fund or not-for-profit corporations set up for bonding parking structure construction.

Table 3-27. Daily Off-Street Parking Rates, Selected Bay Area Locations

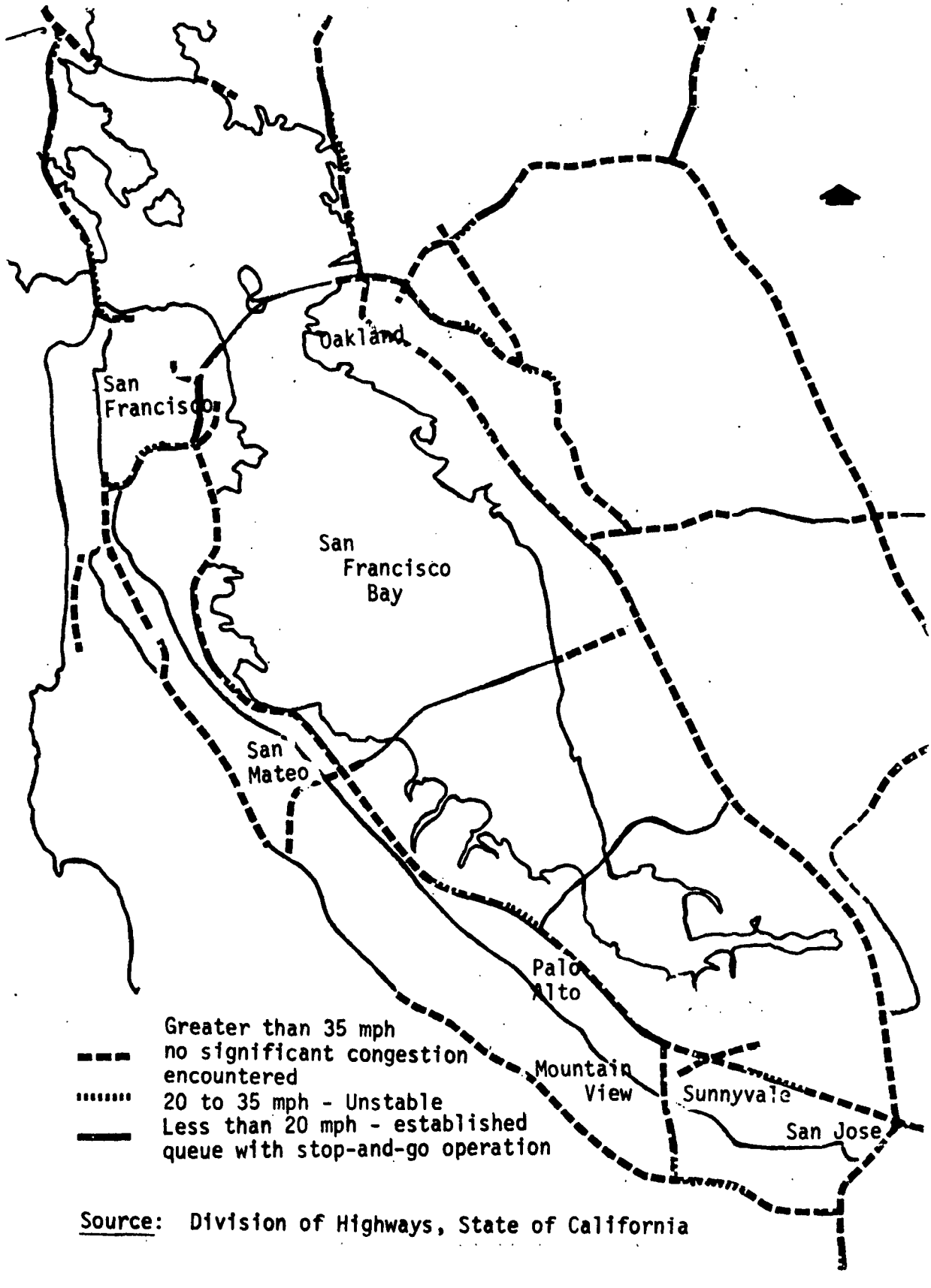
Location	Daily Rate
San Francisco CBD	$2.50 - 5.00
San Francisco Airport	$2.00 - 2.75
Oakland Airport	$1.00 - 1.75
Oakland CBD	$1.00 - 1.50
Berkeley CBD	$1.00 - 1.50

Table 3-28. Parking Spaces, San Francisco CBD

Category	Space	
On-Street		
Metered	4,951	
Signed	4,293	
Unlimited	1,928	
Special Zones (Yellow, White, Green, Special Permit, Taxi)	4,459	
Illegal	12,495	
Sub-total		29,126
Off-Street		
Private Lots	7,774	
Public Lots *	18,612	
Private Garages	1,670	
Public Garages *	21,558	
Sub-total		49,614
TOTAL		78,740

Source: "San Francisco Downtown Parking," Downtown Parking and Traffic Survey, 1966.

* Connotes availability to public only and not public ownership.



Source: Division of Highways, State of California

Figure 3-10. 1970 Freeway Peak Period Operating Conditions

3.4 REFERENCES

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3-19. Personal communications with Tax Assessment Department staff personnel, San Francisco, California, June 1973.

4.0 CONTROL STRATEGY DEVELOPMENT

In 1975, the baseline control strategy, fundamentally consisting of the present California-federal new vehicle control program and the present California retrofit program, falls far short of obtaining the emission levels which will allow the federal air quality standards to be met. As shown in Table 4-1, emissions of RHC remain much higher than allowable emissions even through 1980. For CO, air quality standards should be met by 1980. To attain the federal air quality standards, in particular the oxidant standard, by 1975 or 1977, an extensive transportation control strategy will be required.

Table 4-1. Baseline Versus Allowable Emission Levels

		1971	1975	1977	1980
RHC	Baseline	567	463	428	396
	Allowable	125	125	125	125
CO	Baseline	2573	1802	1470	1091
	Allowable	1364	1364	1364	1364

This chapter develops a transportation control strategy for the San Francisco Bay Area AQCR. Section 4.1 discusses possible further controls for stationary sources, aircraft, and motor vehicles. The motor vehicle controls are of three types: 1) controls of documented feasibility, 2) controls of uncertain implementability, and 3) transportation controls to reduce VMT. Before formulating a new, proposed strategy with their controls, the ARB strategy is evaluated. Section 4.2 critiques the ARB strategy according to the accuracy in its baseline projections, as well as the appropriateness of its amended control effects. Finally, Section 4.3 combines potential controls into a TRW proposed strategy. This strategy breaks into Phases I and II according to whether or not controls of uncertain implementability are included.

4.1 ALTERNATIVE CONTROL MEASURES

4.1.1 Stationary Source Controls

Stationary source controls are applied to RHC emissions from surface coatings, degreasing operations, dry cleaning, the handling and transfer of gasoline, and open burning. As exhaust emission control standards for motor vehicles become more stringent, the proportional share of RHC emissions from these sources will increase. This section provides source category descriptions and, where available, cost estimates for controls on a per unit basis.

4.1.1.1 Surface Coatings

This category consists of RHC's emitted from the application of protective and decorative surface coatings. There are two main emission categories:

a) Solvent evaporation with no change in chemical form
b) Solvent evaporation with a change in chemical form resulting from heat or flame contact.

The main sources in these two categories are architectural coating and paint baking, respectively.

The Bay Area Air Pollution Control District has enacted regulations concerning organic solvent usage which are comparable to Los Angeles' Rule 66. Since Rule 66 represents relatively stringent control, the potential for further control of emissions from this source category is limited.

The proposed controls consist of a tightened version of Los Angeles County Rule 66 to further eliminate RHC emissions. They are:

a) Substitution of water-based for organic-based coatings
b) Use of powdered and/or high solids content coatings.

It is estimated that a further 50 percent reduction in RHC emissions from this source is a reasonable expectation once the proper substitutions are developed and marketed (4-1). To allow a reasonable lead time for full implementation it has been assumed that a 30 percent reduction will be attained by 1975 and a 50 percent reduction by 1977.

4.1.1.2 Degreasers

This source category consists of RHC's emitted from degreasing operations. Almost all hydrocarbon emissions from degreasing come from three solvents: trichlorethylene (TCE), 1,1,1-trichlorethane (1,1,1-T), and perchlorethylene (PCE). There is currently a considerable degree of uncertainty concerning the reactivities of these compounds. According to the Los Angeles County APCD reactivity index, TCE is considered reactive while 1,1,1-T and PCE are considered non-reactive. This classification of the solvents will be assumed for the purposes of the present study.

The present state of control for RHC's from degreasers consists of limited substitution of non-reactive for reactive solvents and condensor or absorber systems to recover evaporative losses.

The proposed control consists of complete substitution of 1,1,1-T for TCE in degreasers using TCE. Necessary process and equipment changes for this substitution are anticipated to be minimal, in fact, 1,1,1-T may actually save on operating costs. The substitution of PCE for TCE would involve higher costs in terms of both equipment changes and operating costs.

It is assumed that a complete elimination in RHC emissions from this source category will result. It is also anticipated that since the required solvents are readily available, this measure can be fully implemented by 1975.

4.1.1.3 Dry Cleaners

Most dry cleaning is done with synthetic solvents, rated non-reactive on the Los Angeles APCD reactivity scale. There are, however, a few large dry cleaning plants that use reactive petroleum solvents. The use of these petroleum solvents is apparently declining.

The proposed control consists of adding activated carbon adsorption systems to the petroleum solvent dry cleaning plants in order to collect the solvent vapors. Such systems have been used extensively in synthetic solvent plants for recovery of the high-cost synthetic solvent (i.e., roughly $2.00/gal versus $.30/gal for petroleum solvent). A 90 percent reduction in emissions from this source appears to be a realistic goal for 1975.

4.1.1.4 Gasoline Modification-Reid Vapor Pressure Change

One method of lowering the evaporative losses is to change the composition of the gasoline, e.g., by changing the vapor pressure. Such a change requires a complete analysis of the impact on all emission subsequent to the change and the resultant change in photochemical reactivity of the modified fuel. According to Nelson (4-2), lowering the Reid vapor pressure from 9.0 psi to 6.0 psi reduces the expected evaporative emissions by 27 percent.

On the other hand, a joint study by the CARB, LAAPCD, and Western Oil and Gas Association (4-3) found much less benefit from such a fuel composition change. Although the study found the average percentage gains in emissions from stationary sources to be in good agreement with Nelson, the total net reduction was considerably less. Overall, the CARB study concluded in Reid vapor pressure from 9.0 psi to 6.0 psi would produce only a net hydrocarbon emission reduction of 9 percent. The key consideration was that "in general, a reduction in vapor pressure using fuels like the prototypes would produce a reduction in emissions due to evaporation of gasoline, an increase in exhaust hydrocarbon emissions, and a decrease in the total organic emissions associated with both gasoline associated sources and all sources, mobile and stationary" (4-3).

In addition, if one considers the impact of the reactivity change, the net benefit from a change in Reid vapor pressure becomes even less yet. Using the R-1 reactivity scale, it was concluded the overall gain from all gasoline related emission sources drops to about 4 or 5 percent and if the R-2 reactivity scale is used, the equivalent gain becomes only 1.2 percent. Thus, when the total resultant hydrocarbon losses (evaporative and exhaust) and the reactivity questions are considered, the gains in hydrocarbon improvements become quite low. If one goes on further to examine the cost associated with such a fuel composition change, the cost effectiveness of this strategy becomes very marginal.

At least two studies have reviewed the cost of such a change. The first (4-4) estimated capital costs at some $60 million and manufacturing cost per gallon at approximately 1.33 cents for large refineries and 2.13 cents for smaller refineries. The American Petroleum Institute (4-5)

indicated that modifying gasoline to have a Reid vapor pressure of 6 psi would increase manufactured costs by 1.24 cents per gallon. Assuming an average markup between refinery and consumer of about 100 percent (Oil and Gas Journal, December 1972), the cost would average 2.5 cents per gallon more to the consumer.

In summary, the key considerations are:

- Changing Reid vapor pressures results in substantial reductions in evaporative losses during fuel transfers.
- A lower Reid vapor pressure may increase exhaust hydrocarbons negating some of the reductions gained.
- A lower Reid vapor pressure may increase the reactivity of the gasoline again, partially negating some of the reductions gained.
- The cost of modifying gasoline to provide a lower Reid vapor pressure is substantial.

In view of the above, changing the Reid vapor pressure of gasoline appears to be a strategy which deserves further investigation, but which cannot be recommended at this time.

4.1.1.5 Evaporative Emission Control - Bulk Terminals

A different approach to controlling evaporative losses from the marketing of gasoline is to use some type of vapor recovery or mechanical trap system. Vapor recovery at bulk or wholesale terminals has been required in the Los Angeles and San Francisco Bay areas. The control consists of floating roofs on storage tanks and a refrigeration-compression system together with loading dock modifications to handle vapors displaced during the filling of delivery trucks. This latter system is estimated to cost roughly $250,000 per bulk terminal facility (4-6). This cost is broken down as $100,000 to $200,000 for the refrigeration-compression unit, and $100,000 for loading dock modifications. Such facilities recover roughly 90 percent of the vapors escaping during loading operations.

Roughly 80 percent of the total gasoline throughput in the San Francisco Area passes through controlled bulk terminals (4-7). This leaves roughly 30 bulk stations uncontrolled at this time. These terminals had previously been excluded from control because of their relatively small capacities.

4.1.1.6 Evaporative Emission Control - Service Station Modifications

Standard Oil Company of California has been experimenting with a mechanical trap (vapor return) system to be used during the filling of service station underground storage tanks (4-8). In such a system, vapors displaced from the underground tanks are returned to the delivery truck during the filling operation. The system as tested consists of a "T" connection to the underground vapor line, valves, and a three-inch diameter vapor return hose. Cost estimates for retrofitting service stations with such a system varied from $900 to $2000 per station, with a most probable figure of $1300 per station (4-9). This estimate is almost entirely because of labor costs incurred in excavation to gain access to the underground line, T-connector fitting, tank purging, and subsequent repair of the ground surface. In terms of efficiency, the tests revealed that an approximate 94 percent vapor recovery is entirely feasible. EPA emission factors for this operation in the absence of vapor return are 12 lb/1000 gallon throughput (splash fill) and 7 lb/1000 gallon throughput (submerged fill).

Recently, the American Petroleum Institute sponsored a study of methods available for evaporative emission control between the service station and the automobile. Of the techniques which are primarily service-station oriented, "control methods would avoid about 71 percent of vapor emission immediately upon completion of the service station conversion. The vapor emission avoided would progressively increase over a period of about 10 years to about 94 percent to 98 percent depending on the particular method considered" (4-10). The variation in the percentage effectiveness over time is dependent upon the development of a safe, vapor tight filling nozzle and a matching standardized automotive fill pipe.

Although many alternatives are available, only three of the most promising techniques are presented. The descriptions of these methods are as follows:

- Case 3 - Vapor Displacement to Underground Storage with No Recovery of Excess Vapors

This control scheme is based on displacing vapor from the vehicle fuel tank to the storage tank from which the fuel was pumped. This is accomplished by making a tight seal at the interface between the fill nozzle and the fuel nozzle and the fuel tank fill pipe. The fill nozzle is designed such that there is a space around the nozzle through which the displaced vapors can be directed to a vapor return line. This line directs the vapors displaced from the vehicle fuel tank back to the underground storage tank from which the fuel is pumped. The volume of the vapors displaced equals the volume of the fuel pumped from the storage tank. The vehicle fuel tank vapor in the underground storage tank is displaced back to the fuel supply truck at each delivery... . Any excess vapors generated at the service station due to temperature conditions is vented to the atmosphere (4-10).

- Case 4 - Vapor Displacement to Underground Storage with Recovery of Excess Vapors by Refrigeration

This control scheme is based on displacing vehicle fuel tank vapors during refueling back to the storage tank from which the fuel was pumped. This is accomplished by making a tight seal at the interface between the fill nozzle and the fuel tank fill pipe. The fill nozzle is designed such that there is a space around the nozzle through which the displaced vapors can be directed to a vapor return line. This line directs the vapors displaced from the vehicle fuel tank back to the underground storage tank from which the fuel was pumped. The volume of the vapor displaced equals the volume of the fuel pumped into the vehicle fuel tank. The vapor in the underground storage tanks is displaced back to the fuel supply truck at each delivery... . Any excess vapors generated at the service station due to temperature conditions are vented to a two-stage vapor compression system with intermediate cooling and final condensation by refrigeration. Condensed vapors consisting of propane and heavier hydrocarbons are returned to the underground storage tanks. The refrigeration unit is of 1.0 ton capacity at -10°F, and it is started and stopped on suction pressure sensing in a vapor holder (4-10).

- Case 5 - Vapor Displacement to Underground Storage with Recovery of Excess Vapors by Activated Carbon Adsorption

This control scheme is based on displacing vehicle fuel tank vapors during refueling back to the storage tank from which the fuel was pumped. This is accomplished by making a tight seal at the interface between the fill nozzle and the fuel tank fill pipe. The fill nozzle is designed such that there is space in the nozzle through which the displaced vapors can be directed to a vapor return line. This line directs the vapors displaced from the vehicle fuel tank back to the underground storage tank from which the fuel was pumped. The volume of the vapors displaced equals

the volume of the fuel pumped into the vehicle fuel tank... . Any excess vapors generated at the service station due to temperature conditions are vented to an activated carbon adsorption unit. All of the hydrocarbons are adsorbed in this unit. The activated carbon unit consists of four transportable canisters containing 25 pounds of activated carbon each. These canisters are regenerated about four times per month during the summer and considerably less during the rest of the year. The canisters are regenerated at the fuel supply terminal and their contained vapors are covered in the terminal vapor recovery system. The canisters are hauled to and from the supply terminal on trucks fitted specifically for this purpose (4-10).

The effectiveness of the Case 3 method was approximated to be 71 percent recovery assuming service station conversions were initiated in 1973 and completed in 1975. Eventually, a 95 percent recovery could be expected when all automobiles were fitted with standardized fill pipes. This maximum control would not occur until about 1985 due to the lead time for normal attrition of older vehicles. Cases 4 and 5 are estimated to have about a 3 percent better vapor recovery due to the condensation or adsorption of the vapors escaping from the storage tanks.

The costs for each case were estimated as follows:

- Case 3 - Vapor Displacement to Underground Storage with Recovery of Excess Vapors

Capital Installed Cost to Service Station

The capital costs show breakout for new and revamp stations.

Capital Installed Cost Per Station

	Material	Labor*
Piping and fittings (screwed)	$ 418	$1,438
(6) tight fill nozzles at $40 each. ($12 of this cost is for the tight seal vapor return feature). (6) combination fill and vapor return hoses at $15 each. ($6 of this cost is for the vapor return hose).	330	78
	$ 748	$1,516
Contingency at 20% material, 10% labor	150	151
	$ 898	$1,667
Concrete removal and repair and tank purging	---	2,500
	$ 898	$4,167

*Labor costs at $16/hour.

New station cost = $898 + $1,667 = $2,565

Revamp station cost = $898 + $4,167 = $5,065

Operating Costs to Service Station

Incremental additional replacement cost of the tight seal vapor return portion of the fill nozzles and the vapor return portion of the hoses at $30/year.

- Case 4 - Vapor Displacement to Underground Storage with Recovery of Excess Vapors by Refrigeration

Capital Installed Cost to Service Station

The capital costs show breakout for new and revamp stations.

Capital Installed Cost Per Station

	Material	Labor*
Piping and fittings (screwed)	$ 883	$1,896
(6) tight fill nozzles at $40 each. ($12 of this cost is for the tight seal vapor return feature). (6) combination fill and vapor return hoses at $15 each. ($6 of this cost is for the vapor return hose).	330	78
Condensation-refrigeration package	5,000	500
	$6,213	$2,474
Contingency at 20% material, 10% labor	1,243	247
	$7,456	$2,721
Concrete removal, repair, and tank purging	---	2,500
	$7,456	$5,221

New station cost = $7,456 + $2,721 = $10,177

Revamp station cost = $7,456 + $5,221 = $12,677

Operating Costs to Service Station

Incremental additional replacement cost of the tight seal vapor return portion of the fill nozzles and the vapor return portion of the hoses at $30/year.

Cooling water** at 3 gpm at $0.20/M gallons, say $28/year.
Power supply for 3 hp motor at $0.03 kwh, say $63/year.
Maintenance and inspection cost, use 6%/year installed; equipment cost = $10,159 x 0.03/year = $609/year.

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*Labor costs at $16/hour.
**Water is used only when equipment is in operation.

- Case 5 - Vapor Displacement to Underground Storage with Recovery of Excess Vapors by Activated Carbon Adsorption

Capital Installed Cost to Service Station

The capital costs show breakdown for new and revamp station.

Capital Installed Cost Per Station

	Material	Labor*
Piping and fittings (screwed)	$ 638	$2,096
(6) tight fill nozzles at $40 each. ($12 of this cost is for the tight seal vapor return feature). (6) combination fill and vapor return hoses at $15 each. ($6 of this cost is for the vapor return hose).	330	78
(8) carbon canisters at $80 each	640	32
Regeneration facilities**	25	12
	$1,633	$2,218
Contingency at 20% material, 10% labor	327	222
	$1,960	$2,440
Concrete removal, repair, and tank purging	---	2,500
	$1,960	$4,940

New station cost = $1,960 + $2,440 = $4,400

Revamp station cost = $1,960 + $4,940 = $6,900

Operating Costs to Service Station/Regeneration Terminal

Incremental additional replacement cost of the tight seal vapor return portion of the fill nozzles and the vapor return portion of the hoses at $30/year. Power supply for 5 hp vacuum pump motor at $0.03 kwh, say $1/year.

The cost effectiveness for each of the systems reviewed is as follows:

Case	Description	$/lb vapor recovered	¢/gal gas pumped	% reduction 1977	% reduction 1985
3	S/S displacement	0.19	0.14	76	95
4	S/S displacement and refrigeration	0.82	0.61	79	98
5	S/S displacement and activated carbon	0.34	0.25	79	98

*Labor costs at $16/hour.
**Regeneration facilities for 167 stations.

From these figures it is obvious that Case 3 represents the most efficient technique for motor vehicle vapor recovery. Cases 4 and 5 offer additional recoveries but the incremental costs associated with these recoveries is very high.

In summary, the controls selected for application to evaporative emissions resulting from the marketing of gasoline are as follows:

a) Vapor recovery at bulk terminal loading facilities (where required).

b) Underground tank vapor return to delivery truck.

c) Motor vehicle tank vapor return to underground tank storage ("Case 3" of Reference 4-10).

4.1.1.7 Open Burning

This control category consists of three sub-categories identified by the California ARB in its implementation plan source inventory. These are agricultural incineration, lumber industry incineration and backyard incineration.

4.1.1.8 Backyard Incineration

The ARB's plan for control of backyard burning should reduce emissions in this category by 50 percent in 1975:

> "...by 1975, backyard burning at single and two-family dwelling units will no longer be permitted in urban areas where alternative waste disposal provisions are available..." (4-10).

4.1.1.9 Lumber Industry Control

Improvements in burning practices to be required of the lumber industry will reduce emissions in this category by 60 percent in 1975:

> "Controls which will promote more complete combustion in the lumber industry's burning processes will reduce the emission of highly reactive organic gases..." (4-7).

4.1.1.10 Agricultural Incineration

Finally, a 20 percent reduction in RHC emissions from the incineration of agricultural wastes is expected because of improved burning practices (e.g., more complete drying of wastes before incineration).

> "By 1975, ... open burning will have been completely banned in this basin....." (4-7).

4.1.2 Aircraft Controls

Aircraft control measures can be divided into three categories: fuel modifications, engine modifications, and modifications of ground operations. The EPA has studied each of these categories to assess the potential for aircraft emission reduction. After a preliminary analysis of fuel modification as a category of control measures, it was determined that no significant reduction in Set II Pollutants could be achieved in this manner (4-11). Fuels can be modified to reduce emission of sulfur oxides and lead, but no significant reduction in emission of hydrocarbons, CO, or NO_x can be attained this way.

Engine modifications were studied in greater detail by EPA. The individual measures in this category are described in Table 4-2. Each of these modifications can reduce the emissions of at least one of the three pollutants mentioned above by between 50 and 90 percent (4-11). Table 4-3 lists the estimated development time, development cost, and implementation cost for each of the engine modifications evaluated. However, as the table indicates, only one -- fuel drainage control -- can be implemented in time to be effective in 1975. This measure also has the lowest estimated total cost. This measure does not, however, reduce aircraft emissions at the airport, since fuel is not now drained from planes during the LTO Cycle as specified by the EPA*. Few of the remaining modifications have a high probability of being implementable by 1977. Cost is also a serious obstacle to implementation of these measures. The estimated total cost of the least expensive turbine engine modification is approximately 150 million dollars; the least expensive piston engine modification is approximately 100 million. In addition, engine modifications require that the engine be re-certified with the Federal Aviation Administration (4-12) after the modification is made; this requirement presents an additional obstacle to the retrofit of in-use aircraft. In conclusion, because of engineering, economic, and institutional constraints, the aircraft control measures listed as engine modifications are not recommended for implementation in the San Francisco Bay Area for purposes of attaining the 1975 NAAQS.

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*See Appendix E.

Table 4-2. Engine Modifications for Emission Control for Existing and Future Engines

CONTROL MEASURE	DESCRIPTION
Turbine Engines	
Existing Engines	
1. Minor combustion chamber redesign	Minor modification of combustion chamber and fuel nozzle to achieve best state-of-art emission performance.
2. Major combustion chamber redesign	Major modification of combustion chamber and fuel nozzle incorporating advanced fuel injection concepts (carburetion or prevaporization).
3. Fuel drainage control	Modify fuel supply system or fuel drainage system to eliminate release of drained fuel to environment.
4. Divided fuel supply system	Provide independent fuel supplies to subsets of fuel nozzles to allow shutdown of one or more subsets during low-power operation.
5. Water injection	Install water injection system for short duration use during maximum power (takeoff and climb-out) operation.
6. Modify compressor air bleed rate	Increase air bleed rate from compressor at low-power operation to increase combustor fuel-air ratio.
Future Engines	
7. Variable-geometry combustion chamber	Use of variable airflow distribution to provide independent control of combustion zone fuel-air ratio.
8. Staged injection combustor	Use of advanced combustor design concept involving a series of combustion zones with independently controlled fuel injection in each zone.
Piston Engines	
Existing Engines	
1. Fuel-air ratio control	Limiting rich fuel-air ratios to only those necessary for operational reliability.
2. Simple air injection	Air injected at controlled rate into each engine exhaust port.

Table 4-2. Engine Modifications for Emission Control for Existing and Future Engines (Continued)

CONTROL MEASURE	DESCRIPTION
3. Thermal reactors	Air injection thermal reactor installed in place of, or downstream of, exhaust manifold.
4. Catalytic reactors for hydrocarbon and CO control	Air injection catalytic reactor installed in exhaust system. Operation with lead-free or low-lead fuel required.
5. Direct-flame afterburner	Thermal reactor with injection of air and additional fuel installed in exhaust system.
6. Water injection	Water injected into intake manifold with simultaneous reduction in fuel rate to provide for cooler engine oepration at leaner fuel-air ratios.
7. Positive crankcase ventilation	Current PCV system used with automotive engines applied to aircraft engines. Effective only in combination with one of preceding control methods.
8. Evaporative emission controls	A group of control methods used singly or in combination to reduce evaporative losses from the fuel system. Control methods commonly include charcoal absorbers and vapor traps in combination with relatively complex valving and fuel flow systems.
Future Engines	
9. Engine redesign	Coordinated redesign of combustion chamber geometry, compression ratio, fuel distribution system, spark and valve timing, fuel-air ratio, and cylinder wall temperature to minimize emissions while maintaining operational reliability.

Source: Aircraft Emissions: Impact on Air Quality and Feasibility of Control. United States Environmental Protection Agency, 1973.

Table 4-3. Time and Costs for Modification of Current Civil Aviation Engines*

Control Measure	Development time (Years)	Development cost (10^6 Dollars)	Implementation cost (10^6 Dollars)
Turbine Engines			
Minor combustion chamber redesign	2.5 to 5	37	383
Major combustion chamber redesign	2.5 to 7.5	74	665
Fuel drainage control	1 to 2.5	1.5	5.4
Divided fuel supply	5 to 7.5	84	102
Water injection	2.5 to 4	25	175
Compressor air bleed	4 to 6.5	90	58
Piston Engines			
Simple air injection	1.5 to 3	9	165
Thermal reactor	3 to 6	25	424
Catalytic reactor	2.5 to 5	22	535
Direct-flame afterburner	3 to 6	25	424
Water injection	1.5 to 3	9	400
Positive crankcase ventilation	2 to 4	4	94
Evaporative emission control	1.5 to 2.5	4	269

*"Civil aviation" includes air carrier and general aviation engines

Source: Aircraft Emissions: Impact on Air Quality and Feasibility of Control. United States Environmental Protection Agency, 1973.

Six methods of modifying ground operations at airports to reduce aircraft emissions have been studied by EPA. These are as follows:

1) Increase engine speed during idle and taxi operations

2) Increase engine speed and reduce number of engines operating during idle and taxi

3) Reduce idle operating time by controlling departure times from gates

4) Reduce taxi operating time by transporting passengers to aircraft

5) Reduce taxi operating time by towing aircraft between runway and gate

6) Reduce operating time of aircraft auxiliary power supply by providing ground-based power supply.

These measures are to be considered for use in connection with turbine aircraft only (4-11), with the possible exception of Number 3. Each measure has the potential for reducing THC and CO emissions at a large airport by amounts which vary between two and 65 percent (4-11). Table 4-4 shows the estimated implementation time, initial cost, and annual operating cost for each of the ground operations control measures when applied at a major international airport. Number 3 can be immediately eliminated because of the development time required. As a result, the remaining measures can be applied only at large commercial airports, rather than at both commercial and general aviation airports, since they are effective only on turbine aircraft. Application of these measures at military air bases has not been investigated by EPA, although it is obvious that the measures would not be as effective as they are at Bay Area airports because military emissions are larger and there is generally much less time spent per plane in the taxi-idle mode of the LTO cycle at the air base.

Table 4-4. Costs and Time for Operations Changes at a Large International Airport

Control Measure	Time (Years)	Initial Cost (10^6 Dollars)	Annual Operating Cost Change* (10^6 Dollars)
1. Increase engine speed	0	0	8.5
2. Increase speed, reduce number	0.3	0	-0.7
3. Control gate departure	5	15	-0.4
4. Transport passengers	2.5	65	5.0
5. Tow aircraft	1	1.2	0.4
6. Reduce APU operation	0.5	1.3	1.5

*Minus sign indicates an estimated savings.

Source: Aircraft Emissions: Impact on Air Quality and Feasibility of Control. U.S. Environmental Protection Agency, 1973.

Measures 1, 4, and 6 are, in general, relatively ineffective in reducing aircraft emissions at major airports (4-11), and, as Table 4-4 indicates, they are more expensive than the remaining two measures.

EPA has determined that measure Number 2 is the most cost effective of all measures listed in both categories studied -- engine modifications and ground operations. Number 5 is more costly and slightly more effective (4-11) than 2 and it is less accurately quantifiable than 2 because of the significant difference in the availability of data. Also Number 5 is more dependent on the geometry and layout of the particular airport. As a result, ground operations measure Number 2 has been selected for further evaluation as a potential control measure.

4.1.3 Vehicular Controls

There are a number of control measures for reducing motor vehicle hydrocarbon, CO and oxides of nitrogen emissions. In this section, each measure is defined and is accompanied by a brief discussion of the technical and economic aspects of its implementation.

The programs to be described are as follows:

- Vehicle inspection/maintenance
- Retrofit measures:

  Vacuum spark advance disconnect
  Lean idle setting
  Catalytic converters
  Air bleed
  Positive crankcase ventilation
  Exhaust gas recirculation

4.1.3.1 Inspection/Maintenance

For a number of years, the State of California has had a program requiring emission control to be inspected or installed on used cars before they are registered by new owners. A Certificate of Compliance from a Class A (licensed) service station is required to meet this measure and to insure the proper idle setting, air/fuel ratio, and ignition timing. The California Highway Patrol (CHP) has also been administering roadside, spot inspections to check for safety as well as idle emissions. Vehicles which fail the emissions test are required to visit the Class A station. About 15 percent of the vehicle population is inspected by the CHP each year.

It has been found that a substantial emission reduction can be achieved when the motor vehicle population is properly serviced. Vehicles emitting three times their specified allowable rates have been identified in the existing inspection program. The emission reduction potential that could be obtained by identifying all vehicles which need servicing is great, especially in a time when emission controls are becoming more complex and prone to deterioration. A more rigorous inspection strategy is desired.

Inspection/maintenance measures are intended to reduce vehicular emission through a program of mechanical and analytical inspection, followed by a mandatory maintenance. Maintenance (tune up, repair, parts replacement, etc.) will, therefore, allow each vehicle to operate in a significantly less polluting fashion.

Generally, maintenance requirements are based on the results of a periodic idle emissions test or a loaded emissions test. By selecting the appropriate percentage failure rate for vehicles tested, it is possible to obtain varying levels of effectiveness for the program. Increasing the failure rate criteria results in higher emission reductions.

The idle emissions test is run by sampling exhaust emissions when the vehicle is in the idle mode. The sample is analyzed to determine pollutant emission levels. Maintenance is required if the vehicle exceeds established emission limits. This procedure is easier and less expensive to run than the loaded emissions test and can be done at most service stations.

The loaded emissions test is conducted using a chassis dynamometer and a trained technician. The nature of the test equipment and skill required to run this test makes it both more time consuming and expensive than an idle test. However, the loaded inspection is a more diagnostic test, and is effective in pinpointing defective engine and emission control components. The vehicle is operated on the dynamometer at different load modes that simulate various modes of normal operation. The exhaust is sampled at each mode in the same way that it is sampled in the idle emissions test. High cruise, low cruise, and idle, are three modes that might be tested. Certain engine malfunctions can then be traced by referring to a "truth chart" which serves as a maintenance aid.

With either test, criteria can be established so that a certain percentage of vehicles will fail the initial inspection and be subject to maintenance. Table 4-5 shows what average annual percent reductions are to be expected in light duty vehicle exhaust emissions for each test as a function of percent initial failure of the vehicle population (4-13).

Table 4-5. Average Annual Percent Reductions

Percent Initial Failure Rate	10	20	30	40	50
Percent Emission Reduction					
Hydrocarbons (loaded)	8	11	13	14	15
Hydrocarbons (idle)	6	8	10	11	11
CO (loaded)	4	7	9	11	12
CO (idle)	3	6	8	9	10

Source: EPA

The impact of inspection/maintenance on emissions is fairly predictable, since the proposed program would be a mandatory one. Public opinion surveys indicate most people favor such a program. However, the tendency of such a program is to be socially regressive because it is the older cars that are the most vulnerable to maintenance. The economic burden will, therefore, hit lower income people harder.

4.1.3.2 Retrofit Measures

Any device or system adjustment that can be added to a motor vehicle after it is sold and which reduces emissions is classified a retrofit. Many emission control retrofits have been evaluated. The more successful and implementable devices are discussed in this section. The reader is referred to two other documents for a more in-depth discussion of these and other devices: "Control Strategies for In-use Vehicles," an EPA document, and "Emission Control of Used Cars," by the Technical Advisory Committee of the California ARB.

Like the inspection/maintenance program, retrofit measures are likely to impact older vehicles to a greater degree than newer vehicles. The reduction effect of different retrofit options on the three major motor vehicle pollutants is shown in Table 4-6, with the installation cost for each option also indicated. It must be assumed that these retrofits are coexistent with an inspection/maintenance program as the values shown for percent reduction of each pollutant can be applied to maintained vehicles only (4-14 and 4-15).

Table 4-6. Retrofit Control Measures

Retrofit Option	Installed Cost	Average Reduction per Vehicle (%) HC	CO	NO_x
Pre-controlled Vehicles				
Lean idle air/fuel ration adjustment and vacuum spark advance disconnect	$ 20	25	9	23
Oxidizing catalytic converter and vacuum spark advance disconnect	195	68	63	48
Air bleed to intake manifold	60	21	58	0
Exhaust gas recirculation and vacuum spark advance disconnect	35	12	31	48
Controlled vehicles				
Oxidizing catalytic converter	175	50	50	0
Exhaust gas recirculation	50	0	0	40

Source: EPA

Each measure shown in the table is defined below with a brief description of each one's technical and economic implications.

- Vacuum Spark Advance Disconnect - This modification to the distributor involves changing cylinder combustion conditions in such a way that up to a 50 percent reduction in hydrocarbons is possible. The durability of such a system is very good. Fuel economy will deteriorate, and in some vehicles this deterioration may be as much as 20 percent. Hotter running engines is another factor which must be considered, with overheating in hot weather and high exhaust valve wear distinct possibilities.

- Lean Idle Setting - This is a measure which might increase fuel economy as much as five percent. The cost of this modification is nominal ($3-$6), and a mechanic with the right instrumentation can perform the setting easily. The buildup of deposits in the carburetor is the only major durability problem aside from the high probability of mechanic or owner tampering due to the expected decrease in idle quality.

- Oxidizing Catalytic Converter - Catalysts offer a substantial reduction in CO and hydrocarbons after the device has warmed up sufficiently. The lowest levels of lead, phosphorous, and sulfur in the currently available fuels will introduce a durability problem to the catalyst. If older cars are to be retrofitted with catalytic converters they will have to be detuned considerably so they can run on no-lead gasoline.

  The operation of the catalytic principle involves the circulation of exhaust gas over the heated bed of material that readily converts hydrocarbons and CO into water and CO_2.

  The installation of the catalyst should be relatively straightforward. It is estimated that the cost may be considerably lower than that shown in the table when they are production items in 1975.

- Air Bleed - This is a low cost, simple installation retrofit measure. If it is well designed, it will reduce emissions at about the same rate as a lean idle setting or leaner carburetor jets. There will be no problem with durability. Driving performance will be reduced, however.

- Positive Crankcase Ventilation - PCV has been incorporated on all new cars in California since 1963 as one of the first emission control measures. It essentially eliminates all of the emission losses from the crankcase area. Air is vented through the crankcase and mixed with the blowby gas. It is then recirculated into the intake manifold through the variable orifice called the "PVC valve."

- Exhaust Gas Recirculation - This measure is designed to reduce oxides of nitrogen emissions substantially. Installation is somewhat difficult and moderately costly. Durability is good provided low lead

gasoline is used and there are no engine malfunctions (e.g., misfire, flooding, or oil burning). Otherwise, the system is liable to become plugged, requiring a low cost repair. Driving performance could be severely hampered with this system. Fuel economy also suffers.

4.1.4 Alternative VMT Control Measures and Their Effects

4.1.4.1 Procedures for Assessing Effectiveness of VMT Controls

To evaluate the relative effectiveness of various VMT reduction strategies, it was necessary to develop an analytical methodology capable of predicting potential transit ridership for a set of critical variables. Unfortunately, it is difficult to quantify factors people use to rate the attractiveness of car pools, bicycling, walking, etc., relative to driving alone or riding aboard a bus or rail vehicle. To date, research on these topics has been limited (4-16 and 4-17).

Parameters affecting transit ridership are better understood. Models have been developed which can reasonably estimate the proportion of total trips between two geographical locations that will be made via mass transit. MTC and most of the current transportation studies in the Bay Area are using a mode choice model developed by BATSC in 1968 from 1965 travel data. However, to use the BATSC mode split model for evaluation of VMT reduction scenarios required three preparatory steps: 1) BATSC data had to be reaggregated and mode choice curves modified to reflect evaluation requirements; 2) several basic assumptions were necessary in equating travel time and out of pocket costs, since the BATSC curves reflect sensitivity to travel time only; and 3) relationships had to be derived for converting increases in transit ridership to VMT reduction.

4.1.4.1.1 Modifying the Bay Area Mode Choice Model

Basically, the BATSC mode split model relates the time advantage of auto or transit travel with percent of total persons using transit. The pattern of home based work and related business trips, referred to here as "work trips," closely approximates rush hour travel. The remaining travel can be grouped as "other trips," and closely approximates typical midday travel patterns.

In an effort to simplify the amount of necessary calculations, BATSC data were aggregated from 291 traffic zones to 30 larger super dis-

tricts. Intradistrict trips were separated out as "local" travel (i.e., generally under 10 miles in length) and the remaining interdistrict trips were subdivided into those destined for: 1) the San Francisco CBD, 2) elsewhere in San Francisco, 3) Oakland-Berkeley, and 4) other locations tabulated by county. BATSC mode choice curves were then adjusted to fit the several trip purposes and origin-destination combinations.

Appendix C contains a detailed description and illustration of procedures. The various resulting mode choice curves are presented below.

Work Travel to Downtown San Francisco

Figure 4-1 illustrates mode choice behavior for travel to the San Francisco CBD from San Francisco locations and locations outside San Francisco. The steep slope of the curves reflects high terminal cost -- traffic congestion and $2-$5 daily parking fee -- and a high degree of transit access. The horizontal axis relates actual auto travel time to actual transit travel time, including wait and transfer time. The vertical axis indicates percent of persons using transit for various transit/auto travel time ratios. These curves reflect a current average transit/auto travel time ratio of 1.6 for rush hour trips to downtown San Francisco. This converts to 37 percent transit usage for trips originating in San Francisco and 52 percent transit usage for trips coming from out of town. These curves are sensitive to travel time only and cannot by themselves be used to assess the effects of changing out of pocket costs such as fares, gasoline prices, tolls, etc.

The San Francisco mode choice curves indicate that cutting transit travel time in half or doubling auto travel time would have the same net effect; for example, a transit/auto travel time ratio of 0.8 would result in an estimated transit usage of 52 and 64 percent respectively, for trips from San Francisco and from outside the City. The steepness of the slope of these curves indicates strong potential for diverting passengers to transit and reducing VMT through traffic constraints applied to corridors entering San Francisco.

Work Trips to Elsewhere in San Francisco

Figure 4-2 shows mode choice behavior for trips to non-CBD locations

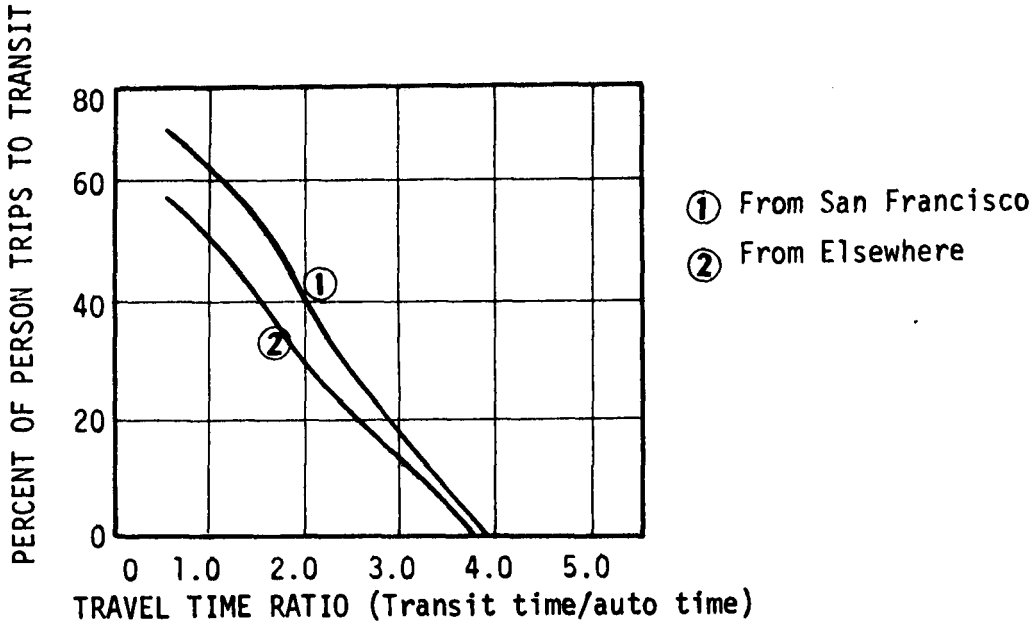


Figure 4-1. Mode Choice for Work Travel to San Francisco CBD

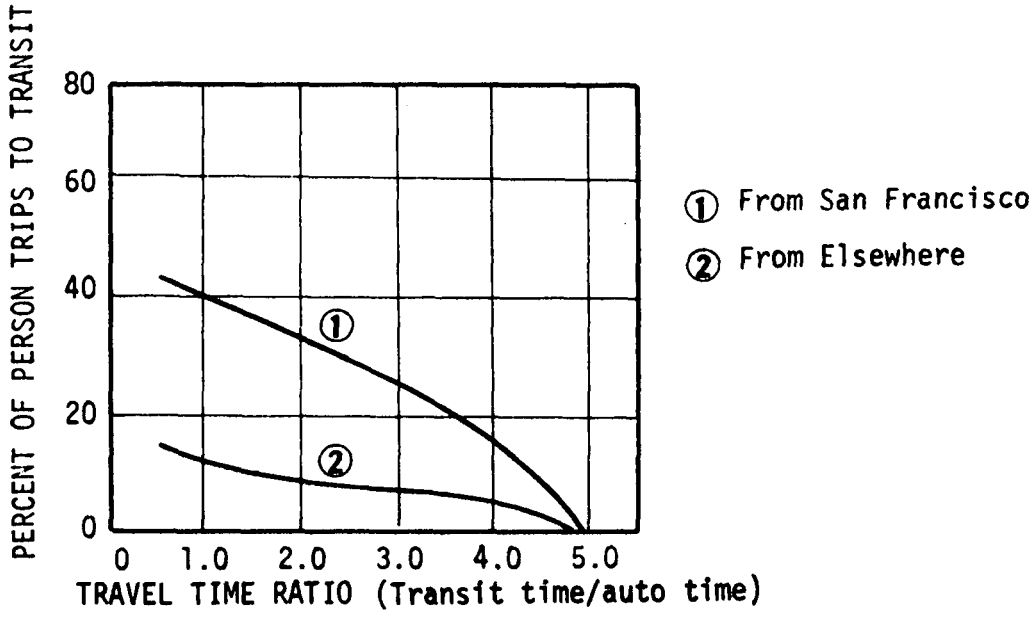


Figure 4-2. Mode Choice for Work Travel to Remainder of San Francisco

in San Francisco. The curve for San Francisco origins is much steeper than the curve for origins outside San Francisco. This reflects the necessity for out-of-town riders to transfer one or more times to reach non-CBD locations and greater auto ownership for residents outside the City.

Current transit usage for trips to non-CBD locations ranges between 20 and 30 percent for San Francisco origins but only accounts for about eight percent of trips coming from outside the City. The relative inelasticity of these curves implies that control measures directed at lowering the transit/auto travel time ratio would not significantly influence the current transit ridership levels. For example, if it were somehow possible to reduce the transit/auto travel time ratio from 3 to 1.5 by some control measure(s), one would probably increase transit ridership from origins outside San Francisco by about 3 percent (i.e. from approximately 7 to 10 percent). To cut the transit/auto travel time ratio in half would require substantial improvements in transit and/or very severe restrictions on the auto.

Work Trips to Oakland-Berkeley

Figure 4-3 illustrates mode choice behavior for Oakland-Berkeley destinations. The curves turn decidedly upward to the left as transit gains a time advantage over the automobile. The shape of the curves reflect parking costs around major employers and the high level of transit access available. Current transit use varies from 14 to 23 percent for trips originating in Oakland, Berkeley or San Francisco down to three percent for trips coming in from low density outlying areas. These data denote again the higher transit ridership for residents within the local region.

Other Work Trips

Figures 4-4 through 4-6 illustrate transit/auto mode choice behavior associated with work trips to locations outside San Francisco, Oakland and Berkeley. Note that with one exception, the curves are relatively flat in the 5 to 10 percent by transit range. These curves indicate that the prospects for diversion associated with improving transit accessibility or increasing auto travel time are relatively low.

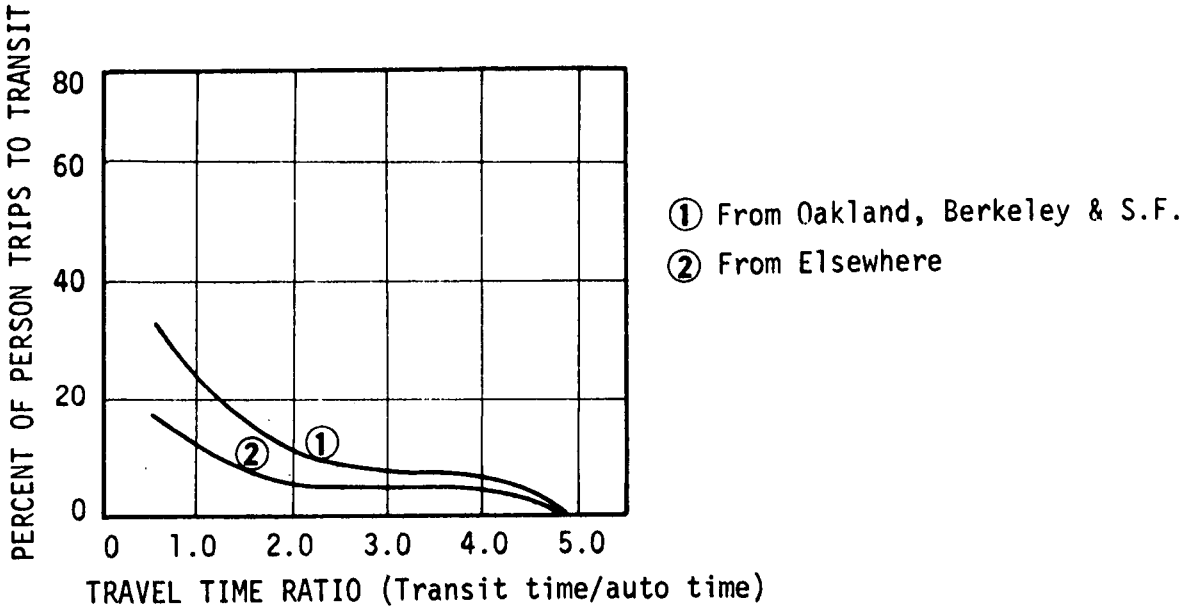


Figure 4-3. Mode Choice for Work Travel to Oakland-Berkeley

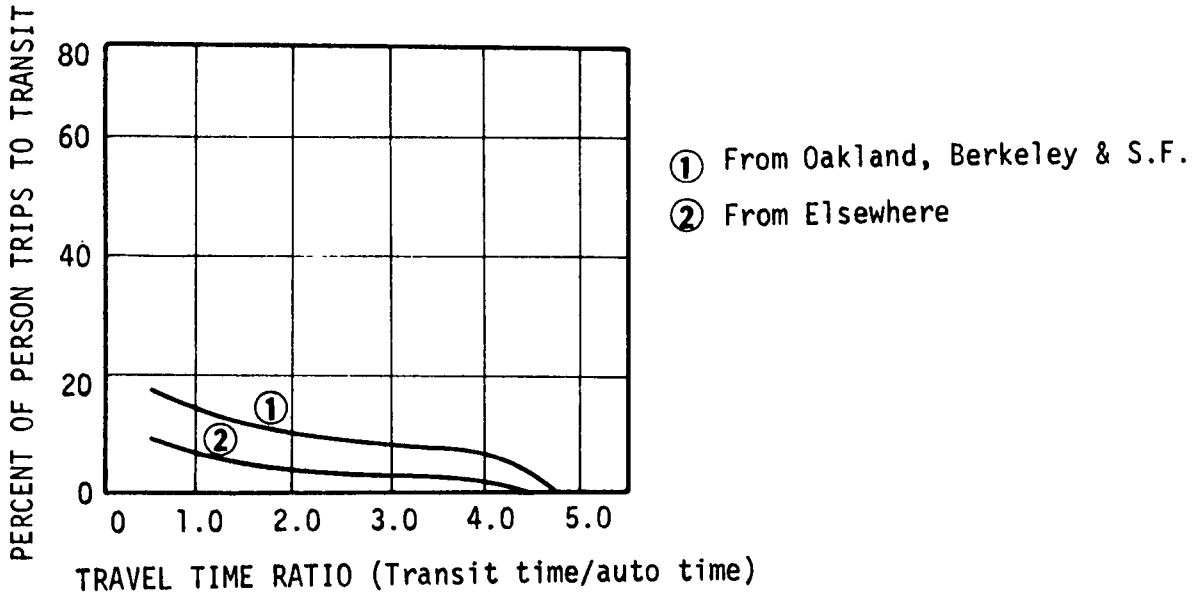


Figure 4-4. Mode Choice for Work Travel to Remainder of Alameda and Contra Costa Counties

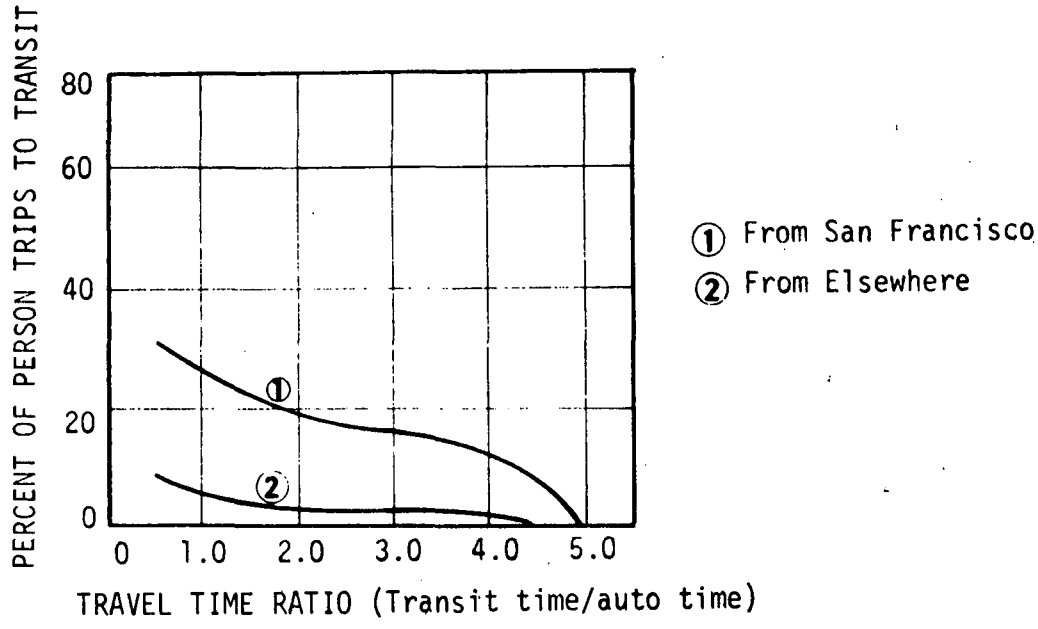


Figure 4-5. Mode Choice for Work Travel to San Mateo and Marin Counties

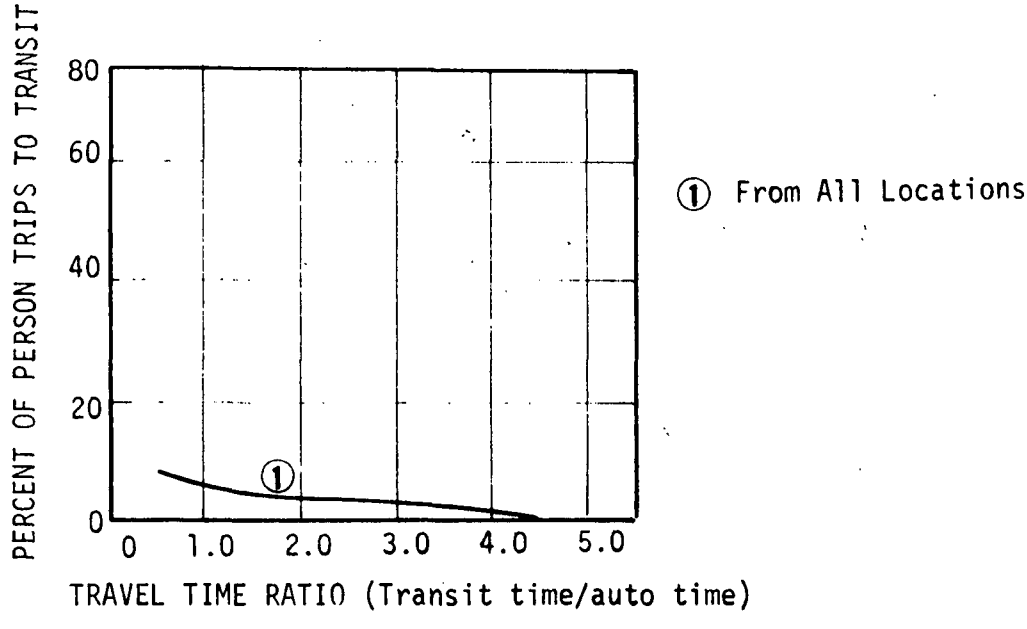


Figure 4-6. Mode Choice for Work Travel to Santa Clara, Solano, Sonoma and Napa Counties

The single exception is the curve for San Francisco residents commuting to neighboring Marin and San Mateo Counties. The steeper slope of this curve is due primarily to lower auto ownership in San Francisco.

Non-Work Trips to San Francisco

Figure 4-7 shows mode choice relationships for non-work trips to San Francisco CBD and non-CBD locations. Note the steep slope to the CBD oriented curve, while a much flatter curve applies to travel to outlying San Francisco. Current midday transit use to downtown San Francisco is about 20 percent. Midday transit use to non-CBD locations ranges between 14 percent for San Francisco origins to 10 percent for origins outside the city.

Non-Work Trips Destined Outside San Francisco

Figure 4-8 illustrates mode choice behavior for non-work trips to Oakland-Berkeley and to the remainder of Bay Area (outside San Francisco, Oakland, and Berkeley). Only the Oakland-Berkeley curve indicates potential diversion from auto to transit given changes in relative auto/transit travel time. Even here though, only modest increases in transit ridership appear possible.

4.1.4.1.2 Equating Travel Cost and Time - The Concept of Impedance

To analyze the effects of change in toll, parking costs, transit fare or other costs associated with auto or transit travel, several assumptions were made to equate costs to travel time. The sum of travel time and cost equivalent, expressed as impedance (Equation 4.1), reflects the total effort involved in making any given trip. Relationships similar to Equations (4.1) and (4.2) have been developed by DeLeuw, Cather and Company (4-18), A.M.Voorhees and Associates (4-17), and others for application elsewhere. Specific assumptions for time penalties, income, and other variables are hypothesized for general analytical purposes only in the absence of data applicable to the Bay Area. Assumptions are believed valid for general order of magnitude comparisons.

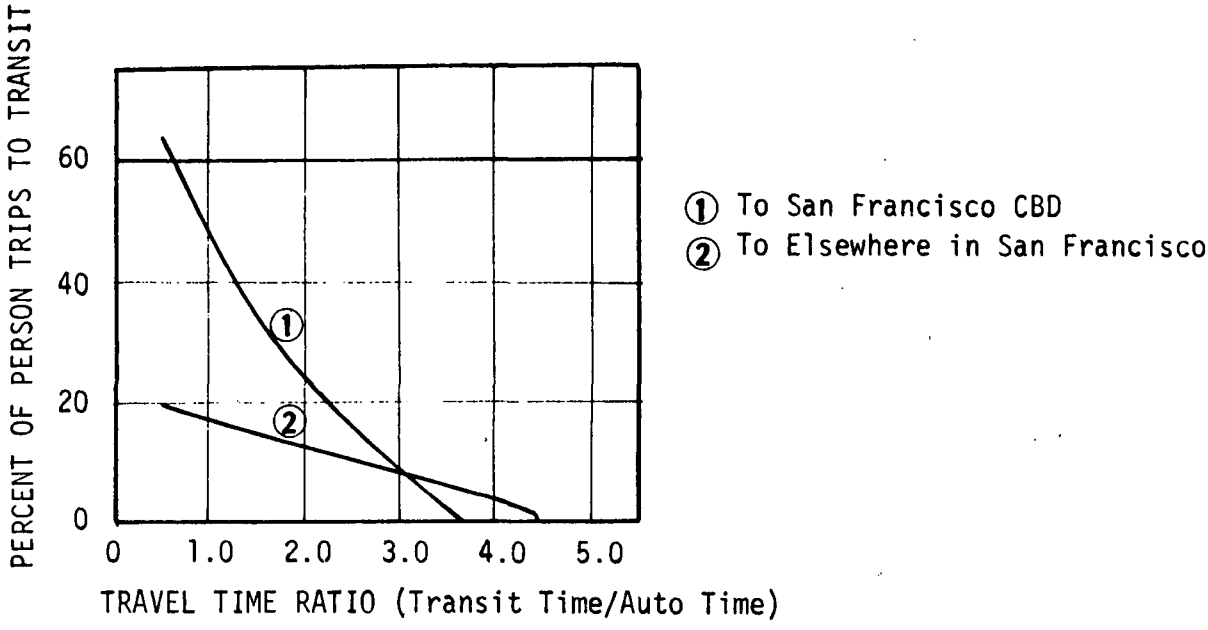


Figure 4-7. Mode Choice for Non-Work Travel to San Francisco

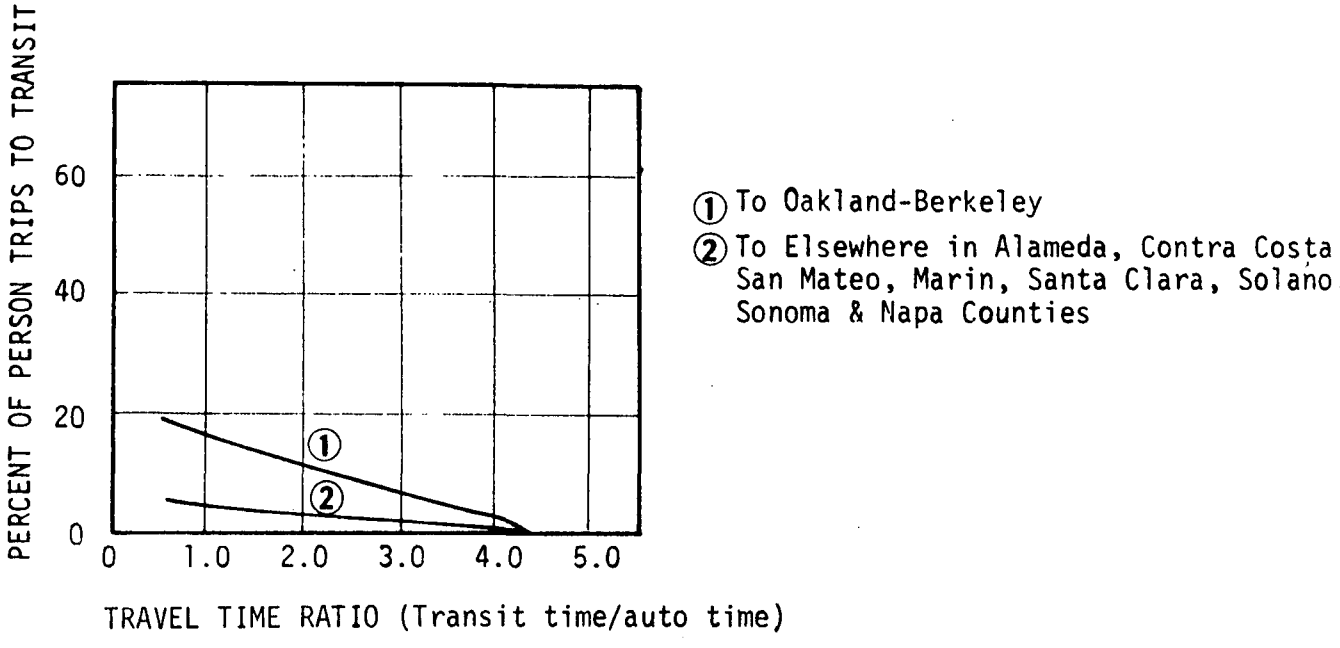


Figure 4-8. Mode Choice for Non-Work Travel to Locations Outside San Francisco

Assume $I_T = W_1 + W_2 + W_3 + Fi$ (4.1)

where

I_T = Impedance (net time effort + money) required for transit trip.

W_1 = Walking time x 2 (penalty perceived)

W_2 = Wait time x 3 (penalty perceived)

W_3 = Ride time

F = Transit fare

i = Factor relating fare to time (based on average hourly wage), here assumed constant at 1 hour per $3.

Assume $I_A = d_1 + d_2 + d_3 + W_1 + (O + T + P)i$ (4.2)

where

I_A = Impedance (net time effort + money) required for auto trip.

d_1 = Driving time under free flow conditions

d_2 = Stop and go driving time x 2 (penalty perceived)

d_3 = Time spent at stand still x 3 (penalty perceived)

W_1 = Walk from parking to destination

O = Out of pocket vehicle operating expense; here assumed to be 5¢/mile

T = Toll

P = Parking cost

i = 1 hour per $3

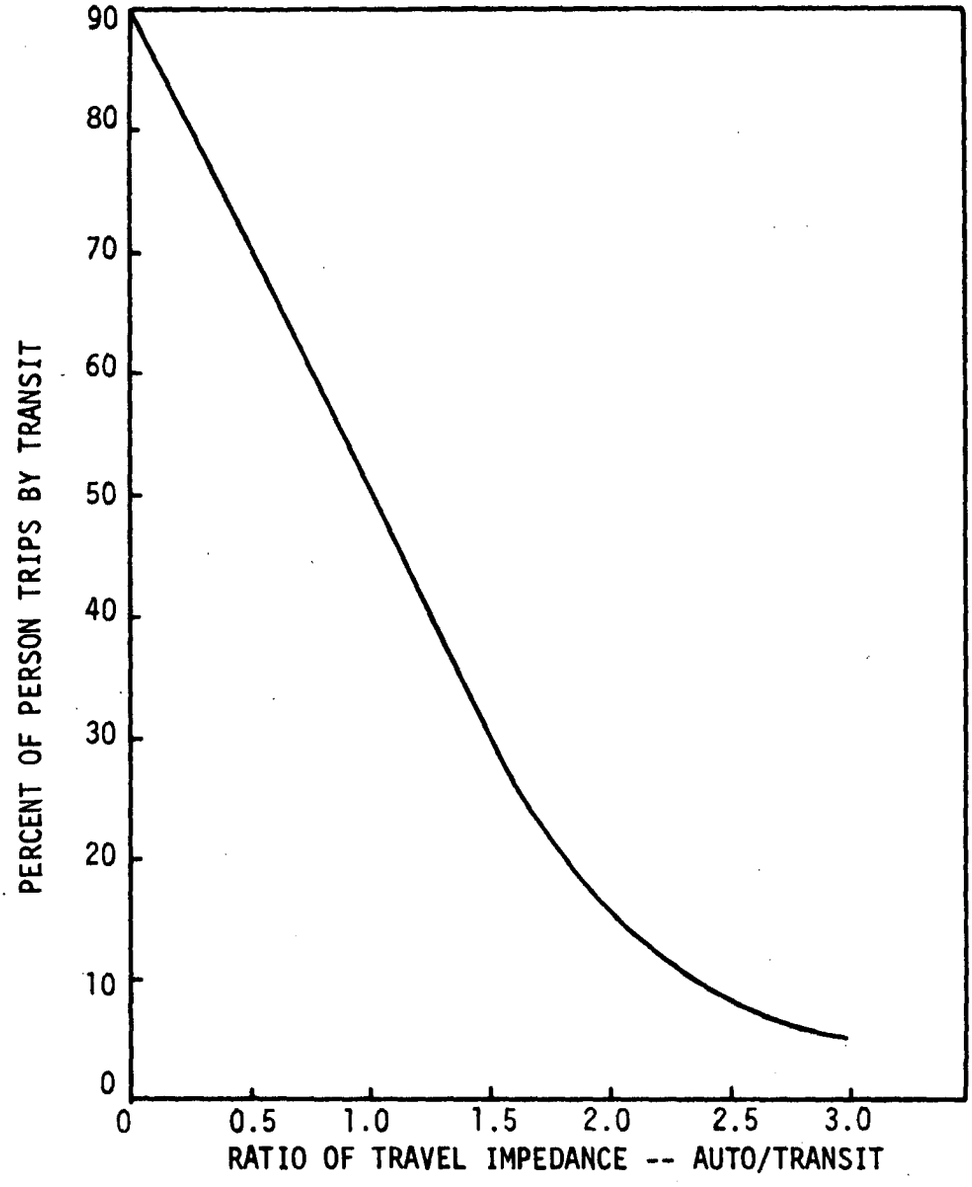


Figure 4-9. Bay Area Mode Choice Reflecting Travel Cost and Time

Source: Postulated from BATSC Mode Split Data

Figure 4-9 shows the Bay Area mode choice curve postulated from the foregoing equations and the BATSC travel data. Points on the various BATSC mode choice curves were converted to impedance, knowing transit fares, wait times, tolls, parking costs, etc.

Sensitivity of Impedance Variables to Control

Table 4-7 describes potential control over the various impedance variables. Lower transit fares and increased driving time, vehicle operating costs, and tolls can be applied with a minimum of administrative problems; their effect is immediate. Improved transit services require response time to become effective and offer greatest potential when applied in conjunction with other controls. Parking controls may be effective but pose administrative problems because of the multiplicity of ownership and special circumstances likely to arise. Some loss of effectiveness in parking control is likely as wives drop husbands off at work, drivers circle the block while riders shop, etc. The effectiveness of measures to increase walking time for auto users is difficult to project, with a likely side effect being to merely add a short transit shuttle trip to the end of a long auto trip.

Using the Concept of Impedance - 4 Examples

Figure 4-10 compares transit and auto impedances for four Bay Area work trip situations. Each round trip originates in Concord. For analysis purposes BART was considered open under the Bay to San Francisco and frequent local bus service (10 minute headways) was assumed available in central Contra Costa County. Impedance for a local trip to Walnut Creek involving a round trip of 10 miles consists primarily of travel time -- riding, driving, waiting and walking. Reducing transit fare would have little effect on the ratio of transit/auto impedances. Doubling the price of gasoline, which would increase mileage costs by 50 percent, also would have little effect. Significant diversion from auto to transit would appear to require direct limitations on auto usage, e.g., gas rationing, restricted car ownership. Significant short term increases in bicycling and walking or elimination of unnecessary trips appear to require similar vehicle controls for effectiveness.

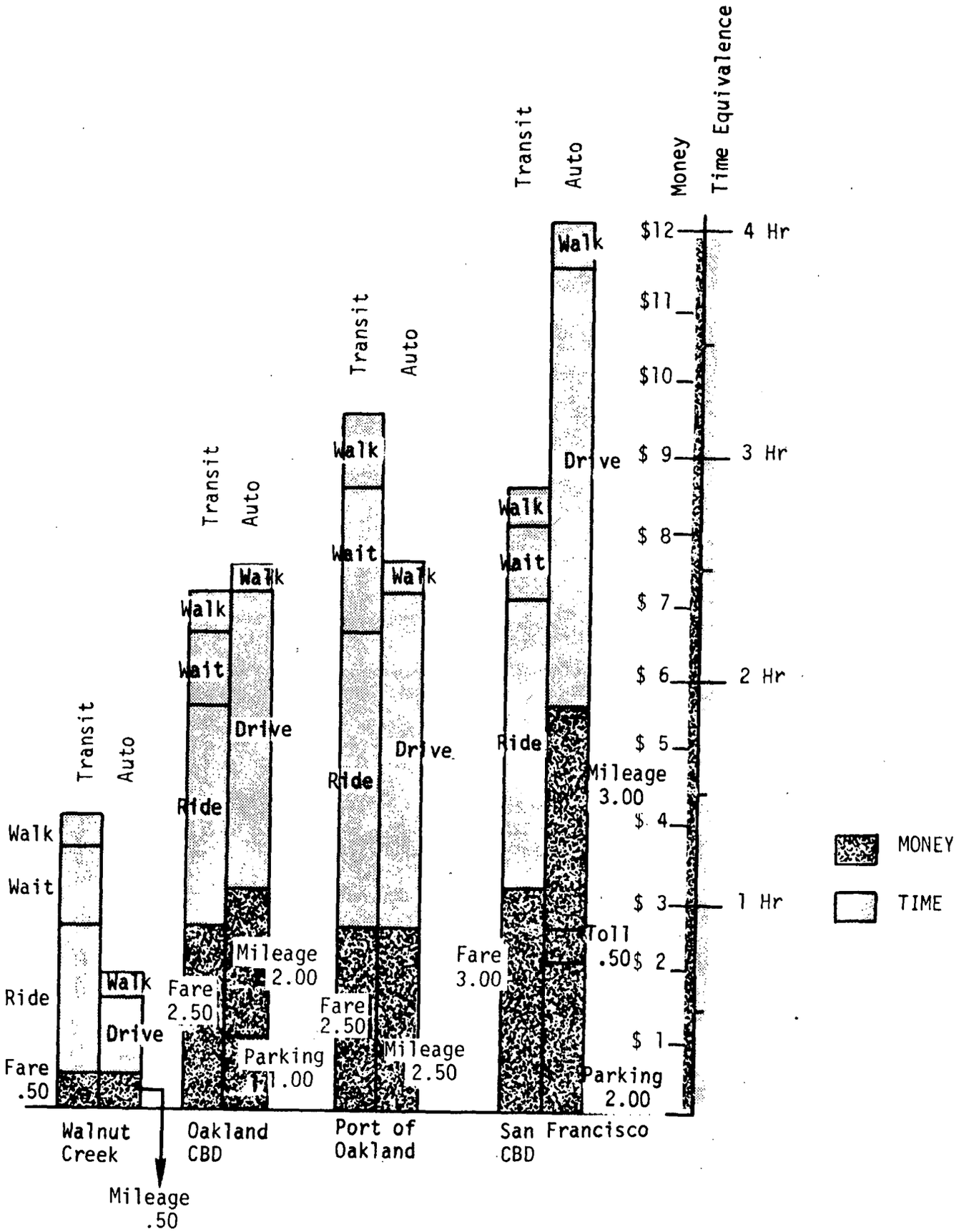


Figure 4-10. Impedance for Round Trip from Concord, Work Purpose

Table 4-7. Control of Impedance Parameters

Impedance Parameter*	Potential for Control	Example(s) of Control Aimed at Decreasing I_A/I_T *
W_1 (walk time)	Low	More bus stops and/or routes; auto free zones
W_2 (transit wait)	Medium	Improve frequency of service;
W_3 (transit ride)	Medium	Exclusive bus lanes; rail rapid transit
F (transit fare)	High	Lower fares
i (income)	Very low	Lower personal income levels
d_1 d_2 d_3 (driving time)	High	Limit number of traffic lanes in use
O (vehicle operation)	High	Gasoline tax, "smog" tax
T (toll)	High	Raise bridge tolls, freeway tolls
P (parking)	Medium	Limit on-street parking, parking space tax, restrict new parking construction

*See Impedance Equations (4.1) and (4.2).

A round trip to downtown Oakland from Concord involves an impedance of about 2 hours and 20 minutes, whether by auto or by transit. About 50 percent transit usage should be expected under such circumstances. Out of pocket costs -- fare, mileage, and parking -- constitute a larger share of impedance than in the case of the local trip. Eliminating fare would reduce the transit/auto impedance ratio to about 0.6, a measure which conceivably could raise transit usage to 65 percent. Traffic flow restrictions along the freeway, e.g., elimination of lanes through the Caldecott Tunnel, could increase the competitive advantage of transit still further.

A round trip to the Port of Oakland represents longer trips to a non-CBD location, one which typically requires a public transit rider to transfer one or more times to reach his destination. Direct transit service offered on a subscription basis would be one way of making the

transit ride more competitive with the auto. It would be difficult in this case to better the 1.25 transit/auto impedance ratio, since BART holds a time advantage due to separate right of way. Eliminating transit fare could reduce the impedance ratio to 1.0. Inducing constraints on travel through the Caldecott Tunnel could have a similar effect.

The fourth situation involves travel to the San Francisco CBD. Impedance associated with this round trip is quite high -- almost three hours by transit and four hours by auto. The transit/auto impedance ratio should be about 0.7 when BART opens, meaning about 63 percent transit usage. For further reduction in auto use, reducing transit fare would be one of the most effective measures. It would take about a $5 increase in bridge toll or parking fees to obtain the same 0.5 impedance ratio possibly by reducing transit fare to a flat 25 cents in each direction. Using a combination of very low transit fare, increased bridge and restrictions on auto travel across the Bay Bridge, a 0.4 impedance ratio appears achievable. This translates to roughly 75 percent of work trips from Concord to San Francisco CBD by transit.

4.1.4.1.3 Converting Percent Transit Usage to VMT Reduction

Mode choice curves provide the basis for estimating trips diverted from auto to transit for various VMT control strategies. To convert trip diversion to VMT reduction requires attention to trip length and auto occupancy, factors which vary with trip purpose and origin/destination combination. Transit experience indicates more long trips may be diverted to transit than short trips with various control measures. To not consider length of trip in assessing VMT reduction would tend to underestimate the effectiveness of controls.

Fortunately, BATSC 1980 vehicle travel forecasts were available in a manner which permitted regional VMT to be disaggregated for the same trip purposes and origin/destination combinations used in projecting percent transit usage (Appendix C, Tables C-6, C-7, C-8).

4.1.4.2 Evaluation of Measures for VMT Reduction

A full range of possible VMT reduction strategies was screened to select those with greatest Bay Area application. The effects of eight scenarios with greatest potential were subsequently quantified:

1. Intercepting auto traffic entering San Francisco via tolls, metering, reduced transit fare, parking regulation (Section 4.1.4.2.1)
2. Suburban employer parking restrictions/subscription bus and carpooling (Section 4.1.4.2.2)
3. Moratoriums on development in automobile dependent regions (Section 4.1.4.2.3)
4. Traffic disincentives/transit preferential treatment (Section 4.1.4.2.4)
5. Free transit fare (Section 4.1.4.2.5)
6. Improved local transit (Section 4.1.4.2.6)
7. Gas taxing/pricing (Section 4.1.4.2.7)
8. Gas rationing (Section 4.1.4.2.8).

Several other scenarios were explored, but their effect was not quantified because of insufficient time or lack of data with which to make reasonable estimates.

1. Toll/metering in corridors not entering San Francisco (Section 4.1.4.2.9)
2. Parking tax (Section 4.1.4.2.10)
3. Vehicle registration surcharge (Section 4.1.4.2.11)
4. Carpooling (Section 4.1.4.2.12)
5. Traffic flow improvements (Section 4.1.4.2.13)
6. Work schedule changes (Section 4.1.4.2.14)
7. Reducing vehicle usage (Section 4.1.4.2.15)
8. Reducing trip requirements (Section 4.1.4.2.16)
9. Network of bicycle paths (Section 4.1.4.2.17).

4.1.4.2.1 Intercepting Auto Traffic Entering San Francisco

Geographic features of the San Francisco Bay region have constrained land use and transportation system development to the extent that large portions of regional travel are confined to closely defined corridors and a limited number of facilities. This presents a unique opportunity to produce significant shifts in modal mix through toll position, auto/transit

pricing schemes, or absolute metering at a limited number of control stations.

If control stations were placed on US 101 and Interstate 280 in the vicinity of the San Francisco - San Mateo County line, these, in conjunction with the existing toll stations on the Golden Gate and San Francisco - Oakland Bay bridges, could toll or meter virtually all travel between the City and County of San Francisco and the rest of the region. Some leakage would occur along the San Francisco - San Mateo border, but alternative routes are unattractive and limited in capacity. Viable transit alternatives exist in all three corridors - - Greyhound bus and Southern Pacific rail commute services in the Peninsula (San Mateo) corridor, Golden Gate bus and ferry service in the Marin (Golden Gate) corridor and AC Transit bus and (after September 1973) BART rail service in the transbay (Bay Bridge) corridor (transbay Greyhound commute services will largely be discontinued with full BART system operation). The potential effectiveness of this measure is very significant. Table 4-8 indicates average weekday vehicle driver trips produced outside the above defined corridor and attracted within it for work and all purposes.

Table 4-8. External Trip Attractions - San Francisco, 1965

	Daily Person Trips	Percent Of Region Total
Work	366,800	20.4
All Purposes	1,051,500	16.9

Source: BATSC 1965 Origin-Destination Survey

In addition large segments of other regional travel passes through the corridor. Capacity on each of the three major commuter bus services and the Southern Pacific rail service could be expanded incrementally to meet increased passenger demands.

Transbay BART capacity may be constrained over the next year by car availability and scheduling (control) problems but should eventually be capable of handling almost any volume of transbay commuters on a standee basis.

Alternate Approaches to Intercepting Traffic into San Francisco

Four approaches could be used separately, or in combination to encourage transit use into San Francisco:

1. Increase tolls coming into the city
2. Impose physical constraints, e.g., bus and carpool lanes
3. Reduce transit fares
4. Reduce parking availability in the San Francisco CBD.

A pricing strategy involving simultaneous raising of tolls and lowering of fares would appear to be the most desirable first line of attack, while relying on traffic restraints and reduced parking as a backup -- to not let faster travel times and cheaper parking undo the effectiveness of the pricing strategy.

There are several advantages of intercepting auto traffic entering San Francisco. First, is the ability to affect modal shifts of large numbers of trips through the addition of only two new control stations (with modification of "control" at the two existing toll stations) and the ready availability of alternative transportation services. Revenues generated through increased tolls could be used to subsidize and expand transit services in the affected corridors. The proposal has flexibility in that control can be imposed on a peak period or all day basis and control can be tightened or eased as necessary to achieve the desired modal shifts, both initially and as conditions change with introduction of non-polluting or low-polluting vehicles to the vehicle population.

Principal drawbacks of the scheme stem from considerations of equity and long term effects. Equity considerations involve placing the burden of control upon that segment of the Bay Area population which travels to or through San Francisco. Over the long term, such controls could increase pressures for new development in the auto-oriented portions of the region rather than in the already highly transit-oriented central portions in which this control is imposed. Dependence on this control for a large proportion of the total regional emission rollback required could result in a continued major air quality problem, particularly in the South Bay area.

Increased Toll

Using mode choice curves for San Francisco-oriented trips, regional trip interchanges, and VMT figures, VMT reductions were estimated for 1) 50 cent toll increase; 2) $2 toll increase; and 3) $10 toll increase (Table C-9, Appendix C). Separate estimates were obtained for a strategy directed toward rush hour commute traffic only and for a strategy applicable on a 24 hour basis. A modest 50 cent toll increase round trip could be expected to induce only a small VMT reduction (0.2 percent reduction for peak hour; 0.5 percent on a 24 hour basis). Even a relatively large $2 toll increase would only yield a net VMT reduction of 0.6 percent for the peak hour and 1.4 percent for 24 hour application. The travel time and cost of the commute trip to San Francisco is already so high that tolls would have to be raised on the order of $10 per round trip to cut vehicular traffic into the city in half (3 percent reduction in commute VMT and 6.8 percent reduction if applied on a 24 hour basis).

Metering

Metering, preempting lanes for buses and carpools or otherwise restricting the volume of traffic flow into San Francisco should theoretically have an effect similar to toll increases, with an hour of time delay each day roughly equivalent to $6-9 worth of toll increase. The major problem associated with the artificial traffic constraint is that if applied in isolation, it is likely to be perceived as counterproductive -- artificially induced constraint which increases the amount of time on the road. Taking away half the lanes entering the city during the peak hour could cut overall VMT by three percent. Midday and evening VMT reduction would be more difficult to achieve.

Lowered Transit Fares

Drastically reducing or eliminating transit fares coming into the city offers incentives to use transit rather than penalties on the auto. Because travel costs are already high going into San Francisco, an incremental decrease in transit fare promises to be more effective than an equivalent toll increase. Free fare on trips to San Francisco should decrease VMT by about two percent if applicable to commute trips and about 4.5 percent on a 24 hour basis.

Parking Restrictions

Reduced parking supply can be viewed as a direct control on auto traffic coming into the city or as a necessary add-on to other strategies aimed at reducing VMT associated with travel to San Francisco. With 37 percent of CBD parking in on-street spaces and an additional estimated 40 percent on government owned parcels off-street (See Base Line Data Section, Parking Conditions), government action alone (without affecting private spaces) could conceivably achieve a reduction of 50 to 60 percent.

A 50 percent reduction in travel to the San Francisco CBD would require a commensurate decrease in parking supply if parking rates are to remain the same while toll increases, transit fare decreases and/or traffic constraints are taking effect. If parking supply stays the same while commuter demand decreases, more San Francisco residents may choose to drive downtown and/or parking rates may drop, partially countering the objectives of constraint on auto travel into the city.

4.1.4.2.2 Suburban Employer Parking Restrictions/Subscription Bus and Carpooling

This scenario was designed to affect that portion of work trips destined to lower density locations outside San Francisco and central Oakland-Berkely. Previous transit analysis of Mare Island Facility in Vallejo (4-19), Lawrence Radiation Laboratory and Sandia Corporation in Livermore (4-20), and the General Motors Assembly Plant in Fremont (4-21) showed that sufficient market existed at major employers to offer subscription bus service. Private charter companies typically provide this service with drivers being employees of the firms served. For a fixed monthly fee, the driver picks up employees within their neighborhood in route to work. Experience indicates such service can be run economically by the private operator where riders commute over 10 miles. For employees living 5 to 10 miles from work, a mixture of carpooling and subscription bus service constitute a reasonable option to the automobile. Employees living closer than 5 miles may bicycle, walk, or husbands or wives may drive them to work and pick them up in the evening, thereby increasing work trip VMT.

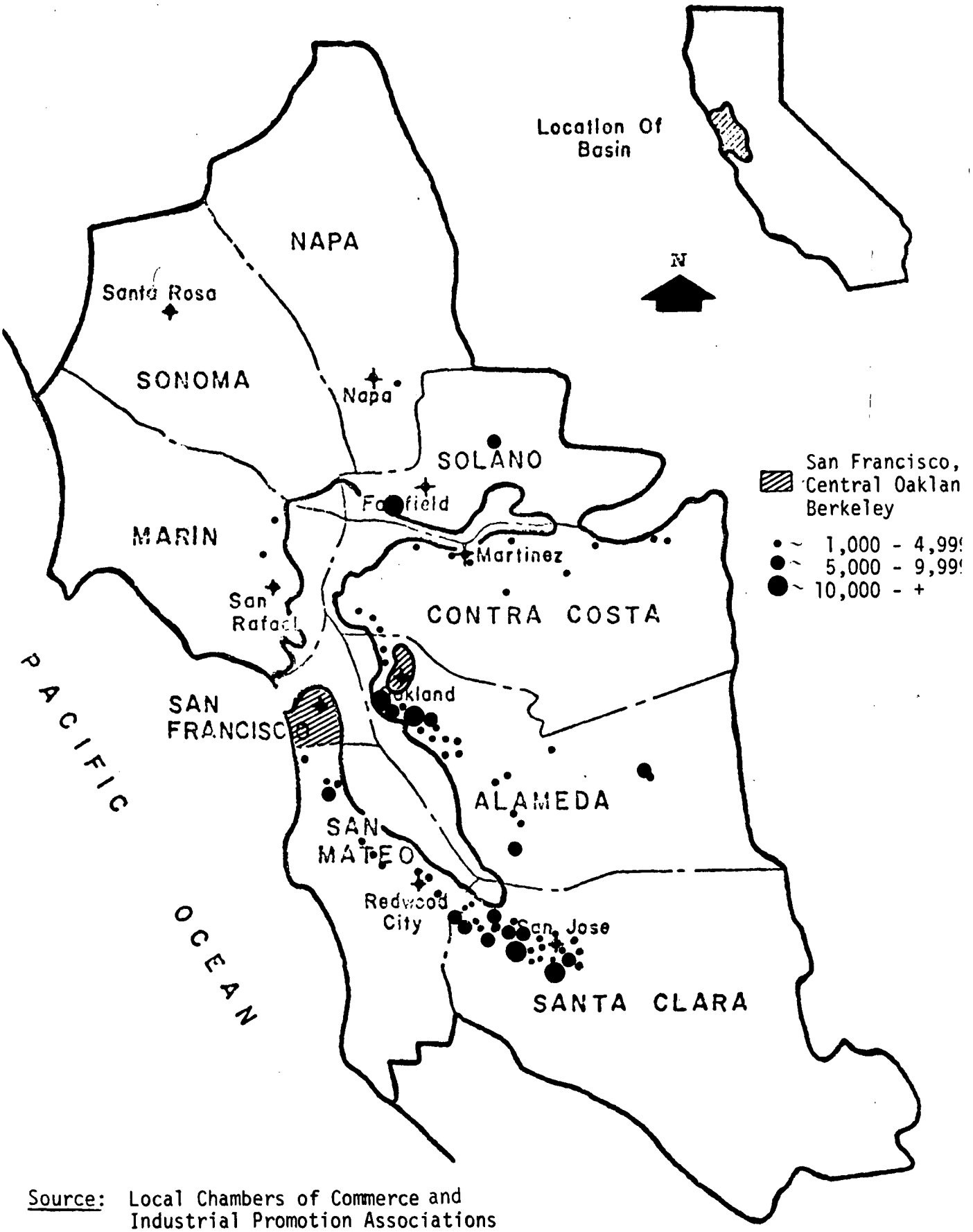
The approach envisioned is for the employer to reduce the number of parking spaces available to employees. Employers of 1000 employees or more are seen as the initial target. Employers of 500 to 1000 and industrial parks would be the next order of priority. A 50 percent reduction in VMT seems reasonable given an estimated distribution of 50 percent living over 10 miles, 25 percent living 5 to 10 miles and 25 percent living less than 5 miles from work (4-20). Considerable slippage is expected in the under 5 mile zone as wives drop husbands off at work and pick them up in the evening, thereby doubling work trip VMT. To offset this probability, prescribed reduction in parking spaces would have to be greater than 50 percent. Initial testing and monitoring will be necessary to set criteria.

Table 4-9 contains a summary of approximate employment at firms of over 1000 employees, for the area outside the intensive transit area -- San Francisco, Oakland, Berkeley (also shown in Figure 4-11). A 50 percent reduction in travel to these generators (reduced parking, subscription bus service and carpooling) could be expected to reduce Bay Area VMT by 1.9 percent (50 percent reduction, 320,000 employee vehicle trips affected out of 3,500,000 Bay Area vehicle work trips, and 42 percent of VMT associated with work trips).

Table 4-9. Employment at Bay Area Firms With Over 1000 Employees*

County	Employees
San Mateo	45,500
Santa Clara	59,000
Alameda	19,600
Contra Costa	17,100
Solano	15,000
Napa	2,000
Marin	4,000
Total	162,200

*Excluding San Francisco, Oakland and Berkeley
Source: Bay Area Chambers of Commerce and Industrial Promotion Associations, 1972-73



Source: Local Chambers of Commerce and Industrial Promotion Associations

Figure 4-11. Major Employers Outside San Francisco and Central Oakland-Berkeley

Applied to an estimated additional 50,000 employment in Oakland-Berkeley outside the central cities, the 50 percent work travel reduction strategy would result in a total 2.5 percent VMT reduction. A more stringent approach directed at eliminating 75 percent of the VMT associated with employers of over 1000 employees would yield 3.6 percent VMT reduction.

Firms with over 1000 employees were singled out for initial application of the parking reduction strategy. Suburban firms of this size constitute about ten percent of the region's employment. These firms tend to attract employees from a large catchment area, and large numbers of employees commuting long distances provide a suitable market for subscription bus service.

Unless areas three to four blocks around a major employer are signed to prevent employee on-street parking, reduction in off-street parking could lose much of its effectiveness. Control of parking around large firms can be effectively administered, however, using a "protected neighborhood" signing. Local resident cars would be identified by special sticker and allowed to use curbside spaces, while other cars would be limited to one hour parking or prohibited altogether. Protected neighborhood signing would be applicable to areas around colleges, hospitals and other large generators as well as manufacturing or office centers. Shopping center employee parking will be most difficult to control. Requirement of an overall parking space reduction at shopping centers might encourage store owners to limit employee parking in off-street spaces intended for customers.

4.1.4.2.3 Moratoriums on Development

Building moratoriums are imposed in California communities for inadequacies in sewer, water and school systems and for preparation of a general plan. The concept behind the moratorium is to prevent further damage from continued development while the local area is coming to grips with its problems. A spin-off of the moratorium is the channel of new growth into areas that have services available.

A moratorium might be effective at reducing VMT if imposed on particularly fast growing, particularly auto dominated areas. Unfortunately, the moratorium offers no positive incentives for development of transit. Its effect are not likely to be immediate, but could be measurable over 3 to 5 years.

A moratorium over the entire urban area would not be effective, but if applied to specific problem locations could channel growth into transit use areas and give time to effect a turnaround in planning and development of transit and land use control.

Moratorium Because of No Local Transit Service

There are a number of subareas within the Bay Area with no local service to feed the long-haul or intercity transit system, i.e., Tri-Cities, Livermore-Amador Valley, Eastern Contra Costa County, Petaluma, and much of the Peninsula and Santa Clara County. Moratoriums on development in areas surrounding BART stations might be somewhat counter-productive since these areas are expected to fill in with large percentages of BART users.

A moratorium was considered for all development within the urbanized area not within 1/4 mile of transit route with 30 minute service. This would provide an incentive for development within transit service areas. A minimum of eight percent transit use could be expected from new development. This control might affect 80 percent of Bay Area growth in the next four years. Population growth in the next four years is expected to be about six percent over the present level. A 0.3 percent VMT reduction could be expected, and although the reduction is small the strategy is consistent with a long range approach needed to combat vehicle-related pollution.

Moratorium Because of Inadequate Regional Transit System

Santa Clara County is the principal problem area relative to inadequate regional transit service. There currently is no county wide, intercity transit network tying into transit systems to the north. Current county plans do envision an improved service within the next year. Meanwhile, growth is taking place at a rapid pace and in a manner

not conducive to transit use. A moratorium on new development might be imposed until the County develops a regional transit system capable of attracting riders from their automobiles. An effective regional system will require on the order of 10 minute peak hour service - 30 minute off-peak, linking all communities in the urbanized area. Exempting individual localities within a county, e.g., San Jose and Palo Alto, which currently have transit, would work against the idea of spurring development of an effective county-wide transit system. The implications of such a moratorium would be similar to the moratorium because of no local transit service.

Moratorium On Major Traffic Generators Outside Transit Centers

Such a moratorium would be directed toward controlling location of regional shopping centers, colleges, or employers with over 1,000 employees in locations outside established activity focal points, e.g., downtowns, transportation centers. This is a holding action designed to prevent deterioration. Six shopping centers and several colleges are currently proposed in suburban locations in the Bay Area. An aggregate effect of five percent induced VMT could be expected as a result of new major suburban traffic generators over a period of five years. Percent by transit to these sites would be on the order of 0 to 10 (five percent average), while percent by transit to similar sites in the portion of the area with more intensive transit (San Francisco, Oakland, Berkeley) is on the order of 10 to 40 (20 percent average):

$$5\% \text{ VMT} \times (20\%-5\%) = 0.75\% \text{ reduction in VMT}$$

4.1.4.2.4 Traffic Disincentives/Transit Preferential Treatment

This category includes a range of devices which improve transit circulation and reliability while inducing auto congestion.

Exclusive Transit Lanes

Transit lanes may be applicable to freeways in Marin, Santa Clara, and portions of Eastern Contra Costs, Southern Alameda and San Mateo County. Where BART and Southern Pacific rail service is available, it would be counter productive to develop parallel transit service on freeways. Outside the rail catchment area, however, freeway lanes could be earmarked

for transit and perhaps carpool use. Physical separation from auto lanes, using rubber cones, etc., is desirable to provide protection. Taking a lane away from auto traffic will contribute to congestion and act as a further inducement to use transit.

Local Traffic Engineering Measures

Closing or metering freeway ramps, narrowing arterial roadways, phasing traffic signals to limit auto traffic or barring cars altogether from pedestrian oriented areas can be effective in reducing traffic through communities and in avoiding environmental damage. Areas in which they might be applied include Golden Gate national recreation area, downtown San Francisco, Chinatown, Fisherman's Wharf, and downtown Sausalito. Special bus lanes on arterial streets and transit preempt of traffic signals can help take advantage of restrictions on the automobile. The aggregate effect of many small measures aimed at reducing auto access is impossible to judge on a regional basis, but such measures lessen the attraction of the automobile. The public should be made aware of the direct linkage that exists between increasing auto accessibility and reduced competitiveness of transit.

To estimate the aggregate effects of exclusive transit lanes and local traffic engineering measures, a transit/auto travel time ratio of 1.0 was assumed, the resulting increase in patronage attributable to traffic disincentives/transit preferential treatment (Appendix C, Table C-9). An aggregate decrease of about 0.3 VMT could be expected.

4.1.4.2.5 Free Transit Fare

As noted under options for reducing vehicular travel into San Francisco, 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. A 2.0 percent VMT reduction was computed from intercity trips not oriented into or out of San Francisco. Very little travel diversion from transit to auto could be expected for local or short trips -- estimated at 0.2 percent VMT reduction (Appendix C, Table C-9).

4.1.4.2.6 Improved Local Transit

Improvements in local transit were assumed to only affect travel within each of the 30 BATSC superdistricts. A typical five mile trip would take about 12 minutes by auto (25 mph), while it would take 16.5 minutes by transit (18 mph). The resulting ratio of transit/auto travel times is about 1.40. Net VMT reduction was determined at about 0.2 percent.

4.1.4.2.7 Gas Taxing/Pricing

A recent study of gasoline price elasticity found that over a short term (one year) a ten percent increase in gasoline price would result in a 4.3 percent drop in gas consumption. Over the longer range (3 to 5 years) a ten percent price increase was found to reduce gasoline sales up to 7.5 percent (4-22). These findings are only known to be valid for increases up to ten percent. Extrapolation to a 20 percent increase (about 50 cents per gallon) indicates an expected 8 to 12 percent reduction in gas consumption and resulting VMT.

Pricing could be regulated through imposition of added state or federal gasoline taxes, or state or local sales taxes. Oil companies could induce the same effect by increasing prices.

4.1.4.2.8 Gasoline Rationing

This measure offers the potential of effecting VMT reductions over the region as a whole. It is flexible in that the level of control can be adjusted to achieve, either alone or in concert with other measures the desired air quality levels and can be phased out if non-polluting vehicles become dominant in the vehicle population. Control at the distribution end (e.g., the regional and country level) offers simplicity in administration, while the more positive individual rationing would complicate the matter. One problem which affects both types of rationing is the size of the region and vast differences in availability and opportunities for use of alternative modes.

Concentration of the VMT rollback in the central portion of the Bay Area, where major shifts to transit are feasible in the short range period, might result under gross rationing because of natural market

mechanisms leading to failure to achieve air quality standards in other subareas of the region. However, subregional slippage effects would probably be minimized by the fact that in no subareas would supply equal or exceed local demand for gasoline. Where the level of gas rationing required to achieve the air quality standards is great, severe hardships could be anticipated, particularly in areas with low transit and carpooling opportunities.

4.1.4.2.9 Toll/Metering in Corridors Not Entering San Francisco

Increase of tolls or introduction of absolute metering are possible on all the existing transbay toll bridges and a new Eastbay Hills (Berkeley Hills) screen line of toll/metering stations. Imposition of the control on these screen lines would spread its effect over a wider portion of the region and over a greater segment of the traveler population than the San Francisco cordon. But, for a much higher percentage of the travelers passing through these extended control screens there is little opportunity to use transit or carpooling for their trip. Stations which could be expected to produce principal shifts to transit would be on State Route 24 (near the Caldecott Tunnel) and on Interstate 580 (at Dublin Canyon). While the other stations would generally have low productivity in inducing mode shifts, they would (in the case of tolls) provide a transit revenue source.

4.1.4.2.10 Parking Taxes

A variety of parking taxes could conceivably be instituted. Parking tax options considered and some likely impacts from them for the Bay Area include:

- A uniform tax on all parking spaces in the urbanized area, with BART parking and parcels with less than 10 units exempt. The suburban shopping centers, employers and parking lot operators would be hit the hardest.

- A tax inversely proportional to the fee charged the user, e.g., parking lot operators and employers who charge would reduce their tax bite. Retail outlets, colleges, and employers in suburban areas would be hit most by this tax. Again, BART station parking lots exempt to encourage transit use.

- A tax on spaces in proportion to the number of spaces per employee, e.g., generous parking means high tax. Suburban shopping centers and parking lot oeprators most severly hit. This measure appears difficult to administer (i.e., determining employee/parking ratio).

- A tax on spaces inversely proportion the local transit tax effort, e.g., low property tax support for transit means high parking tax.

- A commuter tax levied on any off-street parking use over four hour duration. This tax appears applicable to downtown San Francisco and Oakland only. Parkers in smaller urban centers would find it too easy to move their car at noon or during coffee break.

In general, parking tax schemes can be viewed as disincentives for auto use and/or sources of transit operating revenue. Shopping centers, employers, etc., may absorb the tax, thus reducing its effectiveness. The tax appears to be a good transit revenue source; the fourth measure is perhaps most egalitarian in that regard.

4.1.4.2.11 Vehicle Registration Surcharge

This control measure involves a surcharge on the "in lieu" portion of motor vehicle registration fees (the portion of the fee which is essentially a tax based on the value of the car). Surcharge rates would be graduated based on emission class of the vehicle (i.e., lower for low-emission vehicles) and the local tax effort (by county) in support of public transportation. In other words, a higher local transit support effort would lead to lower surcharge rates. The funds so generated could be utilized to support the MTC's regional transit programs.

This measure is not seen as one which would cause persons to give up second and third family cars, which would require very high surcharge rates and strike primarily at lower income groups. The concept is one of providing an incentive for voluntary retrofits of older vehicles and also to provide a new source of funding for public transit in areas which have not devoted a significant tax effort to this enterprise. Thus, the proposal has potential immediate and long term positive effects and acts most directly in heavily auto-oriented areas. It is also relatively uncomplicated to administer as it utilizes the

existing mechanisms of the Department of Motor Vehicles.

4.1.4.2.12 Carpools

Table 4-10 indicates regional trip making and auto occupancy by trip purpose. The table shows that work trips, the prime target for carpool activity, have lowest car occupancy, less than 1.2 persons per vehicle.

Table 4-10. Regional Trip Making and Auto Occupancy by Trip Purpose

Trip Purpose	Average Weekday No. of Trips (000)	Percent of Trips	Average Car Occupancy
Work	2,626	22.2	1.18
Personal business	1,248	19.6	1.41
Social	795	6.7	1.62
Recreational	535	4.5	1.46
Shopping			
Convenience	1,223	10.3	1.28
Comparison	409	3.5	1.18
School	1,418	12.2	2.76
Other home based	1,095	9.3	1.81
Non-home based	2,447	20.7	1.44

Source: BATSC, 1965

Essential elements in developing work commute car pool activity appear to be:

- A "critical mass" concentration of employment activity
- Public information
- Carpool formation matching assistance on a continuing basis
- Incentives (time, cost, convenience)

In the Bay Area, both incentives and matching services have been provided for the Bay Bridge corridor. Questionnaires were distributed to 25,000 carpool commuters (6 to 9 A.M.) with the intent of matching individuals having similar origin-destination and trip time characteristics thereby providing carpool formation services. However, only some 1000

forms were returned and only a very limited number of carpools were actually formed. This failure appears to indicate both an inherent resistance to carpooling and the lack of special incentives at that time. In late 1971, three reserved toll booths with approach and egress lanes were provided for carpools (3 or more per car) at the Bay Bridge approach. Initially, tolls were eliminated for carpools, subsequently a $1.00 charge per month were imposed (normal auto toll is $.50 per westbound crossing). The reserved lanes afford users a substantial time saving (up to about 5 minutes) in the toll plaza area. Despite these incentives, peak period carpools increased to only about 2000 (from an existing 1000) out of some 23,000 peak period crossings. Moreover, there is some suspicion that numbers of carpool occupants were diverted not from their own cars but from transit.

In the attitude survey undertaken in conjunction with this control strategy development program (see Appendix G), some 16 percent of the respondents indicated significant interest in carpooling and some potential for actually getting into one. Over 70 percent favored exclusive bus and carpool lanes on freeways and expressways. Thus, more potential for carpooling may exist than demonstrated to date in the Bay Bridge experiments. However, because of the uncertain effectiveness in inducing carpooling, this is not recommended as a primary strategy. To be sure, auto restrictive controls proposed in other sections of this report will result in significant carpool formation and all possible incentive measures to increase carpooling are encouraged.

4.1.4.2.13 Traffic Flow Improvements

Measures to achieve emission reductions through improved traffic flow fall in two categories: construction of new major traffic facilities (e.g., 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 is alleged to activate latent travel demand. In the long run this may reinforce auto dependence

and increases vehicle miles traveled. Over the short range time frame of primary concern in this study (to 1977) the air quality impacts of new traffic facilities can be assumed positive. However, over this period only a minimal amount of new major facility mileage will come into use. Though its impacts on air quality in that period will be positive, its contribution in terms of regional air quality is too small to quantify.

Operational improvements to existing streets and highways cover a broad range of programs. These include freeway improvements such as ramp metering, lane additions, and removal of bottlenecks; and surface street improvements such as areawide signal system integration, intersection channelizations, minor widenings of streets and intersection approaches, institution of one-way street systems and the like. Because they do not produce dramatic shifts in accessibility, operational improvements generally do not lead to activation of latent travel demand and their impact on emissions and air quality over the study period is assessed as positive.

Extensive traffic operational improvements programs are planned or ongoing in the Bay Area. However, operational and flow improvements do not have a high payoff in terms of vehicle emission reductions for several reasons:

- Levels of traffic service and average travel speed in the Bay Area are already high. The net result of flow improvement programs is likely to be preservation of the existing level of service under higher future traffic loads rather than an increase in average travel speed.

- Reductions in emissions with increases in travel speed become quite marginal at speeds above 20 mph, particularly toward 1977 as post-1975 model vehicles become a greater and greater percentage of the vehicle fleet (4-23). Current average travel speed is well above 20 mph and the percentage of operations in the high leverage area (below 20 mph) which could actually be affected by operational improvements will produce emission reductions too small to quantify.

- Major bottlenecks where flow improvements could potentially result in emission reductions meaningful in terms of regional air quality are identifiable. However, such flow improvement levels (as in the Bay Bridge corridor, for example) are achievable only through construction of major new facilities, not operational improvements. Such new facility construction will not occur in the period of concern.

In summary, flow improvement measures are seen as positive in terms of effect on air quality but their specific contribution to areawide emission reduction in the Bay Region is small and difficult to quantify. Where potential improvement projects in areas of operation in the high leverage speed range below 20 mph can be identified, they are encouraged.

4.1.4.2.14 Work Schedule Changes

Changes in work schedule have been proposed as a control measure in some cities as they tend to produce marginal flow improvements by reducing commute period traffic congestion and reducing total work commute travel. Two types of schedule changes have been identified, e.g., staggered work hours and the four-day week.

Potential for air quality improvement in the Bay Area as a result of staggered work hours appears minimal. In the approach corridors to downtown San Francisco, where greatest impact of such work staggering might be expected, peak period congestion already extends over more than an hour both morning and afternoon. This indicates the extent to which natural and capacity enforced staggering already exists and the futility of further staggering efforts.

In areas of dispersed employment activity staggering is less meaningful. Dispersed employment location and unfocused trip patterns in themselves result in a spread of traffic over the street and highway system. In such areas, work staggering over and above that which naturally exists raises the spectre of resonant waves of congestion on the system.

Achievement of meaningful results through work staggering appears to require spread of starting and quitting times over more than two hour periods. This seems difficult because of constraints both of human temporal activity patterns which have become ingrained and the requirement in many business activities for maximal overlap of working hours with other

local work activities and with business hours in the eastern time zones.

The air quality problem in this region results from excessive areawide hydrocarbon emissions on an all day basis. Such a problem responds most directly to decreases in total daily areawide VMT. Staggered work hours do not decrease total daily VMT but simply spread the time of VMT generation. Such a strategy is most applicable when the problem is a short duration, localized concentration of pollutant, particularly carbon monoxide, which results from temporal concentration of traffic flow. Staggered work hours also tend to reduce the potential for car pooling, a measure which does relate well to a hydrocarbon problem as it tends to directly reduce VMT. For these reasons, staggered work hours are not identified as a high-payoff pollution control measure for the Bay Area.

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

Table 4-11, which compares average weekday and average weekend-day trip activity supports this contention.

Table 4-11. Average Weekday Trips Compared with Average Weekend Day Trips, 1965

Trip Purpose	No. of Weekday Trips (000)	Percent of Trips	No. of Weekend Trips (000)	Percent of Trips
Home-based				
Work	2,626	22.2	856	7.5
Personal Business	1,248	10.6	1,935	17.0
Social	795	6.7	1,500	13.2
Recreational	535	4.5	994	8.7
Shopping				
Convenience	1,223	10.3	1,744	15.4
Comparison	409	3.5	589	5.2
School	1,448	12.2	52	0.5
Other home-based	1,095	9.3	1,438	12.6
Non-home-based	2,447	20.7	2.268	19.9
Total	11,826	100.0	11,376	100.0

Source: BATSC 1965 Origin-Destination Survey.

(This is particularly true if, as seems most likely, the extra days off are split on Mondays and Fridays creating three-day weekends). Thus, this measure does not respond well to the region's areawide hydrocarbon emission problem. Because of this, as well as problems of institutional feasibility, the four-day week is not recommended as a control measure. If, in combination with or independent of the four-day week, 20 percent of the vehicle fleet could be restrained from driving on any given day, an effective reduction in VMT could be achieved.

4.1.4.2.15 Reducing Vehicle Usage

The most direct way to reduce emissions from motor vehicles is to reduce their use. The effectiveness of measures which reduce VMT are potentially limited only by the amount of travel which is auto captive and essential. This general goal can be approched by three types of measures: reduce trip requirements, provide transportation alternatives, and establish vehicle restraints. The use of vehicles cannot be significantly restrained without providing some alternative means of transportation. A corollary appears to be that significant mass transportation ridership increases do not occur without some form of natural or artificial vehicle restraint (without order of magnitude service improvements).

4.1.4.2.16 Reducing Trip Requirements

An essential part of air pollution episode procedures, this measure is implemented when certain air pollution alert stages are reached (e.g., emergency closing of offices, schools, etc.). As a general measure, there are no present means available to effectively reduce trip requirements. Trip generation is built into life styles and land use patterns; therefore, it is not possible to dramatically alter the number or types of trips in our time period of interest. Positive land use policies could channel future development into concentrated nodes each containing a full range of urban activities with walking the primary linkage. Such a land use program would not likely have a substantial impact for one or two decades or perhaps longer.

As described in an earlier section, a four-day work week would reduce work trip requirements, but would probably induce increased

recreational trips and trips for other purposes. Thus, another possible approach to reducing trip requirements is a substitution of communications for travel. Communications technology has already replaced the need for travel in certain occupations. Over 13 million shares are traded on the New York Exchange daily, predominately via telephone and telecommunications, without direct personal contact. Another parallel phenomena is the degree to which computerization is changing the entire business world. Computer installations at widely scattered points are now linked into extensive computer utility networks. Information may be input in San Jose, processed in Palo Alto, and transmitted for printing in San Francisco. No travel or deliveries are involved -- all through electronics technology.

These kinds of operations are spreading rapidly and may be expected to continue. The important question is whether substitution can lead to actual decreases in travel. Recent experience would seem to indicate to the contrary, considering the substantial increases in urban travel over the past two decades, even as television, space satellites, computer technology and other advances in telecommunications come into being. In any event, it is certain personal travel requirements will not diminish in the short time period this study covers.

4.1.4.2.17 Network of Bicycle Paths

BATSC data indicates that about one-quarter of Bay Area VMT is generated by local trips (intradistrict or trips less than 8 to 10 miles in length). Bicycle usage would be ideally suited for a large portion of such travel.. Most of the Bay Area has relatively level topography and climate is mild most of the year. Greater use of bicycles could be encouraged through designation and protection of bicycle lanes and incorporating bike/pedestrian paths in new developments. A carefully laid out bicycle grid system with 3 to 4 blocks between bike paths is envisioned as an inducement to use bicycles for a variety of purposes besides recreation.

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 undoubtedly occur for children in getting to school, recreation, etc. as parents pre-empt the car for more essential functions.

4.1.4.3 Results of VMT Reduction Analysis

Quantitative analysis found that control strategies directed toward VMT reduction would be no more than about 15 percent without imposition of gas pricing or rationing measures (see Table 4-12). The most effective measure would be controls over traffic toward major generators such as the San Francisco CBD and major employers in outlying areas. Work travel over longer distances encountering traffic congestion, toll and parking costs are the most subject to diversion from auto to transit. Short local trips are most difficult to divert to transit. In the short time-frame of the next 2 to 4 years, walking, bicycling or local transit will only become attractive options to the automobile under more stringent and direct controls such as gasoline pricing or rationing.

The most desirable strategy would be one which offers incentives for transit use or carpooling commensurate with restraints imposed on auto use. Reduced transit fare coupled with increased bridge tolls, for example, should be publicly more acceptable than imposing a constraint without offering an attractive option. Major suburban employers may wish to financially underwrite subscription bus service with parking fees imposed on employees who drive. The recommended first line of attack would be reliance on pricing mechanisms which make transit more attractive while making driving less advantageous.

It is recommended that restrictions on auto flow and parking be viewed primarily as back up measures to pricing mechanisms and improved transit. As increased toll/reduced fare begins to take effect, exclusive bus lanes, bus and carpool lanes, or other traffic constraints could be imposed to keep congestion at current levels and insure maximum effectiveness of the pricing mechanism. Similarly, constraints on auto parking could be imposed, e.g., prohibition of additional off-street spaces, to make certain parking costs stay at or above their current levels.

New major transit improvements, BART in particular, will likely bring temporary reductions in traffic congestion along freeways parallel to BART and a tendency for parking lot operators to lower parking rates to attract greater usage. Some evidence of reduced congestion has been observed on approaches to the Caldecott Tunnel, and several parking lot

Table 4-12. Summary of Impacts for VMT Reduction Strategies

Strategy Description	Approximate Percent VMT Reduction
1. Intercept autos entering San Francisco	
o 50 cent added toll	
- commute traffic only	0.2
- 24 hour basis	0.5
o $2 added toll	
- commute traffic only	0.6
- 24 hour basis	1.4
o $10 added toll	
- commute traffic only	3.0
- 24 hour basis	6.8
o Physical constraints (bus and carpool lanes)	
- half lanes reserved	3.0
o Reduce transit fares	
- commute traffic only	2.0
- 24 hour basis	4.5
o Parking reductions	
- 50 percent CBD reduction	4.0
2. Suburban employer parking restrictions/ subscription bus and carpooling	
o 50 percent reduction in auto use, firms 1000+ employees	2.5
o 75 percent reduction in auto use, firms 1000+ employees	3.8
3. Moratoriums on development	
o Outside transit service area	0.4
o Major generators outside established centers	0.7
4. Traffic disincentives/transit preferential treatment	
o Excluding entrance to San Francisco	0.2
5. Free transit fare	
o Local Service	0.2
o Intercity, excluding entering San Francisco	2.0
6. Improved local transit	0.7
7. Gas taxing/pricing	
o 20 percent price increase	8-12
8. Gas rationing	
o 80 percent current level	13-17
Maximum attainable without gas pricing or rationing	≈ 15

operators in the Oakland CBD have lowered rates, both presumably as a result of BART opening to Oakland. Reduced freeway traffic and reduced parking demand is likely to be temporary only, unless constraints are applied to keep driving costs at their present level. To keep driving impedance high, constraints should be employed concurrently with BART opening, including reservation of bus and carpool lanes on freeways and arterials parallel to BART (e.g., Bay Bridge, U.S. 101, I280, Caldecott Tunnel, Market Street in San Francisco, one-way street system from freeway off-ramps) and selected metering, narrowing or closure of freeway off-ramps (e.g., I-280 off-ramp at San Jose Avenue). Restrictions that increase congestion above present levels are likely to be perceived as restraint without regress.

4.1.4.4 An Alternative Approach to VMT Reduction

The analysis presented in the study thus far has centered on short term control measures which could conceivably be implemented within a 1975 to 1977 timeframe. It has been further noted that many of the short term transportation system controls will run counter to existing long-range goals within the region. In reality, many of the institutional and political constraints will dictate the shape and form of transportation services within the region. Properly guided, many of the involved agencies can direct planning to minimize adverse environmental impacts, such as air pollution. Most if not all of the transportation groups in the Bay Area do explicitly consider the air pollution consequences of their activities. The question then becomes to what degree is the majority of current transportation and land use planning compatible with the envisioned constraints needed to achieve the desired air quality?

It appears conceivable and probable that large VMT reductions could be achieved in the long run and with a minimal of socio-economic impacts, through better land use and transportation planning than with many of the control measures considered. Serious questions are raised by the appropriateness of certain controls in light of current land use and transportation planning programs both at the regional level and at the detailed, almost site planning level. Regionally, the status of MTC's transportation and land use modeling efforts for the Bay Area serves as a case-in-point. At

the local level, an example is taken of developing land use and transportation in the Livermore-Amador Valley, one of the more critical pollution sectors of the region.

Regional Land Use and Transportation Modeling

MTC is currently updating the transportation modeling undertaken by BATSC 5 to 8 years ago. Since that time, the rate of population growth has slowed with public sentiment swinging away from more highway construction and toward transit improvements (e.g., SB325 funds, proposals for diverting highway trust funds for transit). In other areas, higher building costs are tending to produce greater densities in new residential developments, and concern for the environment has led to building moratoriums, increased open space acquisitions, and tightened land development controls (e.g., new coastal commissions, legislation requiring zoning to conform with the general plan, and environmental impact reports). Citizens opposing unlimited, sprawling development have become increasingly effective in controlling the character of new development, a force which for the first time permits the region to realistically consider shaping urban development through concerted transportation improvement and land development controls. These groups must also be considered in the development of short-term transportation controls.

MTC is scheduled to complete, by June 30, 1973, their land use and transportation model development and calibration. Land use allocations in the model will be sensitive to travel time, but not costs such as parking and tolls. By August 15, 1973, MTC is projected to have coded nine or ten transit networks for 1980 and 1990. Included in the work will be two or three alternative levels of development or land-use plans (e.g., northern tilt, southern tilt). It is recommended that MTC's land use/transportation model be used when appropriate to assess the impact of several alternative control measures. For short term measures, it should be relatively easy to assess the effects of constrictions on bridges, exclusive bus lanes on freeways, and improved transit. Similarly, the analysis of alternative land use/transportation configurations on regional VMT can be readily accomplished. Important in the comparative analysis would be how VMT could be minimized regionwide with as few controls and restrictions as possible and yet remain consistent with regional planning goals. A plan is envisioned in

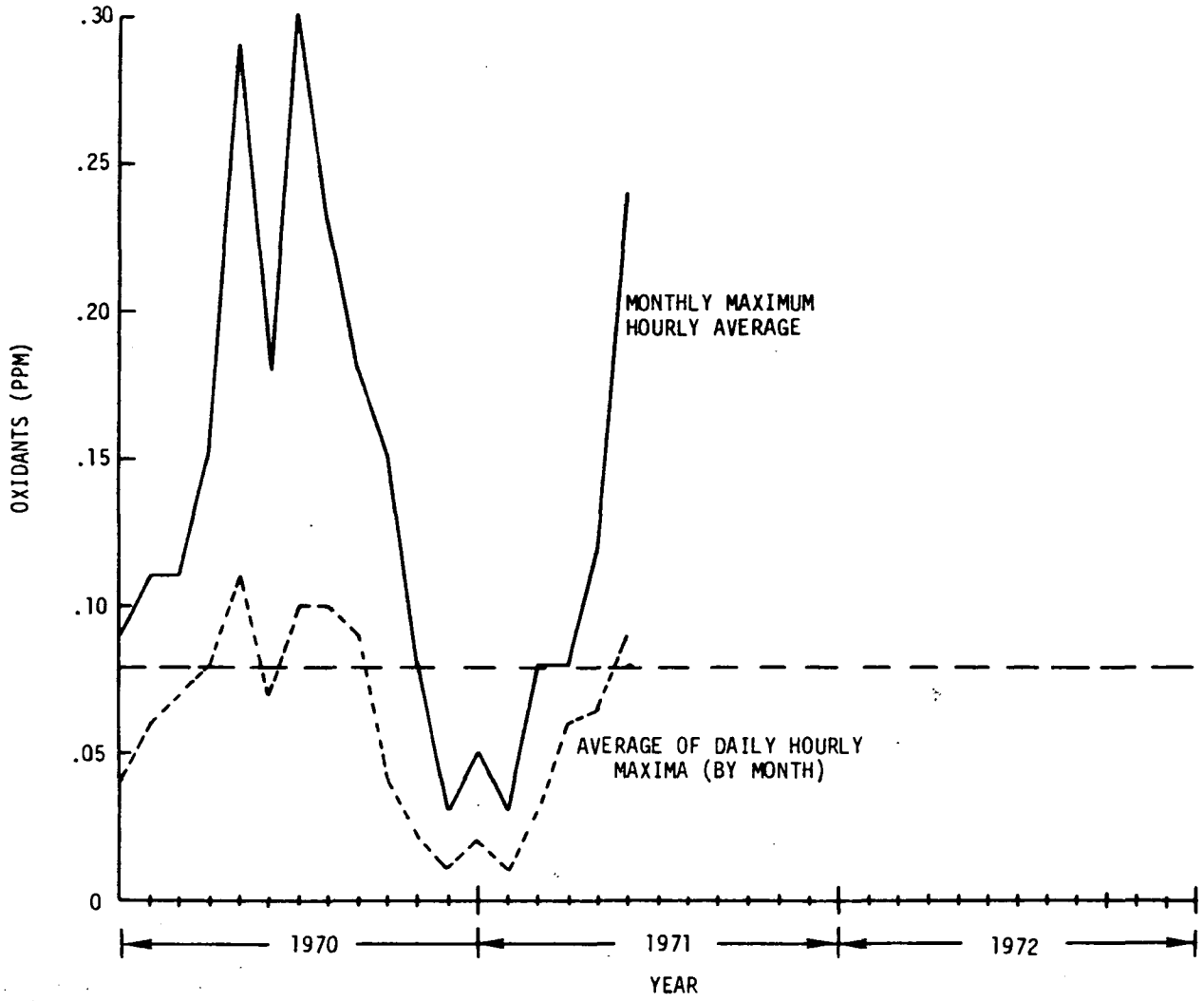
which long range VMT control strategies become an integral part of regional transportation/land-use planning.

Local Planning Considerations: Livermore-Amador Valley Example

The Livermore-Amador Valley, 40 miles east of San Francisco, is faced with the prospects of unprecedented growth in the presence of one of the Bay Area's worst smog conditions. Figures 4-12 and 4-13 illustrate the levels of oxidants which have been experienced recently in the area. It can readily be seen from the data that oxidant levels three to four times the standard are not uncommon. The initial 75-mile BART system has been completed to a point within 10 miles of the Valley, and plans are nearing completion for an 8-lane interstate highway linking the Valley with the heart of the region. Prospects appear good that the Valley, which is presently on the outskirts of the Bay Area, will soon be thrust into the mainstream of development. Meanwhile, frequent temperature inversion locked in by a ring of hills and pollution fed through Dublin Canyon from the west combine to form one of, if not the worst, potential air pollution conditions in the Bay Area. In view of the geographical and meteorological conditions which prevail and contribute to the air pollution problem, it is recommended that long-term measures to maintain acceptable air quality be considered and evaluated.

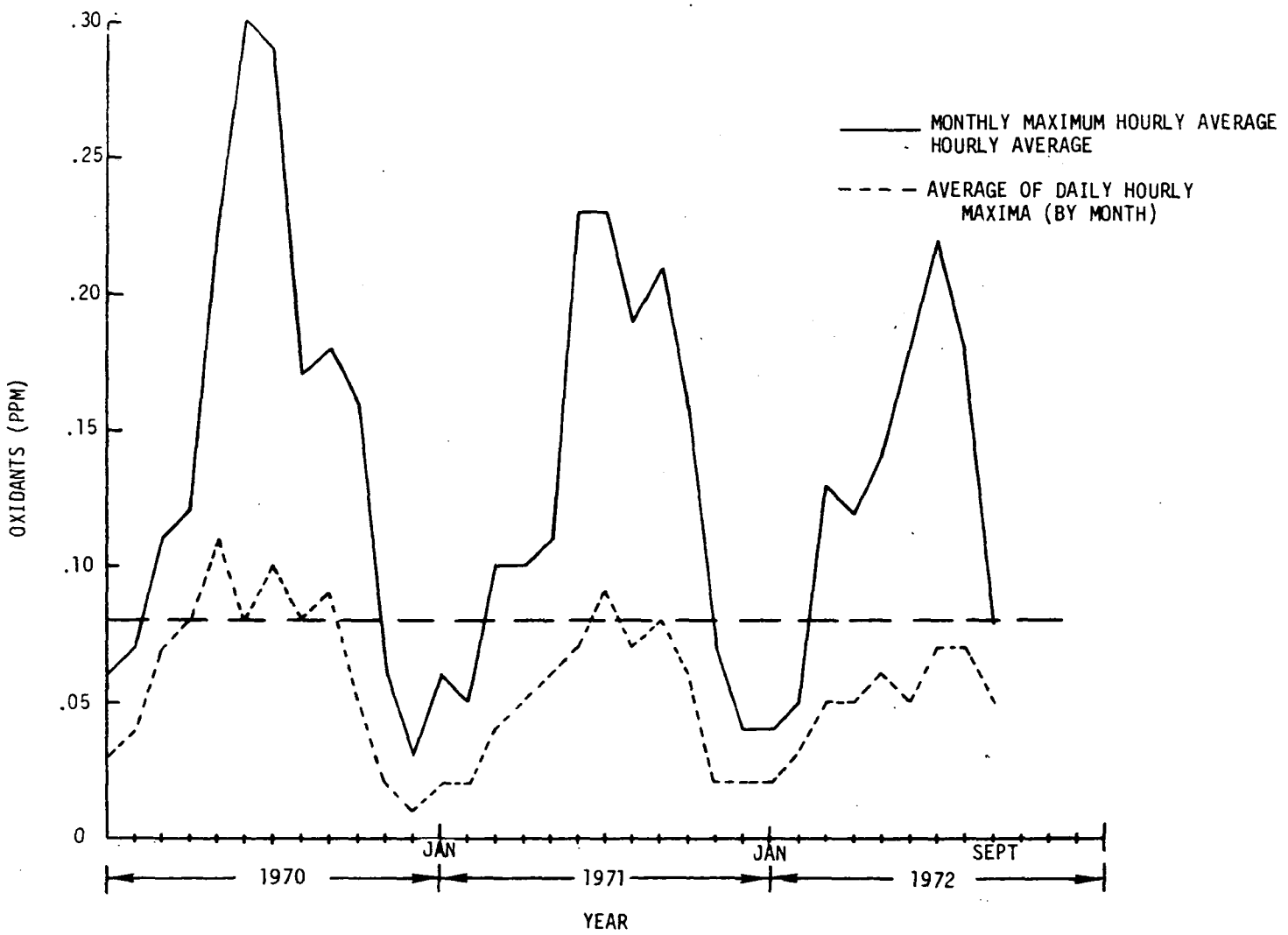
The automobile dominates development patterns in the Valley. The pattern of dispersed development and an extensive street and highway system make it impractical for a bus system to accomplish a reversal in increased automobile usage. However, a number of reasons--traffic congestion; air pollution; excess land consumed by highways, streets, and parking lots; loss of open space and environmental amenities--may make it desirable to consider development alternatives which feature less extensive use of the automobile in the Valley. Such alternatives will not be easy to achieve, but the promise of a more livable future should justify their thorough consideration.

A BART extension would have a sizable impact on commuter automobile usage. Rapid transit can transport persons quicker and less expensively than they can usually drive and park, thereby encouraging commuters to choose transit over the automobile. However, rapid transit extension will



SOURCE: STATE OF CALIFORNIA, THE RESOURCES AGENCY, AIR RESOURCES BOARD, CALIFORNIA AIR QUALITY DATA, 1970-72

Figure 4-12. Air Quality Measurements in Livermore (Monitored at Rincon and Pine - 1970-71)



SOURCE: STATE OF CALIFORNIA, THE RESOURCES AGENCY, AIR RESOURCES BOARD, CALIFORNIA AIR QUALITY DATA, 1970-1972.

Figure 4-13. Air Quality Measurements in Livermore (Monitored at Railroad Street - 1970-72)

accentuate growth pressures in the Valley and growth effects must be weighed against potential benefits.

Although BART or other means of high speed public transportation can have substantial impact on automobile usage along a corridor, rapid transit will have no effect on the large number of short automobile trips made within the community. BART stations are typically located up to three miles distance from some portions of the communities they serve, making it unlikely that many commuters will choose to walk. Frequent local feeder bus service to rapid transit stations would offer the commuter the opportunity to make his entire trip by transit, but unless BART parking fees or other auto constraints are introduced, high auto ownership and auto convenience make diversion of the feeder trip to transit an up hill proposition.

Development of a system of bicycle paths linking residential areas to major community activity centers and transit stations offers another alternative to automobile usage. To attract people to use of bicycles, attention should be given to providing exclusive bicycle paths through the community particularly along major streets. Safe, attractive bikeways could make inroads on automobile usage for short trips such as school trips, recreation trips and perhaps even short work trips.

Careful attention should be paid to design of efficient, safe and attractive pedestrian walkways. Placement of pedestrian walkways back from major streets and provision of landscaping should make walking more pleasant. An inviting pedestrian circulation system should be able to attract persons making short trips.

Structuring Urban Development

Land development and transportation are closely interrelated; they may even be viewed as opposite sides of the same coin. The complement of reduced vehicle travel is an urban development pattern which facilitates use of transit, bicycling, or walking. Such an environment requires years of concentrated, carefully conceived planning, promotion, and control over new development (zoning, subdivision regulation and other legal tools) as well as public investment in improvements to encourage transit usage, bicycling and walking.

Structuring of urban development in new towns, even those without rapid transit, has lead to reduced vehicle tripmaking, reduced street and highway mileage, and increased acreage and usability of open space. Residential development is frequently clustered along open spaces with pathways linking homes to schools, playgrounds and shopping opportunities. Pedestrian and bicycle travel patterns are made more efficient, and the quality of life is improved.

An extension of BART to the Valley would present the community potential for shaping an environment in which transit can compete with the automobile on a local as well as an interurban corridor basis. The challenge is to shape a development pattern which allows the benefits of transit usage--reduced air pollution, land consumption, and transportation costs--to spread from transit stations out into the community. Corridors of higher-density residential development containing major traffic generators such as hospitals, schools, and shopping centers should be consciously developed in a pattern radiating from rapid transit terminals. These "transit corridors" can be saturated with bus service (such as frequent shuttle service) so that land owners and developers can build with the transit user in mind and those who want to orient themselves to transit usage can depend on convenient bus service (see Figure 4-14).

As an example, land within a half-mile band along a designated transit corridor can be reserved through planning and zoning for apartments or townhouses, clustered single-family homes, employment centers, or major public facilities. Careful attention should be paid to efficient, safe and pleasant pedestrian circulation from activity centers to bus stops, avoiding a barrier of walls, parking lots, or other obstacles to transit usage and pedestrian and bicycle circulation.

A rather detailed level of planning and coordination -- involving site planning by both developer and the city -- will be required to focus development along transit corridors and encourage use of other modes of transportation besides the automobile.

Current land use plans for Valley communities call for continuation of low-density development and auto orientation 20 years into the future.

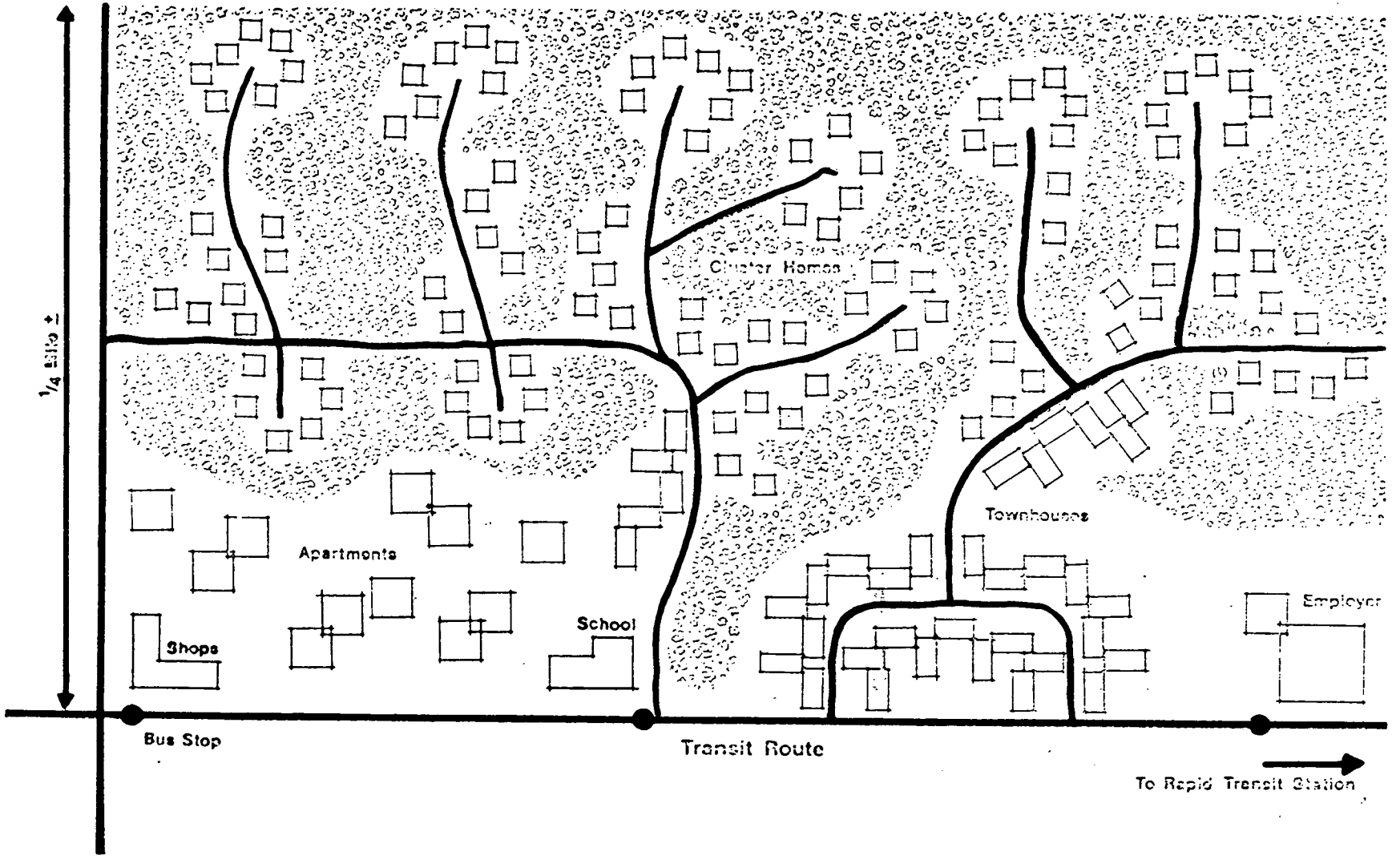


Figure 4-14. Urban Development Structure with "Transit Corridors"

If such planning is allowed to become reality, much of the potential offered by a possible BART extension to the Valley will be permanently lost.

Review of existing land use plans and zoning is paramount, therefore, if transit development opportunities are not to be lost to low-density sprawl. Higher land values and pressures for increased density in the Valley give impetus to the desirability of structuring apartment and townhouse development into a pattern which is in the long-range interests of the community. Such structuring offers the possibility for reserving large open spaces in tradeoff for higher density along selected corridors, thus avoiding overcrowding and retaining a part of the natural environment for future generations.

4.2 THE CALIFORNIA ARB IMPLEMENTATION PLAN

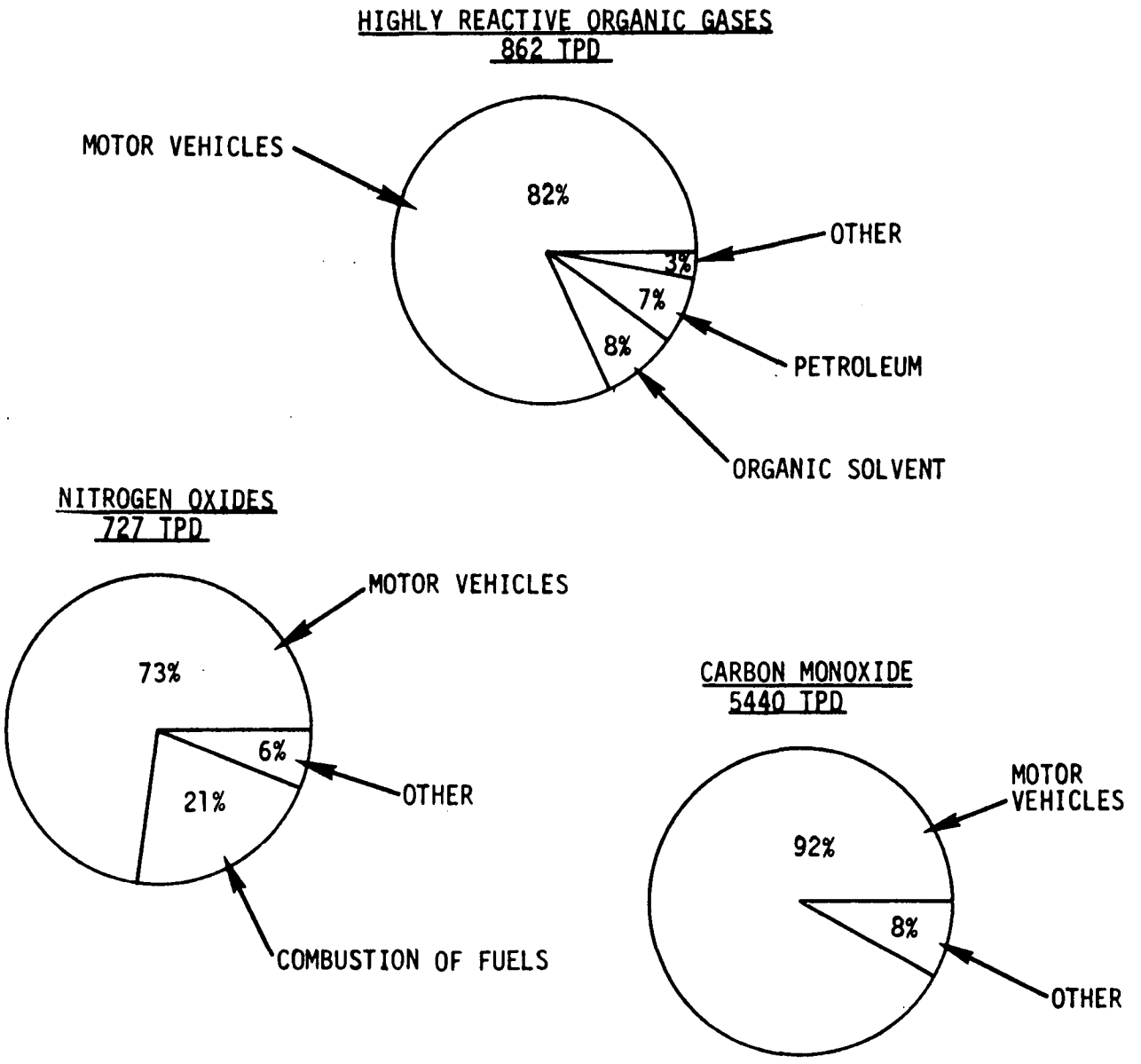
The state of California ARB Implementation Plan for achieving and maintaining the NAAQS was submitted to the EPA in February 1972. The plan consists of measures to control emissions from both mobile and stationary sources. The ARB analysis shows that enforcement of these measures will result in the attainment of Federal Air Quality Standards in the San Francisco Bay Area Air Basin by 1977. The following sections provide a review of the California plan for the San Francisco Basin. Section 4.2.1 is a discussion of the ARB baseline emissions inventory, and Section 4.2.2 provides an examination of the ARB control strategy.

4.2.1 Baseline Emissions Inventory

4.2.1.1 Results

The base year for the San Francisco Bay Area Air Basin plan was chosen to be 1970. During this year the maximum hourly oxidant recorded was 0.30 ppm; and the maximum 8 hour CO average was 13 ppm. Conforming to the conventional proportional rollback method, the ARB determined that source emissions of RHC emissions must be reduced by 73 percent, and CO emissions by 31 percent to attain air quality standards in the Basin.

The baseline emission inventory was quantified individually for each county in the Basin. The total Basin inventory was then used in the development of a Basin-wide control strategy. The relative air contamination generated by the major sources is illustrated in Figure 4-15. The absolute values of the various source pollutant emissions are shown in Table 4-13.



Source: California Air Resources Board (1)

Figure 4-15. Percentage of Emissions from Major Sources in San Francisco Bay Area Air Basin, 1970

Table 4-13. San Francisco Bay Area Air Basin's Estimated Average Emissions of Contaminants into the Atmosphere, 1970 (Tons Per Day)

Emission Source	Organic Gases Reactivity High	Organic Gases Reactivity Total	NO_x	CO
Petroleum	57.7	175	19.8	16.9
Organic solvent users	70.7	354	.2	
Chemical, metallurgical, mineral		35.1	2.0	5.9
Incineration	6.2	49.6	.6	110
Combustion of fuels		3.6	153	1.8
Lumber industry		.3		3.1
Agriculture	9.1	86.7		211
Motor vehicles	703	984	532	5010
Aircraft	14.8	29.5	8.7	64.8
Ships and railroads		5.7	10.7	19.0
TOTAL	862	1720	727	5440

Source: California Air Resources Board

4.2.1.2 Methodology

Base year (1970) air contaminants generated by motor vehicles were estimated in 1970 by the ARB on the basis of total regional gas consumption and vehicle emission factors (emissions per gallon). The estimated quantity of each pollutant species emitted from vehicles of various types and model years was determined by calculating the product of the fraction of regional gas consumption attributable to the subject vehicle type and the appropriate emission rate in grams per gallon.

Projections of motor vehicle emissions in future years were estimated utilizing procedures outlined in the "Motor Vehicle Emissions Inventory 1970-1980" (4-24). The bases for the estimates are motor vehicle population projections vehicle model distribution, vehicle mileage, and emission

rates as determined by the 7-mode test procedure. The estimated quantity of each contaminant emitted from vehicles of various types and models is the product of the number of vehicles, the corresponding average annual mileage, and the appropriate emission rate in grams per mile.

The baseline inventory for stationary sources in the California ARB Implementation Plan derives fundamentally from the 1970 California inventory (4-24). This 1970 inventory, in turn, is based on joint efforts of the ARB and the local APCD's in estimating stationary source emissions. For each stationary source category, these emissions are calculated by multiplying source activity levels by appropriate emission factors. The activity levels are basically estimates of throughput (e.g., in petroleum marketing) production (e.g., of a certain industry), sales (e.g., of organic solvent), fuel consumption (e.g., in the residential-commercial sector), and tonnage of wastes burned (e.g., in agriculture). These estimates are obtained partially by survey but more often by contacting appropriate agencies (e.g., Western Oil and Gas Association, U.S. Bureau of Mines, agricultural associations, University Service Departments, etc.). The emission factors are taken from the EPA's "Air Pollution Emission Factors, Preliminary Edition," April 1971, or are as developed by local APCD's. Hydrocarbon reactivity factors in the ARB inventory are all based on Los Angeles County, APCD assumptions. Projection of the 1970 ARB stationary source inventory are made through 1975, 1977, and 1980 according to the assumptions that each source expands in proportion to population growth.

The method used by the CARB to calculate emission due to aircraft is essentially that recommended by EPA in AP - 42: Compilation of Air Pollutant Emission Factors (4-25). The number of LTO cycles in each are correlated with the particular classes of aircraft, and the appropriate emission factor recommended by EPA was used, according to the following formula:

$$\text{Aircraft emissions} = \text{Emission factor} \times \text{Number of engines per aircraft} \times \text{Number of LTO cycles}$$

RHC's were calculated as 50 percent of total hydrocarbon emissions for both jet-driven and piston-driven aircraft.

Table 4-14. Percentage Growth in Population and Motor Vehicles for Various California Regions (1960 to 1980)

Region	1960 - 1972			1972 - 1980 (Projected)	
	% Population Growth	% Motor Vehicle Growth		% Population Growth	Growth TRW
		Actual	Calculated		
San Francisco	28.39	64.11	61.91	16.14	21.87
Sacramento	29.62	67.01	65.45	16.54	45.39
Fresno	14.35	41.30	38.10	7.75	11.26
Kern	14.61	39.93	40.92	8.52	17.66
San Joaquin	19.98	43.03	42.40	12.61	21.73

4.2.1.3 Limitations of the Analysis

The ARB quantification of motor vehicle emissions is confronted with the analytical difficulties that are inherent to the state of the art (discussed in Section 3.2.2). In addition, the ARB procedure contains other questionable limiting assumptions. For example, the emission rates applied in the analysis were based on the State 7-mode test cycle. This test, and the sampling procedure used to establish the emission rates, have been updated to the current federal test procedures which are acknowledged to yield more representative vehicle emission rates. Another questionable approach utilized in the ARB inventory determination involves the projection of vehicle populations by the assumption their growth is in direct proportion to population increase. Table 4-14 provides historical growth data for the various study areas of the critical California air basins and demonstrates the discrepancy between growth trends for population and total regional vehicle registrations. Also included in the table are the TRW growth projections, based on the multiple linear regression procedure (Appendix D), for motor vehicle registrations in the various California air basin study regions. Another questionable assumption made by the ARB is that total regional VMT may be determined from regional annual vehicle mileage and vehicle population for the region-registered vehicles. Implicit in the assumption is the existence of a contained community with all vehicle travel performed within its boundaries. The limitation of this assumption is most often evident in small regions where much through travel is prevalent.

Another ARB procedure subject to potential unreliability centers around the conflicting use of two different methods in calculating motor vehicle emission inventories, namely: the base year emissions which are based on gas consumption figures, and the projected vehicle emissions which are based on vehicle mileage distributions. The inconsistence contained in this approach causes some difficulty in drawing valid comparisons between the base year emission inventory and the projected emission inventories.

The least reliable aspect of the ARB motor vehicle emission inventory concerns hydrocarbon reactivity assumptions. The ranking of hydrocarbon reactivity is a controversial issue. For example, the ARB utilizes a reactivity scale which designates diesel exhaust non-reactive, while the EPA considers this exhaust 99 percent reactive. Evaporated gasoline, considered 50 percent reactive by the ARB, is 93 percent reactive according to the EPA. Since the conventional oxidant rollback procedure centers on the reduction of the reactive element of the hydrocarbon inventory, the uncertainty surrounding the reactivity scale is probably the most significant limitation mitigating the calculation of a meaningful air contaminant inventory.

The most obvious distinction between the ARB relative baseline emissions profile and that developed by TRW is the level of air pollution arising from motor vehicle operations in the base year. The ARB selected 1970 as its base year, corresponding to a lower oxidant measurement for its rollback determination. The ARB determined 83 percent of all reactive organic gases were generated by motor vehicles while TRW placed the figure at 64 percent. The combination of earlier base year and higher relative motor vehicle emissions provide the ARB with a substantial difference in baseline control leverage via motor vehicle controls.

The baseline stationary source inventory of the California ARB Implementation Plan is derived from the 1970 California ARB inventory (4-24). It therefore contains all of the limitations inherent in the 1970 inventory. These include errors in estimating source usage and source emission factors. Such errors might be considerable, but most of these figures (especially the source usage figures obtained from the appropriate responsible agencies), should be fairly reliable. The only very unreliable parameters in the 1970 inventory are hydrocarbon reactivities. As discussed in more detail in Section 3.2.1, hydrocarbon reactivity assumptions are much in dispute, and values can change from 0 percent to 99 percent in comparing different reactivity scales. The 1970 ARB inventory uses Los Angeles APCD reactivity assumptions which differ considerably from recent EPA values by Altshuller.

The projection of the 1970 inventory to 1975, 1977, and 1980 may also contain considerable error for certain sources. The ARB has assumed that each type of emission will grow as population. However, certain sectors are expanding much more rapidly than population while other sectors are expanding slower or are contracting. Projection assumptions that are more oriented toward growth in specific industries and/or sectors would be much more realistic.

It is believed (4-26) that a significant degree of error exists in the ARB estimates for aircraft emissions because of miscalculation. As a result, the ARB is currently revising the aircraft emission inventory to correct these errors. New and more complete data on aircraft operations, including those at the numerous general aviation airports and at military air bases, should be included in this revision, and recent EPA revisions to emission factors published in Reference 4-25 should be utilized. The use of the reactivity factor should also be reconsidered because of the EPA recommendation of 90 percent for both jet-driven and piston-driven aircraft.

4.2.1.4 Summary

It is evident there are several aspects of the ARB inventory based on questionable information or procedures. Because of these limitations, TRW has developed a separate emission inventory based on procedures which are acceptable to the EPA. Because of the numerous differences in procedures and base information utilized in the two approaches (TRW and ARB), the utility of a lengthy and detailed review of the ARB Implementation Plan would appear to be of limited value here since only the analysis performed by TRW will be considered meaningful. For this reason the ARB strategy and its impact on baseline emissions is considered only briefly in the following section.

4.2.2 ARB Control Strategy

4.2.2.1 The Plan and Results

The key elements of the California control strategy in the plan for the San Francisco Bay Area Air Basin includes measures to reduce emissions from both stationary and mobile sources. These measures include:

a) The state's current motor vehicle emission control program

b) Vehicle emission inspection and maintenance

c) Control of emissions related to the distribution and marketing of petroleum products

d) Control of the emissions from aircraft and ships

e) Control of the emissions from the lumber industry's burning processes

f) Control of the emissions from open burning.

The estimated effects of the most current (April 25, 1973 revision) control strategy on the baseline emission inventory (April 25, 1973 revision) is shown in Table 4-15. The impact of the strategy measures, with respect to ambient air quality, has been estimated by the ARB as portrayed in Figures 4-16 through 4-18.

4.2.2.2 Limitations of the Control Strategy

The control strategy proposed for motor vehicles consists only of an inspection and maintenance program. The ARB has claimed standard emission reductions for this measure. Implementation will yield an overall reduction of 2 percent of the ARB base year reactive hydrocarbon emissions in 1975. These results are consistent with the TRW analysis.

The ARB stationary source control plan consists of three basic types of measures:

Table 4-15. Effects of Control Strategy San Francisco Bay Area Air Basin (Tons/Day) (Reference 4-27)

CONTROL OPTION	CARBON MONOXIDE				NITROGEN DIOXIDE 1/				OXIDANT 2/			
	1970	1975	1977	1980	1970	1975	1977	1980	1970	1975	1977	1980
Stationary Sources 3/	449	479	489	514	176	191	196	206	186	196	201	206
Emission Reductions												
Petroleum		--	--	--		--	--	--		- 13 4/	- 23 4/	- 55 4/
Organic Solvent Users		--	--	--		--	--	--		- 36	- 46	- 46
Chemical		--	--	--		--	--	--		--	--	--
Metallurgical		--	--	--		--	--	--		--	--	--
Mineral		--	--	--		--	--	--		--	--	--
Incineration		-205	-210	-225		--	--	--		- 9	- 9	- 9
Combustion of Fuels		--	--	--		--	--	--		--	--	--
Lumber Industry		--	--	--		--	--	--		--	--	--
Agriculture		- 45	- 45	- 50		--	--	--		- 1	- 1	- 1
Projected Emissions (Stationary)	449	229	234	239	176	191	196	206	186	137	122	95
Mobile Sources (Under Current Program) 3/	5132	3166	2240	1506	547	346	268	191	720	299	214	145
Emission Reductions												
Inspection and Maintenance		-114	-126	- 79		--	--	--		- 9	- 14	- 8
Catalytic Converter Retrofit		--	-625	-325		--	- 11	- 5		--	- 42	- 22
Retrofit Evaporation Control		--	--	--		--	--	--		--	--	--
NO_x Exhaust Retrofit, HDV		--	--	--		--	--	--		--	--	--
Conversion to Gaseous Fuel		--	--	--		--	--	--		--	--	--
Control of Aircraft and Ships		-205	-213	-225		- 23	- 23	- 25		- 23	- 24	- 26
Projected Emissions (Mobile)	5132	2847	1275	877	547	323	234	161	720	267	134	92
Projected Emissions (Directly Emitted)	5581	3076	1509	1116	723	514	430	367	906	404	256	187
Photochemically Generated Particulate Matter		--	--	--		--	--	--		--	--	--
Projected Controllable Emissions (Total)	5581	3076	1509	1116	723	514	430	367	906	404	256	187
Allowable Emissions	3864	3864	3864	3864	738	738	738	738	242	242	242	242
Emission Reductions Needed		--	--	--		--	--	--		162	--	--
Ambient Air Quality	(8-hour Ave.-ppm)				(Annual Ave.-ppm)				(1-hour Ave.-ppm)			
1970	13				.049				.30			
Projected		*	*	*		*	*	*		.13	*	*
Standard	9				.05				.08			

1/ Control strategy based on control of oxides of nitrogen emissions.

2/ Control strategy based on control of highly reactive organic gases; a proportional relationship was assumed to exist between ambient oxidant levels and highly reactive organic gas emissions.

3/ Includes increase in emissions due to growth.

4/ Primarily due to vapor recovery system for gasoline marketing operations.

5/ Adjusted to reflect the effects which natural or accidental phenomena may have on ambient levels.

*Calculated emissions are close to or less than those required to meet national standard.

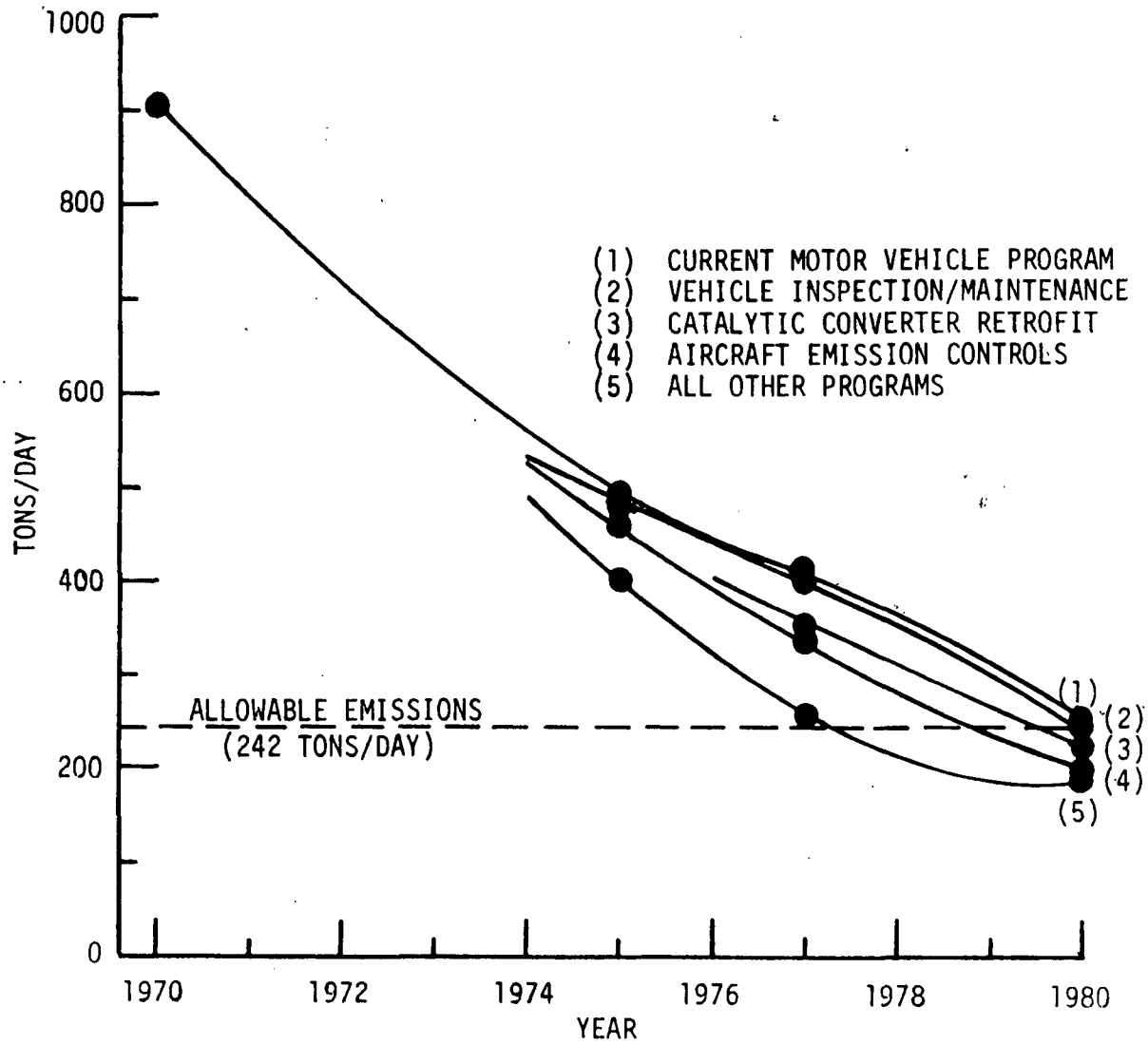


Figure 4-16. Proposed California ARB Strategy Oxidant Emission Controls Based on Controlling RHC for the San Francisco Region (Reference 4-27)

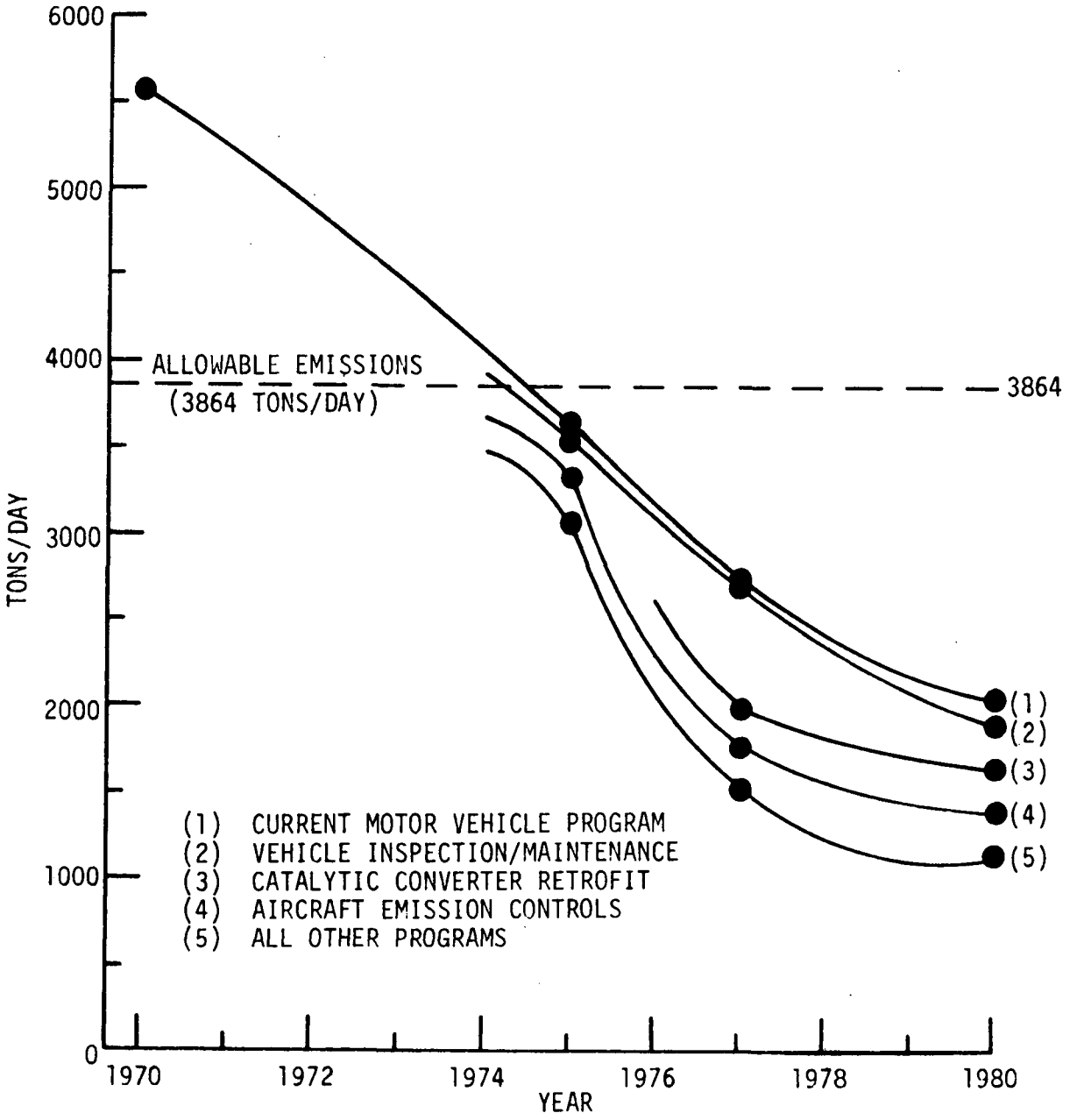


Figure 4-17. Proposed California ARB Strategy CO Emission Controls for the San Francisco Region (Reference 4-27)

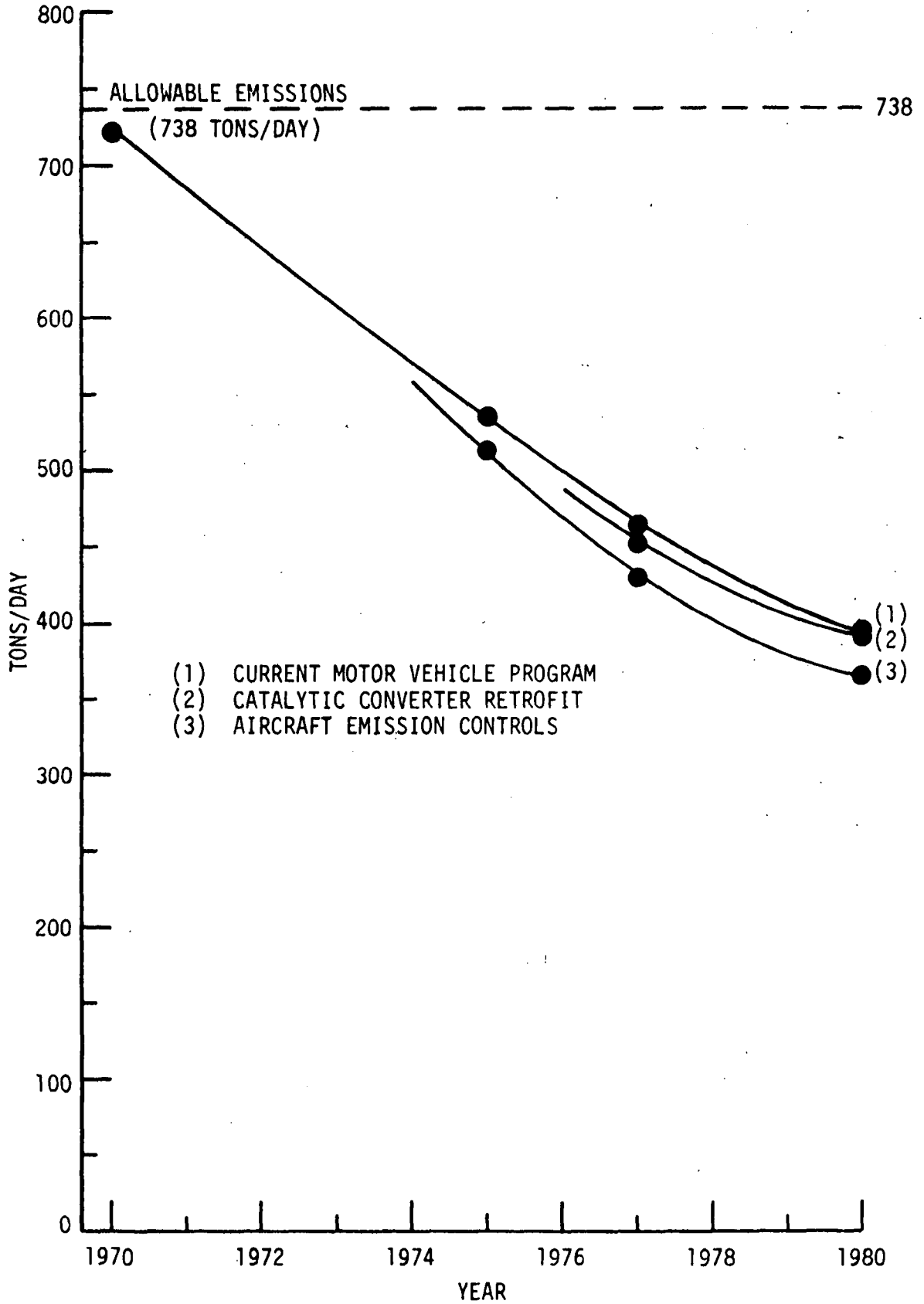


Figure 4-18. Proposed California ARB Strategy NO_x Emission Controls for the San Francisco Region (Reference 4-27)

(i-) Regulation of burning processes in the agriculture, incineration, and lumber categories

(ii-) Vapor control systems for petroleum marketing operations

(iii-) A tightening (and extension) of "Rule-66" regulations concerning organic solvent reactivity.

Calculating percentage emissions reductions because of elimination of given percentages of certain burning processes is straightforward, and if ARB plans for eliminating certain burning processes are carried out, the projected percentage emission reductions would be reliable. However, some emission reductions have been claimed by the ARB for burning process modification as well as burning process elimination. Depending on the reliability of emission factors for the modified process, these reductions may not be certain and should be viewed with more caution than reductions claimed from burning elimination.

The ARB plan for vapor control in petroleum marketing operations (bulk stations, service station tanks, and auto tank filling), involves some technical difficulties. However, a recent API report indicates that such control is feasible and supports the emission reductions claimed by the ARB. Assuming that this control measure can be implemented according to schedule, the ARB reduction claims are realistic.

The least reliable part of the ARB stationary source control plan involves the proposed controls for organic solvent users. As noted earlier, there appeared to be some inconsistency in the ARB's reactivity assumptions for organic solvents; regions controlled by Rule-66 and regions not fully controlled by Rule-66 were both assigned 20 percent hydrocarbon reactivity. For proposed future controls, the ARB has assumed that a further 80 percent reduction in RHC could be obtained in most air basins by tightening and extending Rule-66 regulations. What is even more troublesome is that the specific control measures to be used to attain a further 80 percent reduction have not been presented. These factors make the ARB organic solvent control strategy the least reliable part of the ARB stationary source control plan.

The CARB has not recommended an aircraft emissions control strategy, but has assumed that the burner-can retrofit program for jet aircraft will

reduce total aircraft emissions by 95 percent in 1977. This is not likely, according to EPA sources (4-28). Not all the types of aircraft which were in use during the base year will be retrofit, and the effectiveness of the retrofit program for reducing hydrocarbon and CO emissions is expected to be approximately 40 to 50 percent reduction. These reductions can be considered only for most Class 2 and Class 3 aircraft -- primarily Boeing 707's, 727's, 737's, and Douglas DC-8's and DC-9's.

4.3 PROPOSED CONTROL STRATEGY

Ultimately, the effectiveness of any control strategy will be measured in terms of its ability to reduce emissions to the desired air quality levels. As noted, the relationship between air pollutant emissions and ambient air quality is not well understood, despite major efforts to develop both sophisticated analytical and statistical models. Many of the other limitations in the data bases and working assumptions have been discussed.

The proposed control strategy fully recognizes inadequacies in the data analyzed; it is presented to be as accurate a portrayal as possible of the air pollution situation given the limits and constraints imposed upon the study. Directionally, the implementation of many or all of the controls will result in significantly improved air quality. In a technical sense, the proposed plan should allow for attainment of the air quality standards by the 1977 target date.

In general, implementation of Phase I measures can be justified on the basis of air quality improvements at reasonable costs and with minor social impacts. These measures are therefore highly recommended for implementation as soon as possible.

The impact of implementing the Phase II control measures is staggering, both in terms of economic costs and the societal disruptions which would result from their institution. Also, it is not clear at this time whether some of these measures are technologically feasible and/or effective. Further evaluation and testing is clearly warranted for these measures before they can be advocated on a wide-spread basis.

The necessity for Phase II control measures results from insufficient emission reductions being demonstrably achieved from the Phase I measures.

The choice of which additional controls will actually be implemented remains to be decided. The measures listed in this analysis were chosen somewhat arbitrarily and are used more for illustrative purposes. They are intended to indicate the severity of additional controls which appear to be necessary to achieve the NAAQS. Other measures could easily have been considered. To some extent, Phase II controls were aimed at controlling heretofore uncontrolled sources, e.g., motorcycles and heavy duty vehicles. The difficulty of achieving additional controls after the Phase I measures can be briefly summarized:

- By 1975 to 1977, no single source category predominates in the emission inventory; that is, all categories contribute a little to the overall problem.
- Major pollution sources, e.g., stationary sources and light duty vehicles, will be stringently controlled by 1975 to 1977, and additional controls on these categories will be difficult to achieve.
- Minor pollution sources, e.g., motorcycles and heavy duty vehicles, although uncontrolled, continue to be a relatively small contributor to the problem; therefore, controls of these categories will have only minor impact.

The control measures outlined are not new and have been proposed elsewhere; no magic solution was found and only incremental improvements can be expected from each strategy. Over the short term, large emission reductions will result from presently planned programs at all levels of government -- federal, state, and local. By the years 1975 to 1977, the remaining uncontrolled emissions will come from many, many sources, the majority of which are controlled. At this point in time, incremental air quality improvements become more difficult, expensive, disruptive, and publicly unacceptable. However, the severity of the air pollution left few alternatives for measures which would be adequate to accomplish the program requirements.

4.3.1 Phase I Measures (Recommended)

4.3.1.1 Gasoline Evaporative Loss Controls

It is evident that as exhaust hydrocarbon emissions are more stringently controlled, the percentage contribution of hydrocarbon emissions from evaporative losses because of normal gasoline handling and transfer operations will increase significantly. Therefore, it is recommended that

controls be required to either prevent or capture these vapor losses before escaping to the atmosphere. Control systems for certain transfer operations are presently available and should be installed as quickly as possible, i.e., bulk terminals and underground storage tanks. Implementation of this measure should result in a reduction of RHC's of approximately 99 tons per day in 1975 and 126 tons per day by 1977.

4.3.1.2 Organic Surface Coating Substitutions

Spurred in part by their contribution to the air pollution problem, the paint and varnish industry has for some time been engaged in research and development of less polluting surface coating formulations. Examples of new formulations entering these markets are water-based or high solids content products. It has been estimated by representatives in the industry that significant inroads can be achieved by 1975 and 1977 to substitute less reactive surface coatings for certain applications. Implementation of such a measure is estimated to eliminate about 13 and 23 tons per day of RHC's by 1975 and 1977, respectively.

4.3.1.3 Dry Cleaning Vapor Control

Certain large dry cleaning plants continue to use reactive petroleum solvents in their normal operations. In these plants, it is possible to install activated carbon absorption systems to control solvent vapors. Implementation of this measure should result in approximately 4 tons per day of RHC's being eliminated by 1975, with the same reduction expected by 1977.

4.3.1.4 Degreaser Substitution

In areas with acute air pollution, substitution of less reactive solvents for presently used degreaser solvents is a control measure which can readily be implemented. Widespread institution of this control measure should result in approximately 10 tons of RHC's being removed from the atmosphere by 1975 and 1977.

4.3.1.5 Burning Regulations

Both current and proposed ARB regulations for backyard, agricultural, and lumber industry incineration practices are aimed at either restricting incineration or requiring more efficient burning practices. It is estimated

that such regulations will have already resulted in a total reduction of RHC's by 1975 and one ton per day by 1977.

4.3.1.6 Aircraft Emission Controls

Current regulations for certain aircraft classes and aimed at reducing smoke and particulates will also result in reductions of other air pollutants. These reductions have been estimated and incorporated into the aircraft emission inventory baseline. In addition, it appears that additional reductions can be achieved by modifying presently practiced ground operation procedures. This control is most applicable to major airport activity centers for which it is proposed. It is estimated that 14 tons per day of RHC's can be eliminated by 1975 and 16 tons per day by 1977 with the implementation of this control measure.

4.3.1.7 Mandatory Inspection/Maintenance

In an attempt to derive the full benefit from both new and used car emission controls, it is recommended that a mandatory annual inspection/maintenance program be established. Initially, to minimize many of the administrative and technical problems associated with instituting such a program, it is recommended that an idle emissions test only be required at the state owned and operated test facilities. After the program has been operative for several years and most of the administrative details adequately worked out, it is recommended that a loaded emissions testing program be instituted by upgrading the testing facilities with the necessary additional equipment and personnel. Implementation of this two-stage program should result in 8 tons per day of RHC's being eliminated by 1975. In 1977, with the implementation of a loaded emissions test approximately 15 tons per day of RHC's can be removed from the atmosphere.

4.3.1.8 Oxidizing Catalytic Converters

The California ARB has been and is currently evaluating catalytic converters as a retrofit for pre-1974 vehicles. Preliminary data indicate that large emission reductions are possible with these devices. The CARB has proposed widespread use of this retrofit as a measure for meeting the NAAQS, even though questions relating to the availability of lead-free fuel and the overall applicability of the devices for all pre-1974 vehicles remain unresolved. Catalysts developed to date require the use of lead-free

gasoline to prevent poisoning of the catalytic element. It remains to be seen what percentage of the older vehicles can operate satisfactorily on lead-free gasoline. Assuming portions of the 1970 to 1974 and 1966 to 1969 vehicles can be retrofitted with catalytic converters, it is estimated a reduction of 30 tons per day of RHC's can be achieved by 1975 and 23 tons per day by 1977.

4.3.1.9 Pre-1966 Retrofit Device

The California ARB has accredited two devices for reducing hydrocarbon and oxides of nitrogen emissions from 1955 to 1965 vehicles. These devices have thus far been required only in the South Coast, San Diego, and San Francisco Air Basins upon change of ownership. The devices are essentially a vacuum spark advance disconnect (VSAD) with a thermal override switch to prevent overheating or an electronic ignition system. Implementation of this measure to all cars should reduce RHC emissions by 3.8 tons per day in 1975 and 1.6 tons per day in 1977.

4.3.1.10 Mass Transit

The level of mass transit available presently is totally inadequate to handle any substantial increases in ridership. Improving mass transit both in terms of frequency and efficiency of service and breadth of coverage in areas served is a necessary first step to attract additional riders. It is also needed for making any measures which discourage private auto use more effective. Finally, should the Phase II measures be implemented, it is imperative as an alternative mode of travel. A much closer examination should be given to establishing express bus and carpool lanes on certain freeways. Park-and-ride facilities, as well as bicycling, should be encouraged in more areas of the Basin.

As shown in Table 4-12, a series of mass transit improvements plus incentives to discourage the private use of the automobile should result in approximately 15 percent reduction in VMT without gasoline pricing or rationing controls. The optimum mix of possible measures from Table 4-12 has not been determined, nor have the corresponding absolute emission reductions been quantified. For that reason the above emission reductions have not been included in the proposed strategy shown in Figures 4-19 and 4-20. The inclusion of these measures would allow a corresponding reduction in gas rationing requirements.

4.3.2 Phase II Measures (If Demonstrably Warranted)

4.3.2.1 Additional Organic Solvent Use Controls

Application of the Phase I control measures on organic solvent uses will result in significant hydrocarbon emission reductions. However, if warranted, it appears that additional reductions may be achievable. These additional reductions will be increasingly difficult to obtain since the remaining emissions are either under tight control already or the sources are very minor and diffuse, making them difficult to bring under control. Examples of this latter category are organic solvent uses in printing operations, pharmaceutical uses, insecticide/pesticide applications, rubber tire manufacturing, plastic and putty manufacturing, etc. Individually, the sources are minor; in their composite they are presently a significant uncontrolled source category. No reductions are claimed from possible controls from these sources in this analysis. As an alternative, however, it is certainly recommended that a closer examination be made of these minor polluters.

4.3.2.2 Eliminating Motorcycle Use During Smog Season

As shown previously, uncontrolled motorcycle emissions are projected to be among the highest of any motor vehicle type on a grams per mile basis. Their overall contribution to the pollution problem has been minor because of the relatively low number of vehicles and annual mileages accumulated. However, as the number of motorcycles increases (uncontrolled) and as more controls are imposed on light and heavy duty vehicles, their emission contribution will become more significant. Two-stroke motorcycles, especially, are notoriously high emitters. In view of the projected importance of this source category, a ban on motorcycles during the summer months when smog is most intense, is a possible control measure. Part of the rationale for this control is that motorcycles are used primarily for recreational purposes, rather than for essential trip-making. A ban on motorcycles during the smog season is estimated to eliminate 15 tons of RHC's in 1975 and 17 tons in 1977.

4.3.2.3 Heavy Duty Vehicle Inspection/Maintenance and Catalytic Converter and Evaporative Retrofit

For essentially the same reasons outlined under light duty vehicles, mandatory inspection/maintenance for heavy duty vehicles can be an effective

control measure. Limited test data is available and has demonstrated its feasibility and effectiveness as a control measure.

Again, a limited amount of data exists demonstrating the effectiveness and feasibility of heavy duty catalytic converter and evaporative retrofits as potential control measures. More extensive field testing is necessary, however, before widespread implementation of these measures can be warranted. It is estimated about 10 tons per day of RHC's could be elminated with these three control measures by 1975 and 9 tons per day by 1977.

4.3.2.4 Light Duty Vehicle Evaporative Retrofit

Still another retrofit being considered for light duty vehicles (pre-1970) is an evaporative control device. The CARB is currently investigating the feasibility of this type of device and if demonstrated effective, they may advocate its use. Others have pointed to the need for such controls but actual working prototypes and field testing data are limited at this time. The technical obstacles appear to be impeding widespread application of this control measure. Also, since the device is to be used on pre-1970 vehicles, its effectiveness decreases with time because of normal attrition of vehicles which can be retrofitted with such devices. Nevertheless, if all the difficulties with this control can be eliminated, it is estimated 21 tons per day of RHC's can be reduced in 1975 and 14 tons per day in 1977.

4.3.2.5 VMT Reduction Through Gasoline Rationing

As a last resort type control, or after implementation of all Phase I measures, additional reductions can be achieved by a program to reduce VMT through gasoline rationing. In light of recent publicity declaring gasoline shortages and/or the energy crises, the public appears to be ready to accept a modest level of fuel rationing. Rationing should be viewed strictly as an interim control to achieve modest reductions. Attempts to impose large scale rationing upon the public will result in numerous undesirable consequences. The effectiveness of gasoline rationing decreases as vehicular exhaust emission characteristics decrease. In fact, if massive rationing is contemplated, the value of extensive retrofitting programs becomes somewhat questionable. As the last measure to be implemented, it appears that a 54 percent VMT reduction of light duty vehicles is necessary for attainment of the oxidant standard by 1977, after imposition of Measures 1 through

5 in Phase II or an 88 percent VMT reduction after implementation of all Phase I measures (including petroleum marketing effect).

4.3.3 Summary of the Proposed Control Strategy

Tables 4-16 through 4-20 summarize the emission level effects of the proposed TRW control strategy for the San Francisco Bay Area. Table 4-17 gives the emission level of THC, RHC, NO_x, and CO from each source type for 1971, 1975, 1977, and 1980 under the Phase I TRW Strategy. The source categories exactly correspond to the source categories in Table 4-16 which gives the baseline emission inventory for San Francisco. The amount of emission reduction for any particular source of interest can be obtained by comparing Table 4-16 with Table 4-17.

Tables 4-18, 4-19, and 4-20 give the details on the effects of the proposed motor vehicle control strategy for RHC, CO, and NO_x, respectively. The upper third of each table gives the motor vehicle baseline emission inventory for 1971, 1975, 1977, and 1980. The center third summarizes the reductions to be expected from the Phase I control measures. Finally, the lower third indicates the effects of the Phase II controls.

Figures 4-19 and 4-20 summarize the proposed TRW emission control strategies for RHC and CO. The effectiveness due to each measure can be seen in relation to those allowable emissions which are necessary to meet the standards. The baseline curve illustrates the federal, state, and local controls which are already, or will be, in effect on all types of sources. The curve for motor vehicles shows the effect of reduction due to the proposed Phase I control measures, which affect light duty vehicles only. Other sources show the reductions due to stationary source controls, aircraft ground operation controls, and Phase II controls.

As discussed earlier, reductions due to mass transit improvements and incentives to discourage auto use have not been included in Figures 4-19 and 4-20. These measures can be expected to reduce VMT approximately 15 percent with a corresponding reduction in gasoline rationing requirements (see Table 4-12).

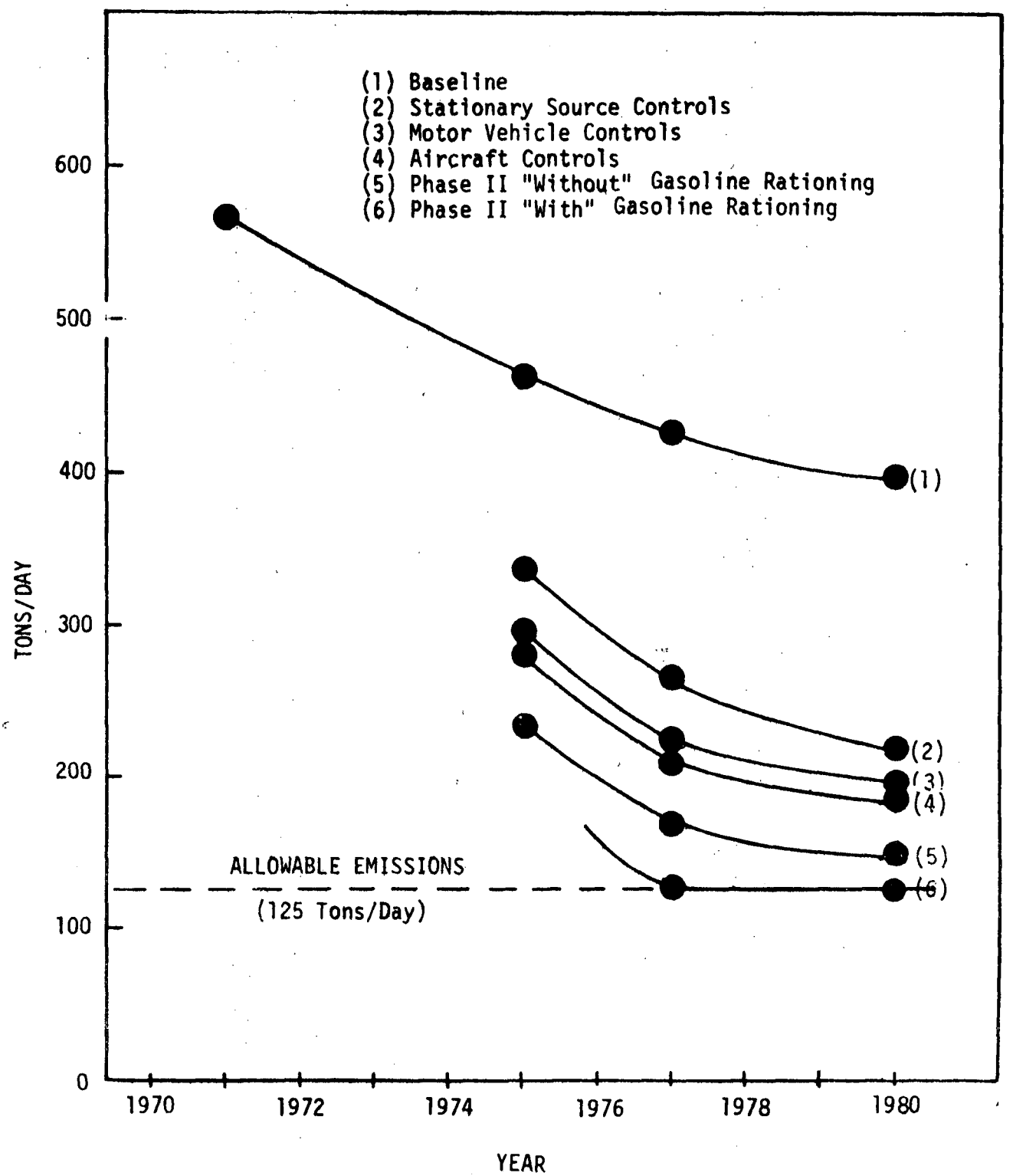


Figure 4-19. Summary of RHC Control Strategy Effectiveness for San Francisco Bay Area (1970 to 1980)

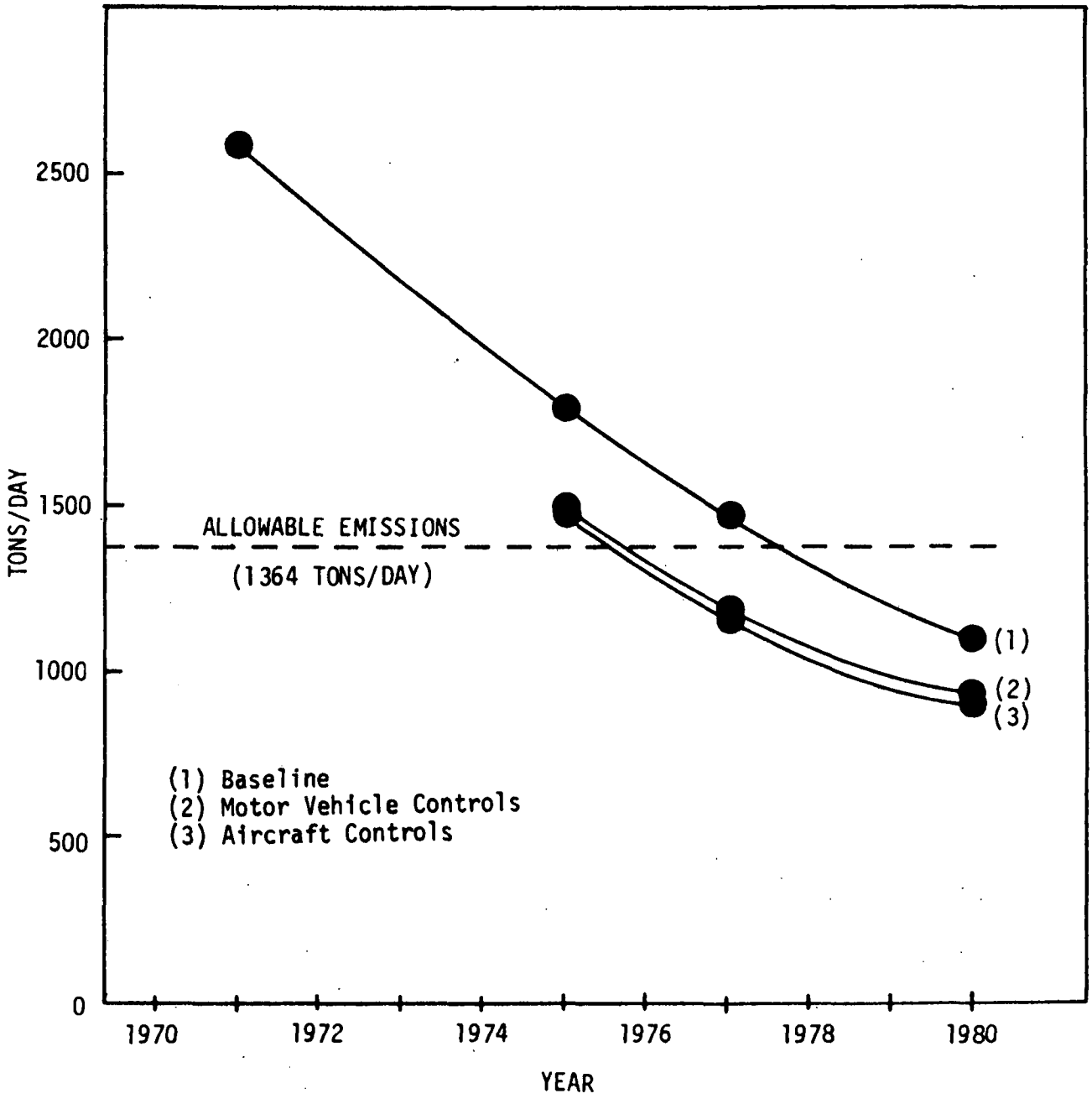


Figure 4-20. Summary of CO Control Strategy Effectiveness for San Francisco Bay Area (1972 to 1980)

Table 4-16. Baseline Emission Inventory - San Francisco Bay Area AQCR

SOURCE	1971				1975				1977				1980			
	THC	RHC	NOX	CO	THC	RHC	NOX	CO	THC	RHC	NOX	CO	THC	RHC	NOX	CO
Stationary Sources																
Petroleum Refining	54	5	55	9	61	6	55	9	64	6	55	9	71	7	55	9
Petroleum Marketing	126	117	-	-	142	132	-	-	150	140	-	-	166	152	-	-
Organic Solvents:																
Surface Coating	210	42	-	-	222	44	-	-	229	46	-	-	246	49	---	-
Dry Cleaning	24	5	-	-	25	5	-	-	26	5	-	-	28	6	-	-
Degreasing	46	9	-	-	49	10	-	-	51	10	-	-	54	11	-	-
Other	80	16	-	-	85	17	-	-	88	18	-	-	94	19	-	-
Chemical Industries	21	-	3	27	25	-	3	32	27	-	4	34	30	-	4	38
Incineration and Agricultural Burning	8	1	-	25	8	1	-	25	8	1	-	25	8	1	-	25
Fuel Combustion:																
Steam Power Plants	1	-	58	-	1	-	61	-	1	-	63	-	1	-	68	-
Residential, Commercial, and Industrial	2	-	62	21	2	-	66	-	2	-	68	-	2	-	73	-
Other:																
Mineral, Food, Lumber, and Metallurgical	17	-	8	10	20	-	10	12	22	-	11	13	24	-	12	15
Subtotal – Stationary	589	195	186	92	642	215	195	78	670	225	201	81	726	245	212	87
Aircraft	34	31	14	110	38	34	21	152	38	34	25	177	37	33	33	192
Motor Vehicles																
Light Duty Motor Vehicles	362	301	326	2137	209	170	273	1301	154	123	213	933	94	73	137	522
Heavy Duty Motor Vehicles	23	19	20	131	23	19	22	149	22	18	21	154	19	16	19	163
Diesels	9	9	78	54	10	10	103	62	10	10	96	56	9	9	87	46
Motorcycles	13	12	-	49	17	15	-	60	19	17	-	69	22	20	-	81
Total	1030	567	624	2573	939	463	614	1802	913	428	556	1470	907	396	488	1091

Table 4-17. TRW Strategy -- San Francisco Bay Area AQCR

Source	1971				1975				1977				1980			
	THC	RHC	NOX	CO	THC	RHC	NOX	CO	THC	RHC	NOX	CO	THC	RHC	NOX	CO
Stationary Sources																
Petroleum Refining	54	5	55	9	61	6	55	9	64	6	55	9	71	7	55	9
Petroleum Marketing	126	117	-	-	36	33	-	-	15	14	-	-	16	15	-	-
Organic Solvents:																
Surface Coating	210	42	-	-	155	31	-	-	115	23	-	-	123	25	-	-
Dry Cleaning	24	5	-	-	3	1	-	-	3	1	-	-	3	1	-	-
Degreasing	46	9	-	-	49	-	-	-	51	-	-	-	54	-	-	-
Other	80	16	-	-	85	17	-	-	88	18	-	-	94	19	-	-
Chemical Industries	21	-	3	27	25	-	3	32	27	-	4	34	30	-	4	38
Incineration and Agricultural Burning	8	1	-	25	3	-	-	12	3	-	-	12	3	-	-	12
Fuel Combustion:																
Steam Power Plants	1	-	58	-	1	-	61	-	1	-	63	-	1	-	68	-
Residential, Commercial, and Industrial	2	-	62	21	2	-	66	-	2	-	68	-	2	-	73	-
Other:																
Mineral, Food, Lumber, and Metallurgical	17	-	8	10	20	-	10	12	22	-	11	13	24	-	12	15
Subtotal — Stationary	589	195	186	92	440	88	195	65	391	62	201	68	421	67	212	74
Aircraft	34	31	14	110	22	20	21	130	21	18	25	152	25	22	33	166
Motor Vehicles																
LDMV	362	301	326	2137	159	128	270	989	110	83	212	647	68	49	136	363
HDMV	23	19	20	131	23	19	22	149	22	18	21	154	19	16	19	163
Diesels	9	9	78	54	10	10	103	62	10	10	96	56	9	9	87	46
Motorcycles	13	12	-	49	17	15	-	60	19	17	-	69	22	20	-	81
Total	1030	567	624	2573	671	272	611	1455	573	210	555	1146	564	183	487	893

Table 4-18. RHC Emissions from Motor Vehicles -- Projected Inventory and Anticipated Reductions (1975 to 1980)

	San Francisco Bay Area						
	1971	1975		1977		1980	
Baseline Emission Inventory[a]	Tons/day	Tons/day		Tons/day		Tons/day	
LDMV	301.0	170.0		123.0		73.0	
HDMV	19.0	19.0		18.0		16.0	
Diesels	9.0	10.0		10.0		9.0	
Motorcycles	12.0	15.0		17.0		20.0	
TOTAL	341.0	214.0		168.0		118.0	
Projected Reductions from Control Measures		Reductions		Reductions		Reductions	
		Tons/day	Percent	Tons/day	Percent	Tons/day	Percent
LDMV Cat. Converter		-30.0	14.0	-23.0	13.7	-14.5	12.3
LDMV VSAD (1955-65)		-3.8	1.8	-1.6	1.0	-0.6	0.5
Inspection/Maintenance[b]		-8.0	3.7	-15.0	8.9	-8.8	7.5
Total Reductions		-41.8	19.5	-39.6	23.6	-23.9	20.3
TOTAL Remaining Emissions		172.2	80.5	128.4	76.4	94.1	79.7
Projected Reductions from Additional Optimistic Measures							
Eliminate Motorcycles (during smog season)		-15.0	7.0	-17.0	10.1	-20.0	16.9
LDMV Evaporative Retrofit[c]		-21.0	9.8	-14.0	8.3	-7.5	6.4
HDMV Cat. Converter + Evap + 50 percent I/M		-10.0	4.7	-9.0	5.4	-7.6	6.4
Total Reductions		-87.8	41.0	-79.6	47.4	-59.0	50.0
TOTAL Remaining Emissions				88.4	52.6	59.0	50.0

a Based on presently proposed control programs
b Based on 10 percent Idle Test Failure in 1975, 50 percent Loaded Test Failure in 1977 and 1980
c 83 percent effective, 65 percent of all pre- 1970 cars
d 50 percent THC effectice, exhaust-64 percent reactive, Evap. - 83 percent effective, 75 percent of all vehicles, 9 percent reduction in HC from IEM

Light Duty Motor Vehicles - (LDMV)

Table 4-19. CO Emissions from Motor Vehicles -- Projected Inventory and Anticipated Reductions (1975-1980)

	San Francisco Bay Area						
	1971	1975		1977		1980	
Baseline Emission Inventory[a]	Tons/day	Tons/day		Tons/day		Tons/day	
LDMV	2137.0	1301.0		933.0		522.0	
HDMV	131.0	149.0		154.0		163.0	
Diesels	54.0	62.0		56.0		46.0	
Motorcycles	49.0	60.0		69.0		81.0	
TOTAL	2371.0	1572.0		1212.0		812.0	
Projected Reductions from Control Measures		Reductions		Reductions		Reductions	
		Tons/day	Percent	Tons/day	Percent	Tons/day	Percent
LDMV Cat. Converter		-275.0	17.5	-196.0	16.2	-109.0	13.4
LDMV VSAD (1955-65)		-6.3	0.4	-1.8	0.1	-0.3	0.0
Inspection/Maintenance[b]		-31.0	1.9	-88.0	7.3	-50.0	6.2
Total Reductions		-312.3	19.9	-285.8	23.6	-159.3	19.6
TOTAL Remaining Emissions		1260.0	80.2	926.0	76.4	653.0	80.4

a Based on presently proposed control programs
b Based on 10 percent Idle Test Failure in 1975, 50 percent Loaded Test Failure in 1977, 1980

Light Duty Motor Vehicle - (LDMV)
Heavy Duty Motor Vehicle - (HDMV)

Table 4-20. Oxides of Nitrogen Emissions from Motor Vehicles -- Projected Inventory and Anticipated Reductions (1975-1980)

	San Francisco Bay Area						
	1971	1975		1977		1980	
Baseline Emission Inventory[a]	Tons/day	Tons/day		Tons/day		Tons/day	
LDMV	326.0	273.0		213.0		137.0	
HDMV	20.0	22.0		21.0		19.0	
Diesels	78.0	103.0		96.0		87.0	
TOTAL	424.0	398.0		330.0		243.0	
Projected Reductions from Control Measures		Reductions		Reductions		Reductions	
		Tons/day	Percent	Tons/day	Percent	Tons/day	Percent
LDMV VSAD (1955-65)		-3.0	0.8	-1.4	0.4	-1.0	0.4
Total Reductions		-3.0	0.8	-1.4	0.4	-1.0	0.4
TOTAL Remaining Emissions		395.0	99.2	328.6	99.6	242.0	99.6

a) Based on presently proposed control programs

Light Duty Motor Vehicles - (LDMV)

Heavy Duty Motor Vehicles - (HDMV)

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5.0 ECONOMIC IMPACT OF THE PROPOSED CONTROL MEASURES

This section summarizes the estimated costs due to the proposed control measures for the San Francisco area.

5.1 GASOLINE MARKETING EVAPORATIVE LOSS CONTROL

In the San Francisco there are roughly 30 bulk terminals which are presently uncontrolled because of their relatively small gasoline throughputs. By requiring that these smaller terminals recover 90 percent of the vapors now being lost to the atmosphere, a cost of roughly $200,000 per terminal will be incurred. This amounts to a total of $6,000,000 for this control measure.

Full vapor recovery from gasoline marketing operations at service stations consists essentially of two vapor return systems; one system transferring vapor from the underground storage tank to the delivery truck; and one system transferring vapor from the vehicle gas tank to the underground storage tank. The cost of retrofitting service stations with the vehicle return system has been estimated in a study performed for the American Petroleum Institute (5-1) to be $5000 per station. The cost of providing new service stations with such a system was estimated to be $2565 per station. In addition, yearly maintenance cost was estimated to be $30 per station. The cost of retrofitting service stations with an underground storage tank vapor return system is estimated to be $1300 per station (5-2). This cost was obtained from a range of cost estimates for such a system of from $900 to $2000 per station. Recently, the Los Angeles County APCD published figures which indicated a cost of roughly $630 per station for the identical system (5-3). Annual costs as well as the cost of fitting new stations with such a system are negligible. Thus, the total retrofit cost for full vapor recovery from an existing service station is $6300, with a $30 per year maintenance cost. The cost to new stations is $2565, with a $30 per year maintenance cost.

The number of service stations in the region was obtained from the San Francisco Bay Area APCD, while the growth rate for new service station

construction was assumed to be the same as the growth rate for the light-duty motor vehicle population in the region. Thus, by 1975, with an estimated number of 4,000 service stations, the cost of full vapor recovery is estimated to be $25,200,000 initially, and $274,000 annually.

The economic savings due to the recovery of the gasoline vapors has not been quantitatively estimated here (although it should be substantial). This is because of the present uncertainty in the price of gasoline and the fact that the petroleum industry must allocate the capital for these systems immediately. Whether they would choose to recover these funds from the consumer (by increasing the price of gasoline), or by waiting long enough for the recovered gasoline to pay for the systems, or by some combination of the above, is not known.

5.2 INSPECTION AND MAINTENANCE PROGRAM

According to a California ARB study (5-4), the cost of an idle-mode inspection and maintenance program conducted at state-owned and operated centers can be summarized as follows:

Initial acquisition cost to the state	=	$1.21/vehicle
Annual costs to the vehicle owners		
Inspection fee	=	$0.96/vehicle
Source and repair cost	=	$3.60/vehicle (at a 10% failure rate)
Potential fuel savings	=	-$1.33/vehicle (at a 10% failure rate)
Annual cost to government		
Lost gasoline tax revenues	=	$0.68/vehicle (at a 10% failure rate)
Total annual cost	=	$5.12/vehicle (at a 10% failure rate)

According to the same study, the most cost effective program for motor vehicle inspection and maintenance consists of a key-mode (loaded emissions) test conducted at state-owned and operated centers. Under this set-up, the initial costs are estimated to $1.98 per vehicle while annual costs (assuming a 50 percent rejection rate) are estimated to be $10.23 per

vehicle. This figure is arrived at under the following assumptions:

Annual inspection fee	$ 1.05 per vehicle
Maintenance cost	$13.35 per vehicle
Potential fuel savings	-$ 8.35 per vehicle
Lost gasoline tax revenue	$ 4.18 per vehicle
Total annual cost	$10.23 per vehicle per year

By 1975 there will be approximately 2,926,200 registered light-duty vehicles in the Bay Area. Therefore, initial costs are estimated to be $6,120,000 and annual costs amount to $17,557,000 per year.

5.3 VSAD/LIAF RETROFIT OF PRE-1966 LDV

According to California Air Resources Board figures, a reasonable cost for this retrofit is $35 per vehicle. By 1975, there will be about 640,250 pre-1966 light-duty vehicles registered in the region. The total cost for the retrofit is then $22,409,000.

5.4 CATALYTIC CONVERTER RETROFIT

A catalytic converter retrofit for 75 percent of 1971 to 1974 model year vehicles and 20 percent of 1966 to 1970 model year vehicles will cost about $175 per vehicle. In 1975, there will be approximately 1,077,000 vehicles in this retrofit category. The total cost is then $188,448,000.

5.5 SOLVENT USAGE

The cost of solvent use controls has been estimated for Los Angeles County at $4,500,000 (5-5). This represented the cost of development of the appropriate solvents. Once developed, the production cost should be similar to present production costs. Hence, this development cost should be apportioned across the nation where such regulations are being applied. In this case, the cost becomes negligible with respect to other costs incurred under the proposed strategy and will be neglected.

The control costs described above are summarized in Table 5-1.

Table 5-1. Estimated Costs of Control for San Francisco Area

	Initial	Annual
Gasoline marketing controls (full vapor recovery)	$ 31,200,000	$ 274,000
Inspection and maintenance		
1975	3,538,000	15,000,000
1977 (additional cost)	2,582,000	14,920,000
VSAD/LIAF for pre-1966 vehicles	22,400,000	---
Catalytic converter	188,000,000	---
Total cost (including loaded I/M)	$253,720,000	$30,194,000
Per capita cost	$51	$7

5.6 REFERENCES

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6.0 SOCIAL IMPACTS

Social impacts are non-monetary costs attributable to the imposition of a set of constraints. These impacts are generally measured by the loss of time, opportunity, and/or inconvenience. The magnitude of the impacts is primarily a function of age, race, and income level. Measures which are intended to influence, control, or restrict the ownership and use of motor vehicles will, in general, result in social impacts. In a similar and related manner, measures which affect personal mobility, mode choice decisions, and regional access also induce social costs. To date, because of the very nature of social impacts, it has been difficult to quantitatively evaluate them. For example, only a limited amount of research has been devoted to estimating foregone or lost opportunity costs with respect to not making a trip.

This section presents a broad overview of the types of social impacts which are likely to result from the implementation of transportation control measures being contemplated, followed by a specific Bay Area application -- identifying social and other impacts for new transit services in the Livermore-Amador Valley. The specific example, taken from a recent transit study, points up that local transit services must primarily be justified on the basis of social benefit (equity, etc.), while long haul or express, bus services offer much greater economic benefit.

In view of the many social impacts which are likely to be encountered as a result of transportation controls and the diverse character of the metropolitan areas affected, it will be important for planning agencies to anticipate and minimize the impact of controls where possible. Increased public awareness and concern have been largely responsible for the desires to live in a clean environment. In addition, public participation in the decision making process will continue to be crucial to the orderly transition and acceptability of various controls. To be meaningful, citizen participation in the form of both structural and informal dialogue will have to be promulgated at the local and regional levels. These engaged in control plan development should get out to the citizens, listen and learn. To be sensitive to local conditions takes time but helps improve and develop

support for control measures. Only then can the final decisions concerning which controls are applicable for a given region be complete and a reflection of the public's desires; this in turn will result in minimizing the social impacts.

6.1 WHO - THE IMPACT ON VARIOUS SOCIO-ECONOMIC GROUPS

The diversity of the region's population and lifestyles results in non-uniform impacts to different socio-economic groups from the implementation of various transportation control measures. In an attempt to fully consider the issue of equity, it is necessary to be cognizant of the groups which are unduly discriminated against by the different control schemes. Special care must be exercised to remain sensitive to the needs of the young, aged, poor, and minorities. In many instances, transportation planners have either inadvertantly or systematically failed to meet the requirements of these groups.

By necessity, the young, old, poor, and minority classes have accounted for a disproportionate share of transit ridership. Since these groups own fewer motor vehicles, their trips may be viewed as having more of a required nature than average trips undertaken. For example, these groups make fewer pleasure or recreational type trips. Controls directed at uniformly reducing VMT may, therefore, impact these socio-economic groups more than the average groups (i.e., white, middle age, and middle income). Factors which must be carefully considered in assessing the impact on these special groups are presented below.

6.1.1 The Young and Aged

Without question, private automobiles are the dominant means of personal transportation, yet, because of age considerations, large segments of our young and elderly population groups are excluded from this transportation mode, unless chauffeured. Table 6-1 illustrates the percentage breakdown of auto ownership by age category.

Table 6-1. Car Ownership by Age of Household Level (6-1)

Age of Household Head	% of Households Owning No Car	At Least One Car
Under 25	19.3	80.7
25 - 34	12.0	88.0
35 - 44	11.6	88.4
45 - 64	13.6	86.4
55 - 64	19.7	80.3
65 and over	44.9	55.1

In certain regards, the young and old stand to benefit from the imposition of transportation countrols; in other situations, these population groups will be adversely affected. Currently, the young and old without autos represent a large segment of a transit systems "captive riders." As shown above, nearly a fifth of those under 25 and more than two-fifths of those over 65 do not own private autos. This implies these families are totally dependent on either public transportation or others with cars for satisfying their transportation requirements. Measures to improve mass transit, such as more frequent, faster, and cheaper service will, in general, benefit the young and old.

On the other hand, many trips undertaken by the young and old are accomplished by chauffeuring activity. Frequently, for reasons of safety, inconvenience or physical handicaps, it is necessary for the young and old to depend on friends or relatives for escorted auto transportation. Under these conditions, VMT reduction measures may adversely affect the young and old. Typically, these trips are of a required nature, e.g., school, dentist, doctor, and uniform restraints on VMT could result in significant inconveniences.

The impact on the younger segments of a population tend to be less critical than similar impacts on the elderly. Supposedly, lost opportunity costs and inconveniences are taken more in stride by the young since "their day will come." With the coming "of age," the younger age groups rapidly gain mobility and accessibility; also, physical handicaps pose less problems with alternative modes of transportation (e.g., walking, bicycling, etc.).

The problems of transportation and the elderly are of a slightly different nature. In fact, "many older people see transportation as the major impediment to their having a personally meaningful and socially constructive retirement. Only a small fraction of the elderly own automobiles and have driver's licenses. This is due primarily to their economic status, and secondarily to health reasons." (6-2) Table 6-2, based on data from the New York Metropolitan region, clearly illustrates the lack of auto availability among the old. In the same study, it was noted that those elderly persons with driver's licenses (24 percent) accounted for more than half of all trips attributable to elderly persons.

> "This indicates that there may be a significant latent demand for public transportation for the elderly. Indeed, when Los Angeles reduced off-peak fares for the low income elderly by 33 percent, there was a 24 percent increase in total ridership, and a 10 percent shift in ridership from peak to non-peak hours. The experience of New York, Pittsburgh, and other major cities are similar. The reasons for the high price elasticity of demand among older people are their low incomes and the fact that few of the elderly embark on the inelastic work trip."

Table 6-2. Percent of Elderly With No Autos Available (6-3)

Household Income Group	Percent of Elderly with Zero Auto Availability
$0 - $2999	88.7
$3000 - $5999	58.2
$6000 - $9999	29.6
Greater than $10,000	20.6
All Income Groups	55.6

Viewed in this context, air pollution controls which will facilitate improved transit services will result in a positive benefit for many of the young and elderly population segments. Restrictions on auto usage will have similar impacts on most age categories but, overall, they will affect the young and aged proportionally less because of auto ownership characteristics.

6.1.2 The Poor

By definition, the lower income families are less able to afford private automobile transportation. Consequently, their position is

closely related to the problems of the young and elderly; as a group, the poor are, for the most part, dependent on public transportation for satisfying most trip making needs. Table 6-3 presents data on auto ownership by income level.

Table 6-3. Car Ownership by Household Income Level (6-1)

Household Income	Percent of Household Owning No Car	At Least One Car
Under $3000	57.5	42.5
$3000 - $4999	30.8	69.2
$5000 - 7499	13.6	86.4
$7500 - $9999	8.4	91.6
$10,000 - $14,999	4.1	96.9
$15,000 and over	3.8	96.2

In considering differential impacts by income levels, the means by which trip purposes are fulfilled is the critical variable. The impacts can be divided into those associated with transit usage and automobile usage.

The impacts on the poor from improvements in public transit are analogous, in many respects, to those previously discussed in Section 6.1.1. Most likely, significant benefits will result from these measures. In addition, it has been suggested that transportation deficiencies are directly relatable to poverty. Thus, improvements in public transportation may contribute to easing some of our social and urban problems as well. In a study of the feasibility of establishing fare-free transit in the Los Angeles region, it was noted (6-2):

> "Since unemployment is a major issue in poverty-oriented study and research, many assert that there is a strong relationship between unemployment and limited transportation to appropriate job centers. Conclusions of many investigative reports on the racial flareups of the 60's concurred and listed public transit improvements among the most vital of their recommendations. The McCone Commission made such a recommendation following an investigation of background causes of the Watts riots."

While the report cited the relationship between transportation and unemployment rates (and therefore poverty groups), it was careful to point out that discriminatory hiring practices and the competitive job markets were also major determinants of high unemployment.

"While non-work trips are generally considered to be more responsive to fare changes, in the case of bus services the inconveniences of boarding and departing from the vehicle with parcels, of making necessary transfers, and of complying with schedules and routes seem to suppress this elastic behavior for shopping trips. In the Southern Los Angeles portion of the employment study which has been discussed, residents in a community with a 50 percent car ownership rate accomplished 94 percent of food shopping trips via private auto or taxi.

"Assuming that service limitations of bus service could be reduced, it is more likely that benefits from improvements in non-work oriented travel would be felt more consistently within low income groups than benefits from enhanced employment opportunities. Shopping facilities can be clearly identified within a community or region, and providing that an individual has money to do so, he may utilize those faciliiies once he has gained access to them."

In other words, improved transit tends to equalize accessibility among income levels, whereas it is currently more readily available to higher income groups.

The impact of auto-oriented controls for low income auto owners is quite different. Currently, as the average income increases, so does the average annual miles travelled per automobile. Equally interesting to note is that up to incomes of $7500 per year, the percentage of total VMT by income group is even less than the percentage of vehicles owned by those groups. This is primarily because of higher income groups owning more than one auto per household.

The vehicular controls being considered in this report are basically of two types--vehicle oriented measures (e.g., retrofit devices, inspection/maintenance) and traffic oriented measures (e.g., auto free zones, parking restrictions, exclusive bus and carpool lanes). Restraints of this nature increase travel costs and times.

Time penalties are generally perceived as more important with higher income groups. In this respect then, equivalent time penalties would result in a more significant impact on the rich or those who place high values on time inconveniences. Such impacts could result from measures such as freeway metering, parking restrictions, auto free zones, or exclusive bus lanes.

Many of the economic impacts associated with motor vehicle oriented measures have been described and discussed in Chapter 4.0.

The overall economic costs of the control programs will indeed be very significant. In the majority of the regions, a substantial portion of these costs are being passed onto the automobile owners. Measures which require auto owners to assume all control costs for their vehicles are highly regressive and tend to discriminate against the lower income groups. For example, emission taxes which penalize polluters in accordance to the amount of pollution released place a heavy burden on the poor, who own older cars with higher pollution emitting characteristics. Regulations which require expensive retrofit devices and inspection and maintenance checks similarly impose heavy burdens on those least able to absorb the high capital, testing, and repair costs.

Equitably internalizing the costs of air pollution control has been the subject of numerous research efforts. Many methods have been proposed for financing control costs. As the dates approach for implementing many of the controls, it will be necessary to experiment with novel financing schemes. The literature is abundant in approaches which attempt to equitably allocate costs among polluters. What is missing are documented case studies of novel approaches which have actually been attempted.

Illustrative of recent proposals for reducing air pollution in California, while remaining sensitive to lower income groups, are the following two examples:

1) An Emissions Tax to Induce Reducted VMT (6-4)- "On the basis of rough predictions of response an initial level of taxation could be chosen. Air quality levels prior to the institution of the tax would be measured and recorded. After the tax had been in effect for, say, six months or a year, new measurements would be made.... If the remaining improvement were less than desired, the level of the emission tax would be raised.... An important objection to a system which minimizes total expenditures is that it ignores the burden which the tax places on particular people (e.g., the poor). If the emissions tax goes to replace other sources of revenue, it is not a net cost for motorists in the aggregate, but it may still be a net cost for certain individuals if their other tax payments are reduced by an amount less than the emission tax. If the emissions tax replaces part of the income tax, for example, the poor may find that their income tax falls by less than the amount of the emissions tax. This is a crucial problem, but it can be dealt with

by providing exemptions from the tax for any person who has an income below a certain level.... In order to achieve desired air quality with this exemption, we may have to raise the uniform tax rate above what it would be if the poor paid the tax without exemptions. This procedure is acceptable because the poor are sheltered from the increased rate by their exemption, and the outcome is that the rich pay proportionately more than the poor for cleaning the environment."

2) Alternative Payment Schemes (6-5)

- User-Pays -- the cost of a control strategy is totally assumed by the owners of the vehicles affected.
- Uniform-Payment-Per-Vehicle-Mile-Driver -- simply stated, this scheme takes the total annualized regional costs and divides by the annual.... vehicle miles driven....
- Uniform-Payment-Per-Vehicle -- in this case, the total annualized regional costs is divided by the number of light duty vehicles in the basin. Each vehicle owner then pays an identical amount per vehicle. Payment could be made by a uniform increase in vehicle registration fees.
- Income-Proportional -- payment of the control strategy is made on a scale that is directly proportional to income. For this scheme, everyone in the region - not just those owning vehicles - is responsible for financing the additional controls.

In the above list, the user-pays scheme must be regarded as the most regressive. That is, the vehicle ownership by model year is sufficiently biased that the largest burden rests on the group with the smallest income. Conversely, the income proportional scheme is the least regressive in this sense.

6.1.3 The Minority Groups

The impacts likely to be incurred by minority groups from transportation controls are similar, in many respects, to those impacts already discussed in the previous two sections. Minority groups have a higher tendency to be poor, without autos, and largely dependent on

public transportation services to meet many basic trip-making requirements. Measures designed to improve public transit will most likely result in a positive impact on the many transit dependent minorities. Controls on vehicle usage requiring substantial economic costs will place heavy burdens on the large share of minorities with low incomes.

Another issue facing minority groups is that of accessibility. As stated previously, inadequate or poor transit service was cited as one determinant of the Watts riots. Apparently, the lack of mobility contributed to the frustrations of unemployment and impeded any attempts to find meaningful work. Employment centers and transportation systems are inter-related. Urban transportation systems which promote dependence on automobile travel systematically exclude many minorities living in the ghettos from equal opportunities. Control measures contemplated should carefully consider potential obstacles to the upward mobility and equal opportunities of the minority classes.

6.2 WHEN - THE IMPACT ON MOBILITY PATTERNS

Among the control measures being considered for reducing air pollution are many which will directly impact existing mobility patterns, or when and where people travel. Examples of some of these controls are:

- Staggered work hours
- Four day work weeks
- Parking restrictions.

6.2.1 Typical Urban Driving Patterns

The magnitude of the social impact to be expected from any measures depend heavily on regional characteristics. Travel patterns throughout the country are highly divergent with respect to trips taken, distances travelled, and times travelling. Present driving patterns have evolved slowly and intuition suggests these patterns will show a high degree of resistance to change. Variations between cities are largely because of land use patterns and alternative modes of transportation. Because of this, one would expect different regional impacts to the same controls.

6.2.2 Reducing Optional Trips

When a person makes a trip from one location to another, it is done to serve some human need or desire. The choice of travel mode, as well as the actual decision to travel, both involve a human decision process. Both decisions are probably made rationally with due consideration for a number of actual and apparent factors. The ability of various individuals to accurately assess these factors varies, but overall, incorrect judgements in both directions tend to offset each other. Upon consideration of the actual and perceived factors relating to a trip, the individual decides whether or not to make the trip and by which mode to travel. Once the decision has been made to make the trip, to eliminate or prohibit this trip would mean that some need would be unmet or purpose unfulfilled.

It must be emphasized that attempting to define which travel is optional or unnecessary is fraught with numerous difficulties. An obvious difficulty involves the definitions of terms such as, "necessary, optional, and essential." Since we are dealing with personal value judgements, what one individual views as unnecessary may be considered very essential to another individual. Even for the same individual and the same trip, circumstances frequently change so that the individual's perception of the need to make the trip change. Another difficulty encountered in assessing individual needs is the dynamic state of decision making as it relates to human values with the passage of time. The steady growth or VMT experienced since World War II has in large part been attributable to an improved quality of life. This affluence has resulted in a higher standard of living with an increased ability to afford more travel and more time to partake of it. What was once the Sunday afternoon drive in the park has now become the weekend excursion to the mountain resort areas.

In order to even approximate what level of trip making is optional or marginally necessary, it is necessary to superimpose one set of human values upon another. The imposition of new values upon others will always result in social costs to the individuals affected. The

magnitude of these costs are related to the severity of the constraints and the individual's ability to adapt to the constraints. It is apparent, therefore, that caution be exercised in carefully weighing the societal costs associated with the gains to be derived and the degree of controls needed to attain any desired level of VMT reduction.

A number of factors enter into any decision concerning whether or not a trip should be undertaken. These factors are in many cases also directly related to the variables which influence the mode choice (to be discussed later). The decision to make a trip is basically in order to meet a need or fulfill a desire. The needs and desires, in turn, are a function of the individual's personal makeup and the environment in which he lives. Each trip made is the result of either an explicit or implicit decision to serve a need. Personality traits are likely to influence the variability of specific trips made, whereas the overall environment is likely to dictate the aggregate demand of all trips made. A ghetto family without a car will make fewer trips overall than an upper class family which has three cars at its disposal. In this case, the differences in opportunity will define the trip making characteristics and needs. Because of differences in household characteristics and physical environments, eliminating identical trips are perceived to have significantly different impact depending on the groups experiencing the impact. Controls which will result in trip reductions should not only consider trips intended for basic functions as working and shopping, but also the human needs for recreation and relaxation.

6.3 WHERE - THE IMPACT ON ACCESSIBILITY

It has frequently been said for Los Angeles that "to have a job, you must have a car and to have a car, you must have a job." This relationship of employment opportunities (especially for certain minorities) to transportation has been alluded to previously. Certain control measures being considered will have a definite impact on accessibility and consequently, they will result in social impacts. For example, the creation of auto free zones to eliminate "hot spot" pollution

problems will result in inconveniences for those wishing to enter the zone by auto. Depending on the extent of the inconvenience, a driver may park in a peripheral area and walk, ride mass transit, or find an alternate place to accomplish the desired trip purpose. The first two impacts are personal time inconveniences; the latter impact has implications for the economic success or viability of the auto free zone. In some cases, air quality improvement and increased economic activity have resulted through the creation of auto free zones. Apparently, the new mall-type environment attracted more shoppers into the region--many of which were previously unwilling to put up with the traffic jams and parking difficulties. In most cases, the success of auto free zones is related to the quality and quantity of parking available outside the zone and the types of transportation available within the mall (e.g., trams, electric cars).

Overall, it is estimated impacts from accessibility restrictive measures are minor and can be very positive. The intent is generally to penalize private transportation while favoring public transit. In addition to being conservation-oriented, such schemes tend to favor many of the underprivileged population segments.

6.4 HOW - THE IMPACT ON MODE CHOICE DECISIONS

Numerous factors affect an individual's choice of travel mode. Those relating to the individual include age, sex, and income. Equally important are variables dealing with the individual's environmental surroundings--land use patterns and transportation systems. It is generally conceded that these latter factors play a key role in determining the levels of trip making. Regional differences in urban land use and traffic patterns are very pronounced and it is extremely difficult to generalize which segments within a community account for any specified level of travel. Davis, California, for example, has more than half of the vehicle trips to its center being made by bicycles. In midtown Manhattan, more than half of the VMT is attributable to taxicabs. The centralization of federal activities and the construction

of a totally new fixed rail transit system in Washington, D.C., will result in traffic patterns very different than those experienced in the auto-oriented, metropolitan Los Angeles region.

Experience has shown that the more important factors in mode choice decision-making are related to the transportation system and its performance characteristics. Basically, the parameters which determine mode choice are the time and money associated with the trip. Viewing the trip in terms of time and money, making the trip requires a certain economic cost. Obviously, the traveler will attempt to reduce the actual and perceived costs.

Most of the controls being considered increase the cost of private automobile travel and/or reduce the cost of public transportation. The purpose of course is to induce higher percentages of people onto public transit. While aiding those dependent on transit services, measures which make it more expensive to drive tend to be regressive. As such, the social impacts experienced will be more heavily felt by the poor.

It has been shown that time costs are frequently a more serious penalty to the middle and high income groups. Consequently, measures which result in time penalties, e.g., ramp metering, exclusive bus and carpool lanes, are often more effective at inducing transit ridership than monetary fees. From an equity standpoint, these controls are highly desirable since the poor place less value on their time. As a result, one would expect a more uniform mode shift by income groups from such controls.

The result of control measures on mode choice decisions will generally favor more extensive public transit usage. Socially, the impacts will initially be viewed as inconveniences and to a limited extent, a loss of personal mobility. In the long run, as adjustments are made to new life styles, these impacts will have been appreciably diminished.

6.5 SUMMARY

The social impacts associated with implementing the proposed transportation control measures will be significant. Many impacts identified will be of a positive nature, e.g., improved mobility and accessibility for deprived population groups, more efficient energy utilization. Other impacts, however, are likely to have negative social impacts, e.g., placing additional burdens or regressive measures on smaller population segments.

Critical to minimizing the social impacts will be the time schedules used for implementation of the various controls. Schedules which allow for personal adjustments to the imposed constraints will most probably result in an orderly transition.

Table 6-4 presents a summary of the overall social impacts likely to occur as a function of the control measures. Estimates for the extent of the overall impacts are intended to present a relative index and have to be qualified by some rather simplifying assumptions. For example, it was assumed that the young, old, poor and minorities owned old cars (if any), drove primarily out of necessity, and placed little value on their time. The "average" American, however, was viewed as relatively mobile, the owner of at least one car, and someone who placed a high value on his time.

The impacts on mobility were considered to be those which impeded when trips would be made and what types of trips would be made; these effects were related directly to the typical urban driving patterns. Accessibility impacts are those which restrict where one goes and the ease with which the trips can be made.

Lastly, a summary of the impact on mode choice decisions is given. This considered the relative effect a given measure would have on the attractiveness of the predominant transportation modes, i.e., the private auto and public transit.

For each control measure, there are usually several kinds of programs which can be instituted and even more ways of implementing them.

Table 6-4. Summary of Overall Social Impacts

	Impact on Various Socio-Economic Groups				Impact on Mobility	Impact on Accessibility	Impact on Mode Choice Decision	
	• Young/Elderly	• Poor	• Minorities	• Average American			• Private Auto	• Public Transit
• Vehicle Oriented								
I/M	-	--	-	0	0	0	-	0
Retrofit	--	--	--	-	0	0	--	0
• Traffic Flow								
TOPICS	0	0	0	+	+	0	+	+
On-Street Parking	0	0	0	-	-	-	-	0
Staggered Work Hours	0	0	0	0	0	0	+	0
Highway Construction	0	0	0	+	+	+	+	-
Ramp Metering	0	0	0	-	-	0	-	+
• VMT Reduction								
Transit Improvements	+	+	+	0	+	+	0	++
Car Pooling	0	0	0	-	0	0	-	+
Parking Control	0	0	0	-	-	-	-	+
Pricing Schemes	--	--	--	-	-	0	-	+
Auto Free Zone	0	0	0	0	0	--	--	+
Gasoline Rationing	--	--	--	-	--	0	--	0

LEGAND (relative impacts)

++ Very Favorable

\+ Favorable

0 Very Minor or None

\- Unfavorable

-- Very Unfavorable

In many cases, the means by which a program is implemented can significantly affect the degree of social impacts encountered. To illustrate this point, several examples are considered below.

- Retrofit devices are shown to have a very unfavorable impact on the young/elderly, poor, and minorities. This has assumed these groups have old cars which are not used much and which require expensive retrofits, e.g., catalytic converters. If individuals in these groups had no car or the government provided subsidies to finance the retrofits, the impacts would be completely different.

- Pricing schemes are also shown to have regressive impacts on the young/elderly, poor, and minorities. This assumes relatively uniform fee or taxing policies on all groups. As discussed in Section 4.1.4, a host of methods are available to insure a more equitable distribution of pollution control costs. Institution of such financing schemes would change the overall impacts on special population groups.

- Gasoline rationing is noted as a very unfavorable impact on the young/elderly, poor, and minorities. This assumes a free market situation where gasoline is limited at the distributor level and the price is allowed to seek its own level. The net result would be almost equivalent to uniform taxing policies. Those less able to afford gas would be priced off the road. If, however, a rationing system was established allocating equal shares of gas to all vehicles at fixed prices, the social impacts would be significantly changed and more favorable.

Impact of Improved Transit Services:
Livermore-Amador Valley Example

The following analysis was developed by DeLeuw , Cather and Company for impact of new transit services, long haul (express) and local, in the Livermore-Amador Valley. It serves to illustrate the type and magnitude of impacts attributable to improved transit services in the

absence of other control measures. The introduction of tolls, traffic constraints and other measures will increase benefits from express transit, but this must be counterbalanced with other costs (inconvenience, etc.) associated with the constraints.

1. Express Bus Benefits

Eight categories of quantifiable express bus benefits were identified. Five of the categories - substitution for the second car in commuting to work, substitution for driving to work and parking, additional income from an improved job, occasional usage, and school transportation savings (substitution for being driven to school) - benefit the express bus user. A sixth category of negative benefits - loss from additional time on the bus - must be subtracted from the bus user benefits. Two other categories - savings from reduced number of parking spaces and savings from reduced traffic congestion during the rush hour - benefit the community-at-large.

Table 6-5 and Figure 6-1 compare express bus costs and benefits, indicating total benefits would be 1.1 to 2.2 times system cost. Note that in the benefit/cost comparison total cost is used and not deficit. To reduce system cost by subtracting revenue would require that an equivalent amount be subtracted from system benefits.

The computation of express bus benefits includes consideration of future community benefit from a reduced automobile usage. For example, if no public transportation system exists, new Valley residents typically must buy a second automobile. An objective of transit service is to reduce the need for high household budget allocation for additional automobiles and thereby reduce traffic congestion, air pollution and the need for expensive traffic improvements. The process of intercepting new residents and encouraging them to use transit is a long term process, an investment likely to make future bus service more economical to operate as well as save new residents money. When residents are forced to buy additional cars, then investment commitments thwart the long-range feasibility of transit service.

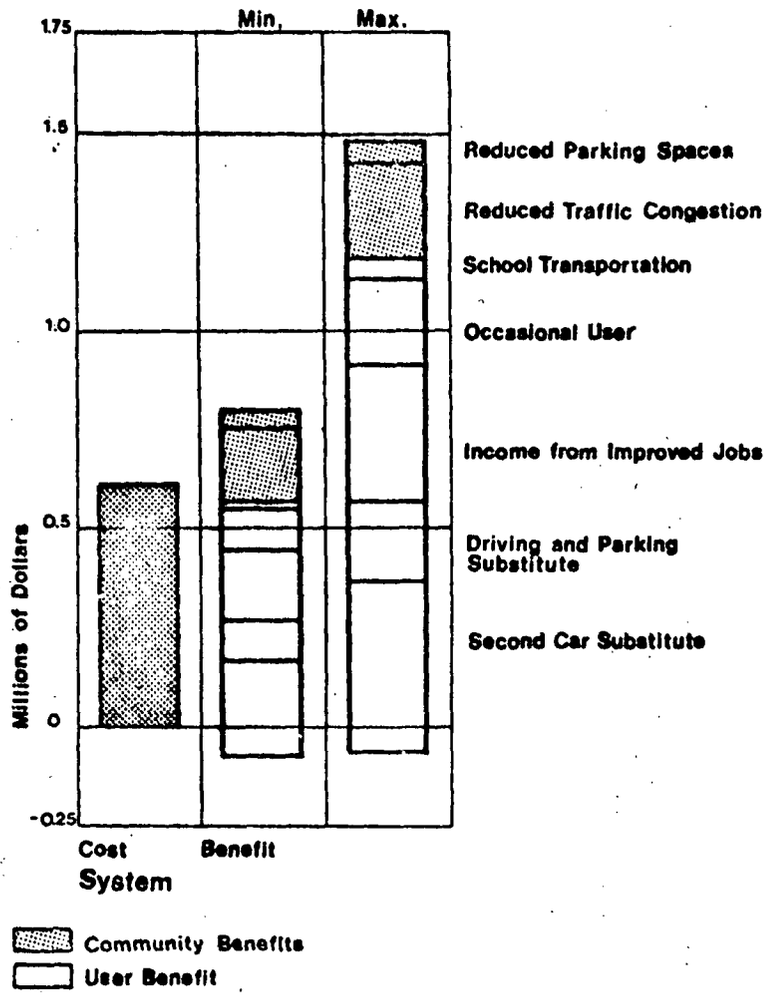

Figure 6-1. Express Service, Benefit Versus Cost

Table 6-5. Annual Express Bus Benefit/Cost Comparison

Benefit Category	Benefit Measure	Number Benefiting	Annual Benefit (in thousands)
Second Car Substitute	$500-1,100/rider	335/day	$170 - $370
Driving and Parking Substitute	$300-600/rider	335/day	100 - 200
Additional Income from Improved Job	$1,000/rider outbound	25-50/day	25 - 50
	$3,000/rider inbound	50-100/day	155 - 300
Occasional User	$10-20/work rider	6,000/year	60 - 120
	$0.75-1.50/ non-work rider	70,000/year	50 - 105
School Transportation Savings	$500-1,000/rider	25-50/day	10 - 50
Loss From Additional Time on Bus	$65-75/rider	950/day	($70 - 60)
Reduced Number of Parking Spaces	$150/space	300-350/day	45 - 55
Reduced Traffic Congestion	$14-18/commuter	13,300/day	190 - 240
Total Benefits			$735-$1,430
Total Capital and Operating Costs[a]			$660-$ 660
Benefit/Cost Ratio			1.1 2.2

(a) Assuming six-minute headways and night and Sunday service.

Source: See Appendix C

The express bus benefit/cost comparison supports initiation of service, particularly from the standpoint of the bus user and the commuter. Greatest benefit would accrue to those persons who use the bus to reduce automobile ownership costs. Since the commuter represents about one-quarter of the Valley labor force, benefits may be assumed to reach at least that portion of all households.

2. Local Bus Benefits

Nine categories of quantifiable local bus benefits were identified. Six of the categories - substitution for being driven to work, second car substitute, driving and parking substitute, additional income from improved job, occasional usage, and school transportation savings - benefit the local bus user. A seventh category of negative benefits - loss from additional travel time by bus - must be subtracted from bus user benefits. Two other categories - reduced number of parking spaces and reduced welfare transportation costs - benefit the community-at-large.

Table 6-6 and Figure 6-2 compare local bus benefits and costs. Total quantifiable benefits ranged from 0 to 10 per cent of costs for 20-minute service on Systems I or II, to 1 to 20 percent of costs for 60-minute service on Systems III or IV, indicating a more favorable benefit/cost ratio for less extensive routing patterns with less frequent bus headways. In no case did benefit/cost analysis indicate quantifiable benefits from the local transit system would exceed costs.

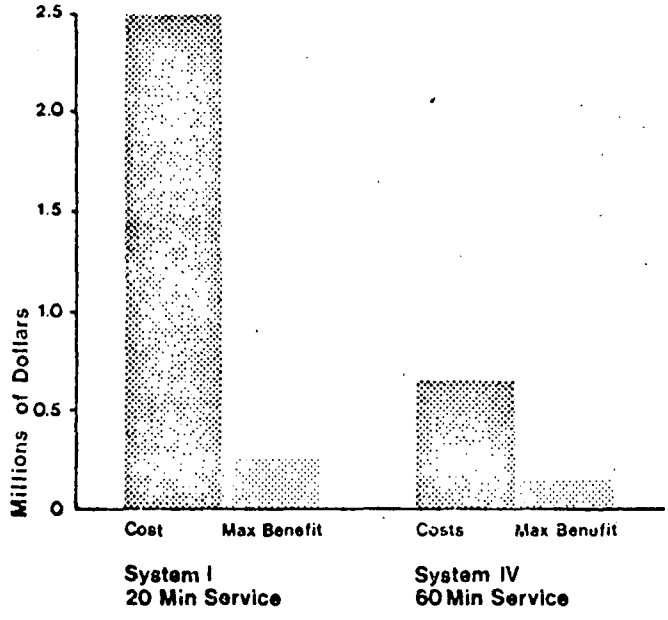

Figure 6-2. Local Service Benefit Versus Cost

Table 6-6. Annual Local Bus Benefit/Cost Comparison

Benefit Category	Maximum Annual Benefit (in thousands) System I (20-minute service)	Minimum Annual Benefit (in thousands) System IV (60-minute service)
Substitute for Kiss n' Ride or Ride to Work	$ 28 - 50	$14 - 23
Second Car Substitute	14 - 28	6 - 11
Driving/Parking Substitute	5 - 10	2 - 5
Additional Income from Improved Job	15 - 30	8 - 15
Occasional User	53 - 210	27 - 116
School Transportation Savings	6 - 41	2 - 12
Loss from Additional Time by Bus	(141 - 155)	(66 - 72)
Reduced Number of Parking Spaces	16 - 19	5 - 7
Reduced Welfare Transportation Costs	10 - 20	10 - 20
Total Benefits	$ 6 - 253	$ 8 - 137
Operating Cost	$2,500	$650
Benefit/Cost Ratio	0 - 0.1	0 - 0.2

Source: See Appendix C

3. Other Benefits

Not all benefits derived from a transit system can be realistically quantified in monetary terms. The following paragraphs discuss other economic benefits which might be attributed to bus transportation for the Valley.

- Increased shopping opportunities for residents. Transit will provide transportation for residents who now must limit their shopping to specific stores, items, or services because of restricted mobility. Transit may expand accessibility and the opportunity for choice -- to take advantage of sales and greater variety of goods and services.

- Increased labor market for local employers. Several Valley employers have been concerned with how to fill selected, lower-salaried positions. The Lawrence Radiation Laboratory, Sandia Corporation, Hexcel, Veterans Administration Hospital, and the Valley Memorial Hospital specifically mentioned such recruiting problems in interviews held during the course of study.

- Bus service may reduce welfare costs by (a) providing access to more job opportunities for persons without automobiles, and (b) reducing the amount of transportation subsidy presently required. The Alameda County Welfare case load attributable to the Livermore-Amador Valley accounts for $3,000,000 expenditures annually, including administration and case-worker salaries and expenses.

- Interstate 580 is a major commercial trucking corridor. Reduction of peak-period congestion can result in trucking cost savings.

4. Social Benefits

Transit is generally recognized to offer opportunities for social and environmental benefits which may justify selection of a particular transit alternative. Although social benefits are attributable to both the express and local bus systems, evaluation of potential benefits is more crucial to selection of a local system. On the basis of the benefit/cost analysis, alternative local bus systems do not generate sufficient economic savings to offset projected costs; however, consideration of social benefits indicates considerable benefit would accrue from the local system.

Although local bus service would be expected to serve only 1 percent of all trips in the Valley if it were instituted, these trips are made predominantly by persons with limited or restricted mobility. Public transit is desperately needed in the Valley as a means of transportation for these persons. Those who are unable to drive (senior citizens, young people, handicapped, or others without driver licenses), those who have no automobile at their disposal, and those who cannot afford to own and operate a vehicle would be principal users and beneficiaries of transit service. Public transportation in the community would offer these citizens opportunity for mobility and remove barriers which isolate or restrict their opportunities for participation and sharing in society's experiences.

Review of Valley demographic characteristics revealed that the mobility afforded by transit would primarily benefit the following non-mutually exclusive groups:

- Approximately 800 Valley families without an automobile, either because they cannot afford one or because no family member has an operator's license.

- About 19,000 youngsters too young to obtain a driver's license.

- An estimated 6,000 residents of driving age who have no licenses.

- About 3,400 senior citizens, many of whom are not physically able to drive.

- Approximately 5,500 persons in families earning less than $3000 in 1967.

These groups constitute a sizable segment of the Valley population. A bus system could provide increased opportunities to get to recreation centers, employment, doctors, day-care centers, shopping areas and to visit friends without dependence on friends or relatives for transportation.

The plight of the senior citizen and low income family is of particular concern to Americans today. Frequently senior residents who have lived their lives in the community and who own their homes and otherwise face a pleasant retirement suddenly find themselves physically unable to drive and unable to get around in the automobile-oriented community. The prospects of having to sell their home, relocate in new surroundings to be close enough to walk to essentialy services and being cut off from the greater accessibility they once had with the automobile is a significant readjustment. Some choose to relocate in other communities where a full range of shopping, recreational, health care and other opportunities are accessible by public transportation. Local transit service might eliminate the need for senior citizens to make such major adjustments at a point in their lives when relocation usually does not come easily.

Lower-income families, including a large number of elderly persons on fixed retirement incomes, are continually handicapped by the high costs of transportation associated with the automobile. These families are often compelled to pay inordinate shares of their limited budgets for automobile ownership and operation thereby restricting the sum available for housing, health care, and other services essential to the well-being of the family. High automobile costs also limit the lower-income family's ability to take advantage of the full range of shopping opportunities, employment opportunities, and housing choice. Better transportation could reduce transportation costs for lower-income families, permitting them to allocate a greater share of their budgets to housing, health care, etc. and to choose consumer goods, jobs, and housing from an expanded market place.

Comparisons among the bus plan alternatives reveal a definite optimum level of service for meeting the needs of senior citizens, lower-income families and other limited-mobility persons. Table 6-7 indicates how the extent of bus coverage critically affects the percentage of captive-rider residences and trip destinations served. With the few bus routes provided in System IV, it is not possible to serve most of the residences and destinations. When the number of bus routes is increased to the level of System III, however, service to limited mobility groups is substantially improved. The increased number of bus routes provided by System I and II does not offer greatly improved coverage of the community and hence, does not significantly improve service to senior citizens and lower-income families. Therefore, System III appears to be the most effective system for meeting needs of limited-mobility groups.

Sixty-minute headways are recommended rather than 30-minute service for two principal reasons: (1) the patronage increase associated with the 30-minute service does not indicate increased benefits would be proportionate to increased costs; and (2) review of the requirements of the principal transit user groups indicates less frequent service will meet mobility objectives reasonably well for substantially less cost. Local transit usage will constitute only 1 percent of all trips made locally. It is economically infeasible to operate at 5- to 10-minute bus headways necessary to make measurable inroads on automobile ridership. Consequently, the predominant riders of the local bus system will be those unable to drive because of age, health, or lack of a driver's license or an automobile at their disposal. Discussions with Valley public officials, recreation departments, senior citizens organizations, major employers, and members of the League of Women Voters indicate that, however desirable a 30-minute service might be, reduction to 60-minute service will not impair utility of transit service. Also, other factors such as just having some bus service available, being able to get where you want to go, coverage of the community, and adherence to schedule are more important concerns of the potential users.

General experience in the transit industry indicates about a 20 percent difference in patronage due to a 30-minute versus a 60-minute bus headway in low-density areas. Twenty percent increase in patronage and resulting revenue is far overshadowed by a 100 percent increase in cost to provide 30-minute service. Discussion with community groups indicates no major difference between social benefits derived from 30- and 60-minute service. Initiation of a basic minimum level of local tansit service would produce greatest benefit. Sixty-minute headways on System III will be the most cost-effective way to meet the objective of assisting persons with restricted mobility.

Table 6-7. Comparison of Social Benefits from Local Transit Service Alternatives

Transit System	Service Frequency	Per Cent Served					
		Study Area Population	Employees	Senior Citizens	Lower-Income Families[a]	Activity Centers[b]	Captive Riders[c]
I	60 Minutes	77	2	90	90	95	90
II	60 Minutes	72	2	90	90	95	90
III	60 Minutes	60	2	90	90	90	85
	30 Minutes	60	2	90	90	90	85
IV	60 Minutes	45	1	60	70	60	50
	30 Minutes	45	1	60	70	60	50
	20 Minutes	45	2	60	70	60	50

(a) As measured by rent level.
(b) Includes centers for senior citizens, lower-income families, and youth.
(c) Percentage of captive riders able to use transit to reach their destination is the product of accessibility of transit to captive riders and accessibility of transit to activity centers. Assumes that activity centers served are twice as likely to be captive rider destinations as centers not served.

Source: De Leuw, Cather & Company

The fundamental question concerning social benefits from transit service is the extent to which Valley residents wish to assist persons with restricted mobility. Results of the employee survey at Lawrence Radiation Laboratory (LRL) and Sandia Corporation indicate residents support public transportation for all potential transit user groups, but particularly for the elderly.

Potential Transit User Groups	Percent Respondents Believing Transit Needed in the Valley for User Group
LRL or Sandia employees	71
Elderly persons	81
School children	51
Lower-Income families	61
Housewives	54
Commuters into and out of Valley	73

The survey results were interpreted to indicate social concern for transportation needs of senior citizens and belief that transit would be effective for meeting needs of the elderly. Strong support for public transportation to assist employees and commuters was judged to be motivated primarily by economic or environmental rather than social concerns, although the use of bus service to get to work would make a car available at home for midday trips by housewives or for chauffeuring children.

5. Environmental Benefits

Reduced automobile usage, reduced air pollution, and ability to structure urban growth and thereby retain cultural and environmental amenities are benefits frequently ascribed to urban transit systems. The ability to make inroads on the automobile and to structure urban growth are definitely within the capability of regional rapid transit systems, but the degree to which such benefits can be attributed to bus systems or bus systems working in combination with rapid transit demands further investigation.

Although air pollution is a major concern to the San Francisco Bay Area region and particularly to Valley residents, monetary value attributable to reduced air pollution cannot be reliably quantified. Table 6-8 indicates reduction in major air contaminants which might be expected with express bus service. A 3 percent reduction in commuter vehicle usage in and out of the Valley yields about 1 percent reduction in the total vehicle miles drive in the Valley and at least a 1 percent

Table 6-8. Express Bus Operations Annual Reduction in Air Pollution

Contaminant	Pollution Description	Decreased Automobile Pollution: 1970 Gasoline Emission (pounds/1,000 gallons fuel)	Decreased Automobile Pollution: Contaminants Eliminated Annually[a] (pounds)	Bus Pollution Contributed: 1970 Diesel Emission (pounds/1,000 gallons fuel)	Bus Pollution Contributed: Contaminants Added Annually[b] (pounds)	Net Annual Change in Contaminants (pounds)
Organic Gases	Enters into photo-chemical process to form smog	378	124,000	20	2,000	122,000 decrease
Nitrogen Oxides (as NO_2)	Enters into photo-chemical process to form smog	158	52,000	120	12,000	40,000 decrease
Carbon Monoxide	Poisonous in quantity	2,070	677,000	30	3,000	647,000 decrease
Particulates	Visible Particles	12.4	4,100	184	18,400	14,300 increase
Sulfur Dioxide	Offensive small; affects plants in quantity	7.8	2,500	50	5,000	2,500 increase

(a) Based on 4,900,000 vehicle miles eliminated by express bus service (estimated annual patronage times average trip length of 10 miles) and an average fuel consumption of 15 miles per gallon. Assumed vehicle occupancy was 1.0. No adjustment was made in pollution due to reduced traffic congestion.
(b) Based on 500,000 annual bus miles and an average fuel consumption of 5 miles per gallon.

Source: Bay Area Air Pollution Control District

reduction in pollution created by motor vehicles. (Reduction in air pollution was assumed to be proportional to the reduction in miles driven although traffic congestion decrease could decrease pollution more than the reduced mileage would indicate.) When this reduction is grouped with effects of other pollution sources besides the automobile and viewed on a metropolitan basis, the net effect of express bus service on air pollution would be minimal.

It is doubtful whether the express bus system would significantly influence land development along prescribed routes. The existence of express routes may encourage new Valley residents to locate within walking distance of the routes to take advantage of commute bus opportunities. This, in turn, might encourage developers to locate apartments near express bus stops -- particularly near central terminals with frequent peak-hour bus service -- to capture the young commuter market. However, potential impact of the express bus system on the structure of the overall community would not be great.

Reducing automobile usage and air pollution and structuring urban growth were found to be outside the capability of any of the conventional local transit alternatives. Each alternative bus system would only be able to attract 1 percent of all local trips which is insufficient to accomplish the indicated objectives. Without very frequent bus headways and extensive route coverage (which are outside the financial capability of the Valley), without a higher density of land development than the Valley now has, or without introduction of rapid transit to the Valley, regularly-scheduled public transit alternatives would not effectively reduce automobile dominance or influence the form of urban growth. The Valley consists of single-family homes on relatively large lots. Traffic patterns are dispersed with shopping, employment, recreation and other activities spread over the entire community. Community facilities, homes, and places of employment are not clustered in a pattern which is conducive to conventional transit service. The scattered locations of the Veterans Administration Hospital, Springtown Retirement Village and the proposed South County Campus of Chabot College are illustrative examples; all attest to decisions which favor and reinforce automobile use and make public transportation service difficult to provide economically. For the present and foreseeable dispersed pattern of Valley development, regularly scheduled bus service may eliminate total dependence on the automobile, but it will not achieve significant replacement or substitution for private vehicles.

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7.0 GOVERNMENT ORGANIZATIONS AND TRANSPORTATION FUNDING MECHANISMS FOR THE SAN FRANCISCO BAY AREA

Among the most important factors to be considered in the development and implementation of any proposed control measures are the institutional constraints. As in any large metropolitan area, there are a multiplicity of agencies and layers of government which will be impacted directly by many of the contemplated controls. For the proposed control strategy to be successfully implemented, it will be essential to enlist the cooperation of the many agencies involved. A necessary first step is therefore an understanding of government organization within the Bay Area, especially as it relates to transportation planning and services.

This chapter attempts to briefly outline what agencies are involved in providing transportation planning and services, what the function and purpose of the agencies are, and how the various agencies are related in the overall governmental organization. In addition, a discussion is made of transportation funding mechanisms within the Bay Area. As discussed previously, several of the control measures evaluated which incorporate significant improvements in public transit -- additional buses or lowered fares -- will require additional sources of revenue. It is uncertain at this time where such additional funds could be obtained, if they could be obtained at all. It is certainly recommended that these questions be adequately addressed before embarking on measures which are technically feasible but which may be institutionally or financially difficult to implement.

7.1 REGIONAL AGENCIES

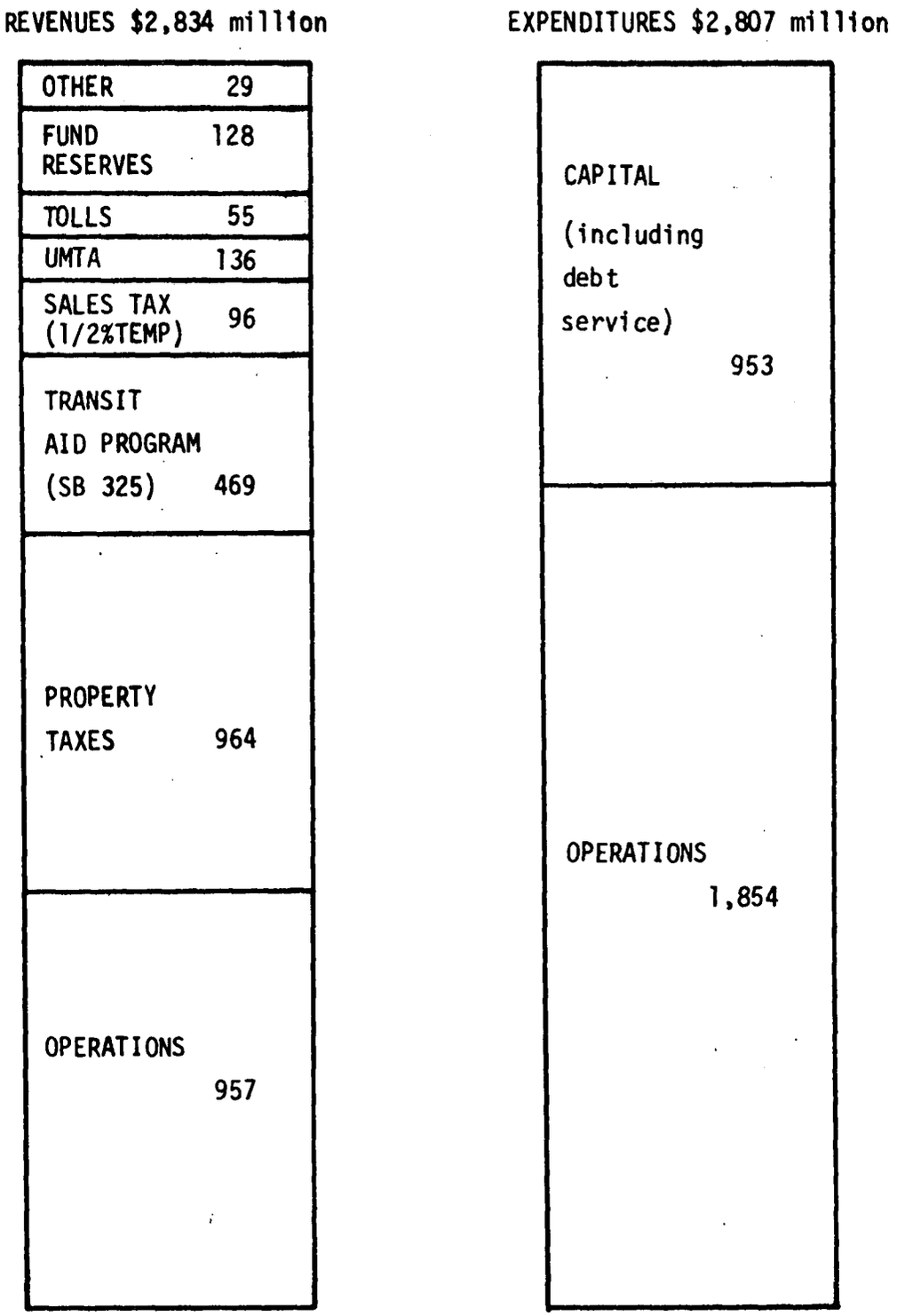
The Bay Area has been experimenting with regional government for almost 30 years. Though probably further along in the development of regional government than most areas of the country, many local political obstacles and conflicts must be resolved before total regional government becomes a reality. The following is a rudimentary list of agencies and organizations that should be dealt with when considering transportation control measures for the Bay Area.

- Bay Area Council (BAC) - Formed in 1945, the BAC is a highly influential voluntary organization supported by business and industry, and leaders in government, civil affairs, labor, and education. The Council concerns itself with regional matters including transportation, land use planning, air and water pollution control, recreational development, and economic advancement. BAC facilitates these concerns by gathering coordinated statistical data, developing informational publications, and lobbying at the State and local level. The BAC was instrumental in persuading the State Legislature to establish the Bay Area Air Pollution Control District (BAAPCD) in 1955 and the Bay Area Rapid Transit District (BART) in 1957.

- Association of Bay Area Governments (ABAG) - ABAG, formed in 1961, is a voluntary association representing the approximately 125 city and county governments of the nine county Bay Area. The organization has no formal powers except to review applications for federal funds for consistency with regional plans (A 95 review process), but it is generally recognized as the Bay Area's comprehensive planning agency.

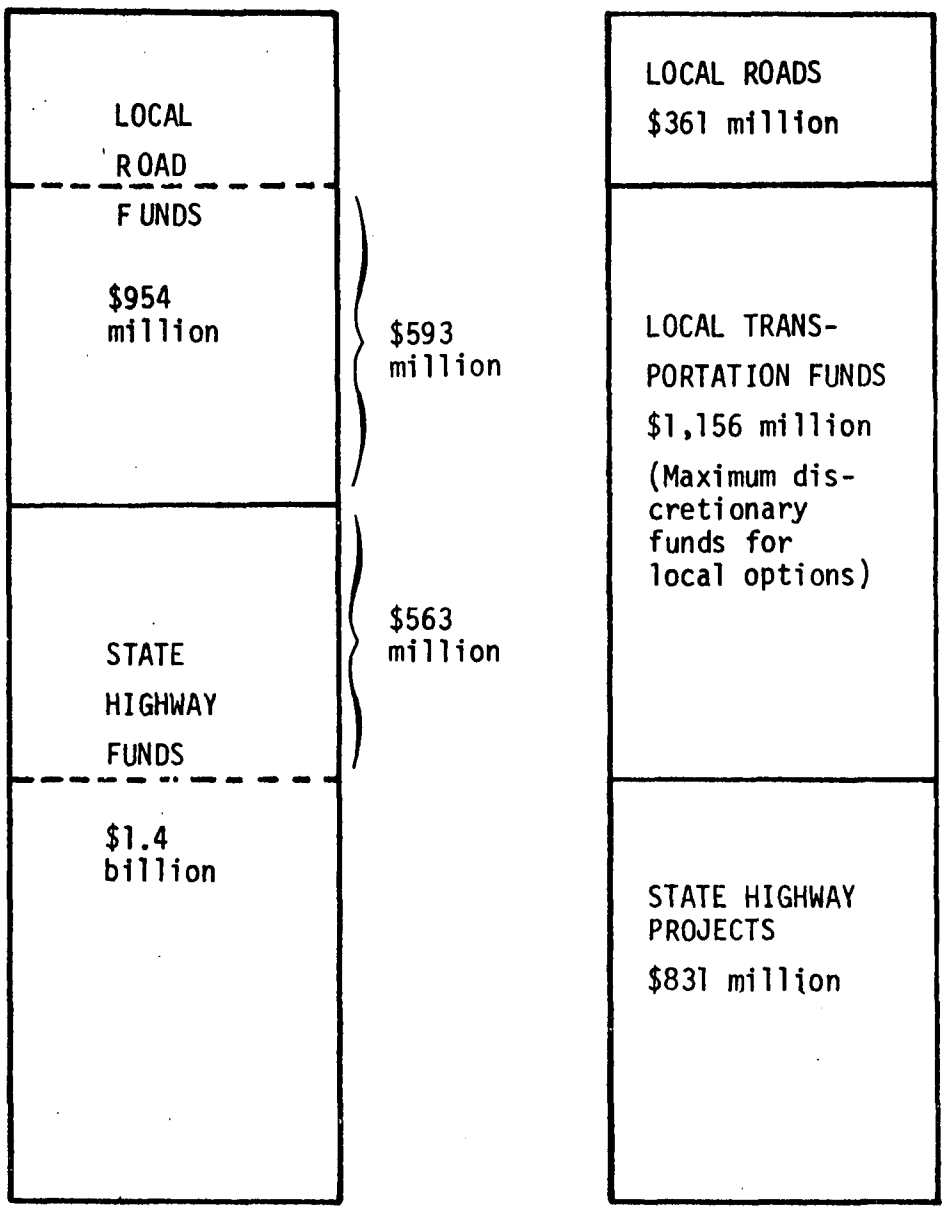
- San Francisco Bay Conservation and Development Commission (BCDC) In 1965, BCDC was established by the California Legislature (McAteer-Petris Act). The BCDC has the legal power to grant or deny permits to fill or dredge the Bay, or develop the shoreline within 100 feet of the water's edge.

- Metropolitan Transportation Commission (MTC) - In 1970 the legislature established the MTC as the Bay Area regional transportation planning agency. Its first task is to prepare a regional transportation plan which is due to be adopted by June 30, 1973. Once the plan is adopted, MTC will have the authority to review and approve new transbay bridges (with the exception of the Dumbarton Bridge), and public multi-county rapid transit system, and any state highway construction in the region. Furthermore, any transportation project or operation using federal or state



Source: MTC Regional Transportation Plan, Section IV

Figure 7-1. Bay Area Public Transit Funds for Existing and Committed Systems (1974-1983)



TOTAL FUNDS AVAILABLE FROM ALL HIGHWAY SOURCES: $2.35 BILLION (1974-1983)

Source: MTC Regional Transportation Plan, Section IV

Figure 7-2. Bay Area Highway Funds with Potential Discretionary Funds

funds must be found compatible with the regional transportation plan. In 1971 the legislature authorized MTC to review public transit projects financed by the state gasoline tax, even before adoption of the regional plan (i.e., SB 325 monies). Even though ABAG has full review power over federal transportation grants, it has agreed to consult MTC in reviewing applications.

Figures 7-1 and 7-2, taken from Section IV, "Financial Plan and Priorities Program," of the proposed MTC regional plan, illustrates how the financial plan is geared towards public transportation. The MTC is committed to reducing the region's dependence upon the automobile and hence VMT. However, the planning time horizon for the MTC is 1985 rather than EPA's 1975. It should also be recognized that the MTC is strictly a planning agency; it does not get involved in any operational functions.

7.2 SUB-REGIONAL AND LOCAL TRANSPORTATION OPERATORS

A variety of sub-regional and local transportation agencies, both public and private, operate within the Bay Area. These agencies, their responsibilities and operations, are summarized below:

7.2.1 Public Agencies

- Division of Bay Toll Crossings (BTC) - This state agency is responsible for operations of the San Francisco-Oakland Bay Bridge, San Mateo Bridge, and Dumbarton Bridge. Tolls generated from these bridges go towards paying off deep on these bridges plus the BART transbay tube and the new Dumbarton Bridge (if built).
- Carquinex Bridges (2) - The governmental organization for the bridge is similar to BTC. It is also noted that the Richmond-San Rafael Bridge is presently strictly a state bridge.
- BART - BART is comprised of a 75 mile rail rapid transit system serving the counties of San Francisco, Alameda, and Contra Costa. The system is projected to be fully operational by

September 1973. Revenues are projected to meet operating expenses. Other sources of capital and operating funds include:

1) SB 325 (Deddeh-Mills Alquist Bill) - approximately 25 percent of San Francisco County's allocation and 50 percent of Alameda and Contra Costa Counties' allocation,
2) Division of Bay Toll Crossing (tube construction),
3) General obligation bonds supported by property taxes in the three counties ($.25 per $100 assessed valuation),
4) Sales Tax Revenue Bonds (1/2 percent in affected counties), and
5) Federal and state transportation grants for capital construction.

- San Francisco Municipal Railway (Muni) - Rail and bus transit for the City and County of San Francisco. Operating 50 percent from the fare box, 50 percent from property taxes, and SB 325. Costs of maintaining the electrical system for streetcars and trolley coaches is underwritten by Hetch Hetchy, the City's power and water agency.

- Golden Gate Bridge/Highway and Transportation District (GGBHTD) - The district has been given authority by the legislature to operate and control all transportation across the Golden Gate between San Francisco and district counties to the north. The district presently meets operating expenses for services between San Francisco and other counties from revenues from the bridge, buses and ferries although only the bridge makes money. The district operates buses in three Bay Area counties--Marin, Sonoma, and San Francisco. The GGBHTD recently proposed to raise auto and transit tolls to support the bus and ferry system. The issue has yet to be resolved but it appears that public opposition exists to raising both tolls and fares. The district also operates intra-county service in Marin County under agreement with Marin County Transit District. Local transit services are underwritten by a 5 cent property tax and SB 325 funds.

The district presently meets operating expenses for service between San Francisco and other Counties from revenues from the bridge, buses and ferries although only the Bridge makes money.

- Alameda-Contra Costa County Transit District (AC Transit) - Bus transit system serving Alameda and Contra-Costa counties west of the East Bay Hills. Presently operating extensive transbay service (i.e., until BART starts transbay service). Revenues are derived from about one third taxes and two thirds from fare box and other operating revenues.
- Santa Clara County Transit District - Commenced operations January 1, 1973, taking over former San Jose and Palo Alto transit operations. An expansion is planned. Farebox and SB 325 underwrite operating cost; no local tax support is possible under existing District enabling legislation.
- San Mateo, Napa, Sonoma, and Solano Counties - All these counties are planning for local (intra-city, possibly county-wide) transit (primarily bus) systems in the future. They will probably raise operating revenue from SB 325, the farebox, and perhaps a small local property tax.

In 1972, approximately $150 million was spent for operating public transportation in the Bay Area. Of this amount, approximately one half came from the fare box and the other half was raised from taxes and use of reserves.

7.2.2 Private Agencies

- Southern Pacific Railroad (SPR) - The SPR loses about $4 million on commuter service annually and shows little interest in making it profitable. A great deal of controversy centers around whether BART should be extended down the Peninsula or whether the Southern Pacific service should be upgraded.

- Greyhound Bus Company - Greyhound presently operates transbay, Vallejo and Peninsula service on a commuter basis. The transbay service will be terminated when BART becomes fully operational.

7.3 BAY AREA TRANSPORTATION FUNDING MECHANISMS

At the present time, transportation in the Bay Area is one of the most advanced multi-modal systems in the country. The current transportation plan for the Bay Area has been estimated to cost $12 billion to construct and about $5000 million per year to operate by 1990. Though the Bay Area has yet to institute a regional transportation operating agency (and may never do so), the MTC is the regional transportation planning agency.

As mentioned previously, the MTC's authorizing legislation required it to write a regional transportation plan and submit it to the appropriate executive branch (probably the new California Department of Transportation) by June 30, 1973. One of the sections of the MTC's plan directly addresses the sources and uses of transportation funds for the Bay Area. The remainder of this discussion will be a summary of Section IV, "Financial Plan and Priorities Program" of the MTC proposed Bay Area Regional Transportation Plan.

7.3.1 Sources of Revenue (1974 to 1983)

Sources of revenue for transportation in the Bay Area are as follows:

- Federal-State Highway Funds - The total California highway funds are estimated to be as follows:

Vehicle registration fees	$ 960 million
Fuel tax	9,168
Federal aid	5,400
Ten Year Total	$15,528 million

Historically, the Bay Area has received approximately 15 percent of this total. Thus, about $2.35 billion will be available from highway funds. Figure 7-2, shown previously, indicates the funds and their potential distribution to local transportation

options. $1,192 million is available exclusively for road purposes and no more than $1,156 million could become available for discretionary use from federal aid and local support.

- Bay Area Bridge Tolls (not including Richmond-San Rafael Bridge) - After meeting all other obligations net $55,000,000.

- Transit Revenue

Transit Aid Program (SB 325)	$ 468.8 Million
Property Tax Funding	963.8
Sales Tax (Currently BART only and through 1976 only)	96.5
Operations	967
Federal Transit Aid - Urban Mass Transportation Administration (UMTA)	136
Local Funding Reserves	128
Other	29

- Additional Potential Sources of Transit Revenue

Double Bridge Tolls	$ 348.6 Million
Transit Fare Increase (e.g., double fare)	505.5
Sales Tax (all counties @ 1/2 percent)	976.8
Property Tax (all counties @ $.25 per $100 assessed valuation)	521.5
One Cent/Gallon Gas Tax	261.9
Federal Aid - Potential UMTA Funds	588
Bonding - Bridge Tolls	180-290
- General Obligation on Property Tax	770
- Revenue Bonds	
a) Sales Tax	1,235
b) Gas Tax	360

7.3.2 Uses of Revenues

Revenue for the Bay Area is used as follows:

- Present Commitments and Existing Systems

A. Highways	$ 1,330 Million
B. Public Transit	
1. Operations	1,854
2. Capital (including debt service)	953

- Proposed Additional Needs

Local Service	Ten Year Total
Operating Deficit	333 Million
Capital Costs	160
LOCAL TOTAL	493

Trunkline Transit	
Operating Deficit	256 Million
Capital Costs	1,540*
TRUNKLINE TOTAL	1,796
COMBINED TOTAL	$2.3 Billion

*Total to 1983. Grand total for 1990 estimated at $4,780 million

8.0 STRATEGY IMPLEMENTATION

This section deals with the implementation of the control strategy proposed in this report. Discussion is confined to two areas: the procedure and time schedule for implementation of the strategy and the responsibilities of the government agencies which will be involved in the implementation of the proposed strategy.

8.1 PROCEDURE AND TIME SCHEDULE

The proposed time schedule for implementation of the control strategy is given in Table 8-1. The dates shown for promulgation of the plan are those prescribed by federal law. Legislative authority for the recommended Phase I measures must be obtained by the end of 1973; gasoline rationing legislation should be obtained by the end of 1975.

As the table indicates, all gasoline marketing facilities should be controlled to the extent recommended by mid-1975. That is, existing facilities should be retrofit with appropriate control systems by that date, and all new facilities built after that date should be required to include control systems in their construction.

A development program for substitutes for organic surface coating compounds is currently underway and should be continued indefinitely. The use of less reactive substitutes should be expanded, beginning in 1974. Carbon absorption systems effective to the degree recommended in this study are currently available and should be installed at all dry cleaning establishments during 1974. Likewise, available substitutes for organic degreasers should be implemented during 1974. Burning regulation, to some degree, has already been instituted by the county APCS's. The additional regulation recommended in this study should be in effect through 1980.

The three vehicle-oriented control measures are mandatory inspection/maintenance, oxidizing catalytic converter, and pre-1966 retrofit device. The first part of the inspection/maintenance program, the idle test with the 10 percent rejection rate, should be carried out during 1975 and 1976. This means that all light duty vehicles should be inspected (and 10 percent should be maintained) during the year 1975 and again during 1976. In 1977

Table 8-1. Proposed Implementation Time Schedule

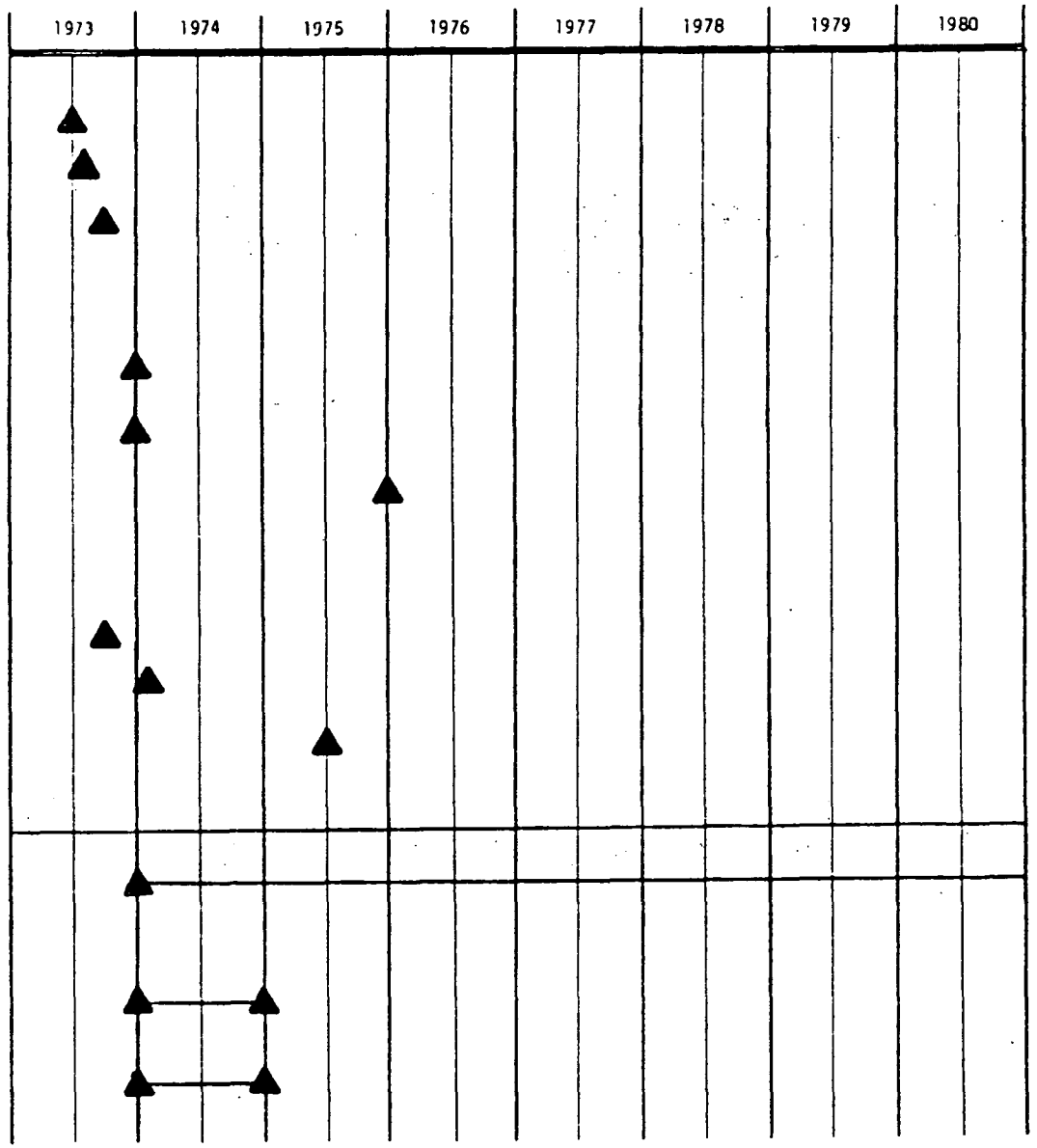


Table 8-1. Proposed Implementation Time Schedule (Continued)

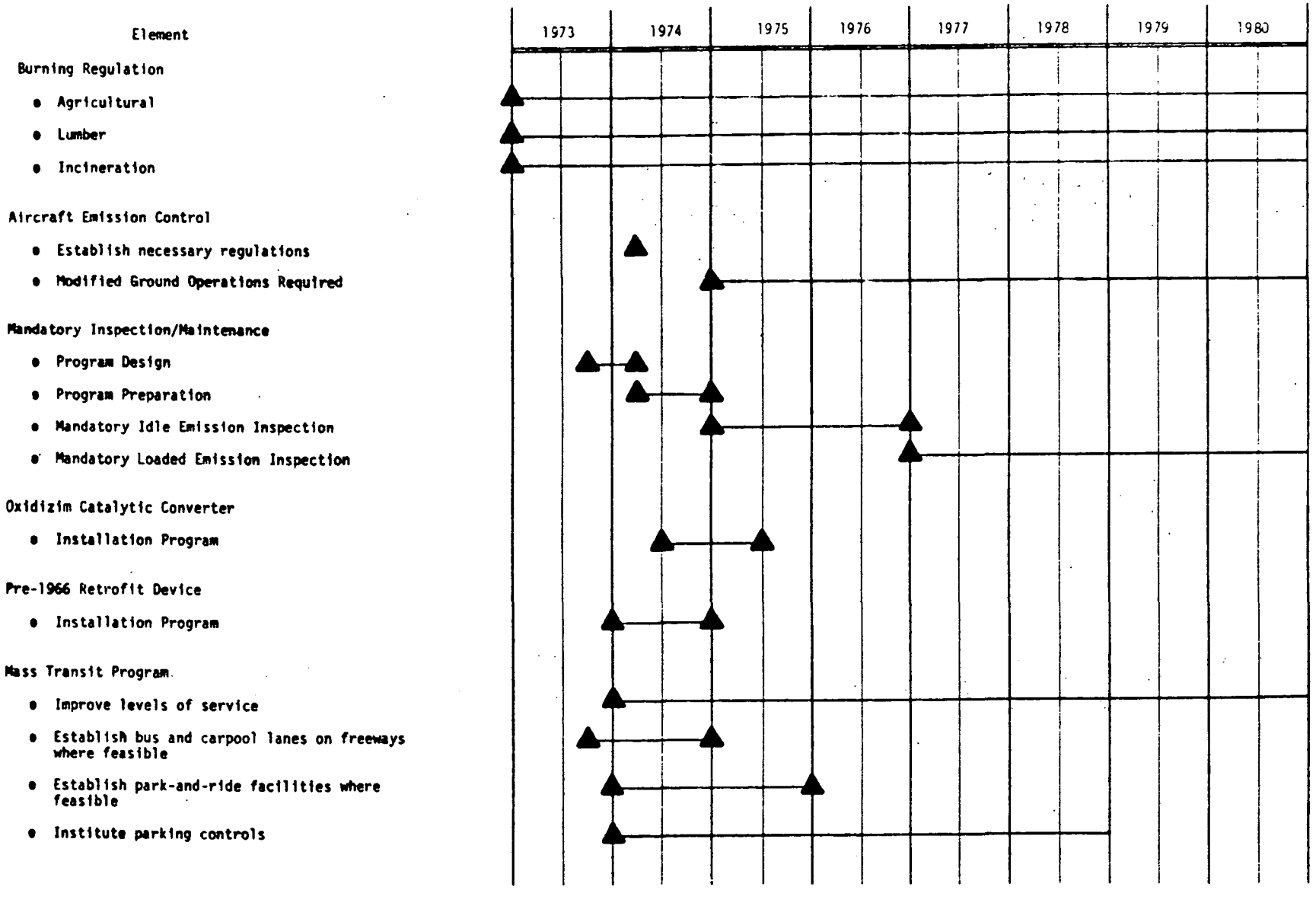
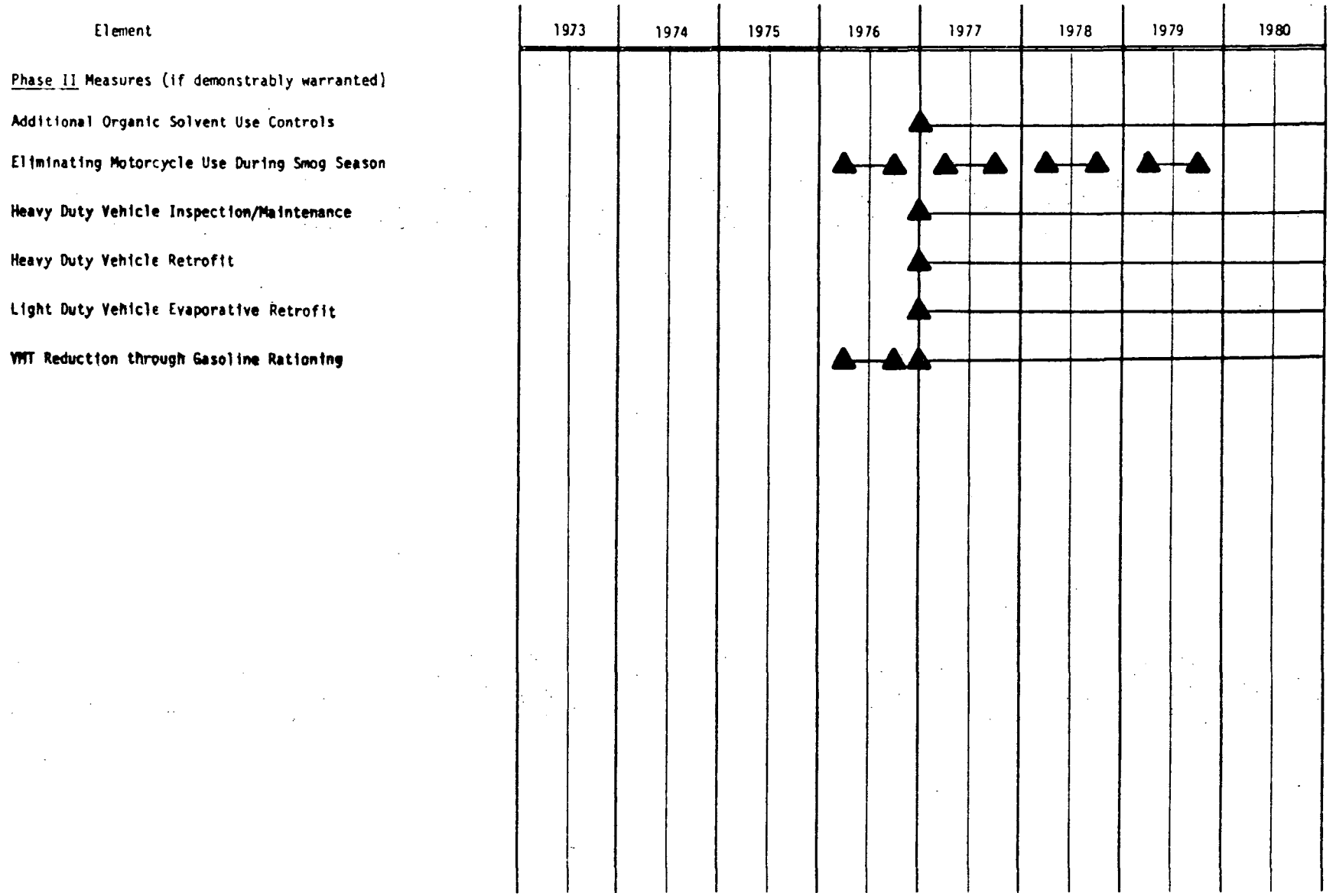


Table 8-1. Proposed Implementation Time Schedule (Continued)



and every year thereafter, all light duty vehicles could be inspected using a loaded test, and 50 percent of them should be required to receive maintenance. The installation of the oxidizing catalytic converter should take place between mid-1974 and mid-1975. The pre-1966 retrofit device should be installed during 1974.

The transportation system-oriented measures recommended for implementation should begin in 1974 and continue through 1980. It is recommended that an aggressive public information program be instituted in 1974 to encourage and advertise increased use of carpooling. Carpooling should be corrdinated among employees at work centers beginning in mid-1974. Construction of parking facilities should be limited as soon as possible, preferably by the end of 1973. Long-term parking rates should be increased by the middle of 1974.

All Phase II measures should be implemented by 1977 if it is demonstrated that they can be effective and that they are necessary. The elimination of motorcycle use during smog season and gasoline rationing involve relatively difficult institutional and administrative problems and should be begun in 1976 so that these kinds of problems are obviated by 1977 for maximum effectiveness of the measures in that year.

8.2 AGENCY INVOLVEMENT

Table 8-2 gives the agency responsible for the implementation of each of the control measures recommended in this study. The sections of the California Health and Safety Code which provide the respective agencies with the authority for implementation of the measures are listed in the table also. It can be observed that the county APCD's have the authority to implement all recommended stationary source controls. All that remains in each case is for the Air Pollution Control Board of each agency to pass or modify appropriate rules and regulations for use within each of the counties.

Vehicle-oriented mobile source controls, on the other hand, require new legislation, with the one exception being the pre-1966 retrofit device. This device is already required in San Francisco. Effective devices of this type have, of course, been accredited by the CARB.

Table 8-2. Agency Responsibility for Control Measure Implementation

Measure	Responsible Agency	Authorizing Legislation (Sections of California Health and Safety Code)
Phase I		
Stationary Source Controls:		
Gasoline marketing evaporative loss control	APCD	24260, 24260.1
Dry cleaning vapor control	APCD	24260, 24260.1
Degreaser substitution	APCD	24260, 24260.1
Organic surface coating control	APCD	24260, 24260.1
Mobile Source Controls:		
Mandatory inspection/maintenance	CARB	TBL*
Oxidizing catalytic converter	CARB/APCD	TBL*
Pre-1966 retrofit device	APCD	24263.8
Transportation System Controls and Improvements	County/City Government	
Phase II		
Stationary Source Controls:		
Additional organic solvent use controls	APCD	24260, 24260.1
Mobile Source Controls:		
Eliminating motorcycle use during smog season	CARB	TBL*
Heavy duty vehicle inspection/ maintenance	CARB	TBL*
Heavy duty vehicle retrofit	CARB/APCD	TBL*
Gasoline rationing	CARB	TBL*
Evaporative retrofit device	CARB/APCD	TBL*
Additional retrofit devices	CARB/APCD	TBL*

*To be legislated

Authorizing legislation must be passed for the other two vehicle-oriented measures. The CARB will be responsible for the mandatory inspection/maintenance program, while, if the oxidizing catalytic converter is required in only part of the APCD's of the state (as is likely), it will be the responsibility of each APCD to implement necessary rules, and, therefore all APCD's must have the authority by state law to implement the measure. Thus, two types of legislation must be passed for implementation of the catalytic converter measure: state legislative authority and APCD rules, pending, of course, CARB accreditation of catalytic converter devices.

Transportation system controls and improvements in Phase I do not involve the requirement for major-authorizing legislation. In each case, it will require the appropriate division of the local city and county governments to implement or modify regulations and to impose, where necessary, procedural constraints and encouragements.

Stationary source measures in Phase II, as in Phase I, require no additional authorizing legislation. On the other hand, mobile source controls in Phase II all must be legislated. All will likely be at least the partial responsibility of the CARB, although like the catalytic converter, it is likely that the legal requirement for the three retrofit measures in Phase II will actually be the authority of each APCD and that each APCD will have the responsibility, after accreditation of hardware by the CARB, to implement the measures in its jurisdictional area. It is assumed for the present that gasoline rationing will be within the authority of the CARB, although the actual legal requirements of this controversial measure are vague.

9.0 OBSTACLES TO IMPLEMENTATION

The relative significance of obstacles to implementation of the proposed control strategy described in Section 8.0 has been estimated using the following definitions of obstacle categories:

- Technical obstacles - obstacles involving the design of hardware, details of administrative procedure, or specification of standards or acceptance limits necessary for implementing recommended control measures

- Political obstacles - obstacles involving the feasibility of productive interaction among appropriate leaders, administrators, legislators, and special interest groups for the purpose of instituting recommended control measures.

- Institutional obstacles - obstacles involving the opposition of institutions required by the plan with those already in existence and necessary adjustment thereof.

- Legal obstacles - obstacles involving writing and passing laws, rules, and regulations required for instituting and administering control measures.

- Socio-economic obstacles - obstacles involving the impact of control measures on the public, commerce, and industry.

9.1 PHASE I MEASURES

9.1.1 Stationary Source Control Measures

9.1.1.1 Gasoline Marketing Evaporative Loss Control

This control may meet minor legislative and socio-economic obstacles. Necessary laws and regulations are easily specified since there is a large backlog of feasibility studies and investigations involving this measure and since several APCD's in the state have already instituted requirements for a similar measure and can serve as a model. There should be very little socio-economic impact because of this measure. The cost of changes in gasoline refining and marketing will indeed be passed on to the consumer, but the actual cost increase per gallon should be small. Public convenience should be little affected; consequently, minimal adverse public reaction is expected for this measure. The design and development of hardware for evaporative control systems at the filling station and on tank trucks may

be a moderate technical obstacle. These technical obstacles must be met by the oil companies in California since it will be their responsibility to select appropriate methods for meeting the proposed standards for gasoline evaporative control. As a result, their reaction to the proposal for the evaporative emission control measure is expected to present a moderate political obstacle to implementation.

9.1.1.2 Organic Surface Coating Substitution

This measure should encounter no political or institutional obstacles. It will encounter some technical obstacles in that substitutes such as water-based coatings, high solids content coatings, and powdered coatings are currently under development and require lengthy testing before promising formulas can be used commercially. A minor legal obstacle is anticipated in writing rules which require the recommended degrees of control by 1975 and 1977. Small changes in the price of the product may create minor socio-economic obstacles.

9.1.1.3 Dry Cleaning Vapor Control

The principle of carbon absorption has been proven as an effective means of controlling evaporative losses of solvents from dry cleaning, and the required hardware is available. Thus, no technical obstacles are anticipated. The local APCD's have the authority to implement such controls, and no institutional obstacles are expected. The only legal obstacle to overcome is the appropriate local rulemaking, and it should be minor. No political or socio-economic obstacles are expected.

9.1.1.4 Degreaser Substitution

Acceptable non-reactive substitutes for current degreaser solvents exist and should encounter no major obstacles to implementation by 1975. Rulemaking may present a minor legal obstacle.

9.1.1.5 Burning Regulations

Burning restrictions have already been instituted to some degree, and it is anticipated that more extensive regulation will not meet significant obstacles.

9.1.2 Mobile Source Control Measures

9.1.2.1 Aircraft Emission Controls

This control measure should encounter only minor political and socio-economic obstacles; however, technical and institutional obstacles may be more severe. The emission controls for new and in-use aircraft engines will have major technical obstacles. The ground operation modification elements of the measure may encounter moderate institutional obstacles with FAA and the affected airport authorities. Negative responses by pilots to the measure are not anticipated.

9.1.2.2 Mandatory Inspection/Maintenance

Part I - Idle Test, 10 Percent Rejection Rate. Part I of this measure is technically simple and requires little more developmental or design effort than has already gone into the random state lane inspection already in existence in California. No institutional obstacles are anticipated since the Department of Motor Vehicles can include inspection/maintenance certification as part of vehicle registration requirements much as it does with retrofit devices. Furthermore, this measure should encounter few legal or political obstacles if a bill requiring inspection and maintenance in the South Coast Air Basin (Assembly Bill 380) passes both houses and is signed by the Governor. Legislation remains a potential obstacle since four similar bills in 1972 and 1973 have not passed the legislature and the administration. Socio-economic obstacles should be minor.

Part II - Loaded Test, 50 Percent Rejection Rate. Obstacles for Part II of this measure will be similar in nature to those expected for Part I, but of larger magnitude. This testing method is more involved and time-consuming than the method in Part I and will require more effort directed toward technical development, design, instrument assembly, and shelter construction. Legal obstacles will consequently be significant, and socio-economic obstacles will probably be greater because of the higher cost and greater inconvenience for the vehicle owner.

9.1.2.3 Oxidizing Catalytic Converters

Major technical obstacles are involved in the implementation of this retrofit measure by 1975. These obstacles are because of several technical weaknesses in current catalytic converter designs. Further development and

testing are required but would not be possible if implementation is to occur by the required dates. The converters will be relatively easy to install, but they must be replaced periodically (between 25,000 and 50,000 miles) and unleaded fuel must be used. Furthermore, the converter is costly as compared to other retrofit devices. For older vehicles, the converter is as costly as compared to the value of the auto. As a result, major socio-economic, political, and legal obstacles are anticipated for this measure.

9.1.2.4 Pre-1966 Retrofit Device

Since exhaust control devices incorporating vacuum spark advance disconnect are already required for these model years in the South Coast, San Diego, and San Francisco Air Basins, this measure will not encounter any significant obstacles to implementation. VSAD is neither costly or complicated, but it is effective and should meet a minimum of social and political opposition.

9.1.2.5 Mass Transit

Mass transit improvements should meet no institutional or legal obstacles, but there will be significant technical, political and socio-economic difficulties to be overcome. Technical obstacles will involve the system design and fare structure of the improvements. Socio-economic obstacles will result from the actual design of the system and the funding mechanism for its institution. Political opposition will depend on how well and in what way the other two major obstacles are met. The funding aspects are expected to be the most controversial portions.

9.2 PHASE II MEASURES

9.2.1 Stationary Source Control Measures

9.2.1.1 Additional Organic Solvent Use Controls

Any additional controls on organic solvent use will encounter major technical and political obstacles and at least minor institutional, legal, and socio-economic obstacles.

9.2.2 Mobile Source Control Measures

9.2.2.1 Elimination of Motorcycle Use During Smog Season

This measure will encounter few technical obstacles, but political and legal obstacles will be quite significant, considering the popularity of

motorcycles in California (especially during the summer) and the potentially significant political strength of motorcycle manufacturers and enthusiasts. There will be moderate socio-economic obstacles because of the recreational and personal values of motorcycle riding, and enforcement will be an institutional problem.

9.2.2.2 Inspection/Maintenance and Retrofit Devices for HDV

Inspection/maintenance procedures for heavy duty vehicles have been developed and tested in only a few areas of the country (New York State, for example); the potential exists for major technical obstacles to implementation in California. Minor political, institutional, legal, and socio-economic obstacles are also expected. Obstacles to implementation of a retrofit program for heavy duty vehicles are expected to be very similar to those described for inspection/maintenance.

9.2.2.3 Evaporative Retrofit Device

Major technical, political, legal, and socio-economic obstacles are anticipated for implementation of an evaporative retrofit program. Although devices for pre-1970 vehicles have not yet been developed, it is expected that they will be costly compared to the value of the vehicle and that installation will not be simple.

9.2.2.4 Gasoline Rationing

A large-scale VMT reduction through gasoline rationing would be extremely difficult to implement. Since nearly everyone would be affected, opposition can be expected on all fronts. Because of the potential severity of the measure, the political, institutional, and socio-economic obstacles will be so great that they are likely to force a re-evaluation of the overall program objectives and constraints.

9.2.2.5 Additional Retrofit Measures

It is expected that additional retrofit measures beyond those specifically recommended in this study will encounter major technical, political, institutional, legal, and socio-economic obstacles during implementation. Most of these additional devices are not cost-effective for application in this air basin and will meet significant opposition.

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APPENDIX A

AIR QUALITY DATA TRENDS, AND MONITORING STATIONS

Table A-1 provides a breakdown of air quality violations as experienced throughout the Bay Area during 1971 and 1972. These data illustrate the wide differences in air quality experienced in the various regional areas. The trend data for oxidant concentration in the San Francisco region is presented in Table A-2. The data show significant improvements during the most recent years. Figure A-1 is a map of the air quality monitoring sites currently taking air quality measurements within the region. Noted on the map are the types of stations at each site, e.g. partial or complete.

Table A-1. Air Pollution in the Bay Area (1971 - 1972)

Location of Stations	OXIDANT				CARBON MONOXIDE				NITROGEN DIOXIDE
	1971		1972		1971		1972		1971
	Maximum[1]	Violations[2]	Maximum	Violations	Maximum[3]	Violations[4]	Maximum	Violations	Annual Average
San Francisco	.19	2	.08	0	11	3	11.7	1	.027
San Rafael	.18	9	.17	5	8	0	7.7	0	.024
Richmond	.28	7	.12	7	13	1	9.1	0	.021
Pittsburg	.20	23	.19	25	6	0	5.1	0	.022
Walnut Creek	.23	36	.17	30	-	-	-	-	-
Oakland	.31	10	.12	1	11	2	7.2	0	.040
San Leandro	.36	21	.17	15	-	-	-	-	-
Fremont	.33	45	.34	44	9	0	6.5	0	-
Livermore	.23	52	.22	27	8	0	6.5	0	.025
San Jose	.15	14	.20	19	17	12	13.8	11	.034
Redwood City	.28	17	.28	17	7	0	9.2	0	.030
Burlingame	.17	5	.14	8	10	1	9.9	0	-
Petaluma	.12	6	.07	0	-	-	-	-	.013
Napa	.14	9	.18	20	9	0	7.4	0	-
Vallejo	.19	11	.26	15	13	6	12.1	5	.018
Fairfield	.18	12	.13	4	-	-	-	-	-
Los Gatos	-	-	.21	15	-	-	-	-	-
Mountain View	-	-	.19	10	-	-	-	-	-
Santa Rosa	-	-	-	-	-	-	-	-	.020

[1] Highest hourly average in ppm

[2] Number of days one hour average of 0.10 ppm was exceeded

[3] Highest 12-hour average in ppm

[4] Number of days 12-hour average of 10 ppm was exceeded

Source: Bay Area Air Pollution Control District

Table A-2. Average High Hour Oxidant Concentrations For Days With Comparable Temperature and Inversion Conditions (April Through October Oxidant Smog Seasons, 1962 to 1972)

Monitoring Station	Average High-Hour Oxidant Concentration (Kl Parts Per Million)											11-year Average
	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	
San Francisco	.14	.12	.15	.09	.08	.08	.05	.04	.07	.05	.03	.08
San Leandro	.13	.16	.19	.19	.14	.12	.11	.12	.12	.11	.10	.14
San Jose	.11	.17	.14	.16	.11	.13	.13	.13	.12	.08	.10	.12
Redwood City	.13	.10	.10	.14	.10	.09	.08	.09	.08	.07	.08	.10
Walnut Creek	.10	.11	.10	.11	.10	.13	.10	.13	.09	.09	.09	.10
San Rafael	.08	.09	.07	.08	.07	.07	.06	.07	.08	.07	.05	.07
BAAPCD Average	.12	.12	.13	.13	.10	.10	.09	.10	.09	.08	.08	.10
Livermore*	-	-	-	-	-	.13	.18	.18	.13	.11	.09	.14

*Station with 6 years of record

Source: Bay Area Air Pollution Control District

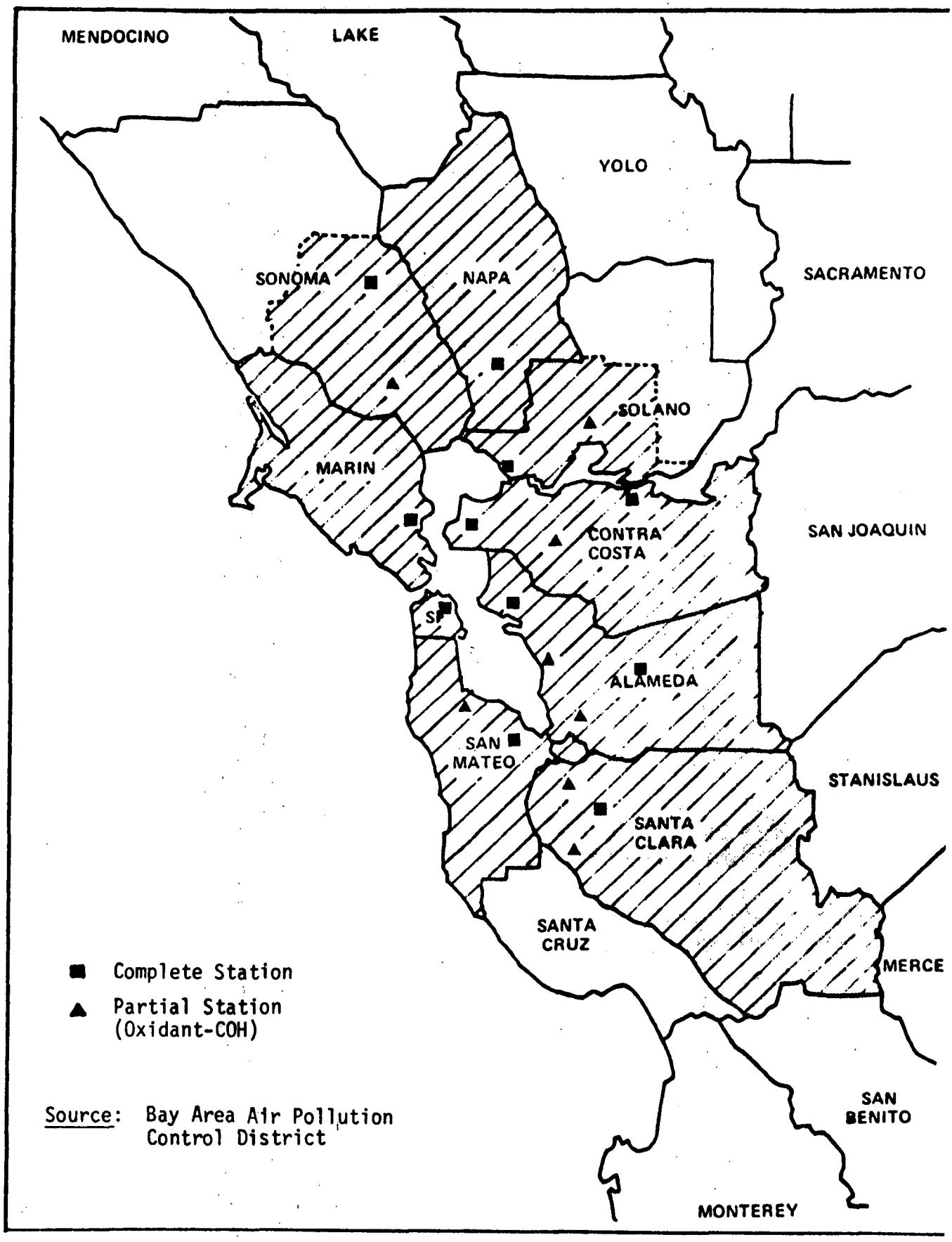

Figure A-1. Bay Area Air Pollution Control District Monitoring Network

APPENDIX B

PROJECTIONS OF MOTOR VEHICLES AND GASOLINE CONSUMPTION

1. INTRODUCTION

Calculations and projections of air pollution emissions depend on data concerning motor vehicles and gasoline consumption (or VMT). An evaluation of the available data disclosed that there were no well-documented sources for such projections, consistent with the most recent census data and latest population forecasts (B-1). The most recent projections of motor vehicle registrations provided by the California Department of Motor Vehicles is based on pre-1970 census data and is thus outdated (B-2). They are currently updating their old projections to reflect the most recent census reports (B-3); however, their results were unavailable for use in this study. It thus became necessary to establish the necessary data base and project these critical variables. This appendix describes the methodology used and presents the results of the analysis.

2. SPECIAL PROBLEMS IN DATA AVAILABILITY

Several problems arise in attempts to accurately forecast region specific growth trends. Among the more critical problems is obtaining adequate historical data compatible with and specific enough to the region of interest. As an example, different agencies use varying definitions for compiling data on motor vehicle classes, e.g., commercial and trucks. These categories are frequently incompatible with those desired for use in estimating pollutant emissions, e.g., light-duty and heavy-duty vehicles. By necessity, therefore, projections were made using the historical data available and then adjustments were made in the projected data to reflect the desired categories for estimating emissions.

Gasoline consumption was projected by apportioning statewide consumption figures to the regions of interest on the basis of population. Due to the methods used to collect gasoline taxes, it is virtually impossible

to get accurate estimates of gasoline consumption by air basin. The estimates of gasoline consumption by region were not used directly in the analysis to compute emissions; rather, they served mainly as a back-up check on VMT estimates provided as computed by other methods.

3. METHOD OF ANALYSIS

Linear multiple-regression analysis was used to estimate several equations, predicting various types of motor vehicles and gasoline consumption. Multiple regression techniques allow estimation of a dependent variable based on values for several independent variables. An equation of the following form results.

$$y = c + a, x, + a_2x_2 + \ldots + a_nx_n$$

where

y	=	dependent variable
c	=	a constant (represents the term a_0x_0)
$x_1,\ldots,x_n$	=	independent variables
$a_1,\ldots,a_n$	=	coefficients

In the above formula, it is assumed that all $x_1,\ldots,x_n$ are completely independent. In studying social phenomena, however, a high degree of interaction between variables is usually found. For example, population, income, overall economic activity, and many other social trends vary together, especially when viewed over a considerable time period.

Using the multiple regression analysis, thirteen years of historical data (1960-1972) were used to generate a set of regression equations (See Table B-1). The historical data for each region included information on 1) population, 2) per capita income, 3) regional economic activity, 4) consumer price index, and 5) various motor vehicles (e.g., autos, commercial, and motorcycles).

3.1 Population Projections (B-4, B-1)

The Population Research Unit of the California Department of Finance provides projections of population in California by counties to the year 2000. Their projections are based on an assumed fertility of 2.45 births per woman and a net migration of 150,000 annually into the state. This

set of projections is commonly called the "D-150" set of projections, with the "D" corresponding to the Bureau of the Census Series D projection of growth and the "150" indicating an overall gain of 150,000 migrants annually into the state. Because of charges that projections frequently turn out to be self-fulfilling prophecy, the Department of Finance also has compiled an "E-0" set of population growth projections. This series of forecasts assume a lower fertility rate (2.11 births per woman) and a net zero growth from in-and-out migration statewide.

In view of the implementation difficulties associated with a "no growth" policy, it has been assumed for this analysis that the D-150 series of projections are the most accurate. The California ARB also uses this set of figures as the basis for their growth rates.

3.2 Per Capita Income and Regional Economic Activity (B-5)

Projections for these indices were extracted from the Standard Metropolitan Statistical Areas (SMSA) summaries compiled by EPA and HUD.

3.3 Consumer Price Index (B-6)

The projected price indices for the region were provided by the Economic Research Unit of the California Department of Finance. This was determined by "averaging" the price index projections for San Francisco, Los Angeles, and San Diego, since price index information was not available for other areas.

3.4 Motor Vehicle Projections (B-7, B-8)

The independent variables used to forecast motor vehicles were population and adjusted per capita income. It has been well documented that economic variables are very important in forecasting demand for goods and services In the case of motor vehicles, it has been shown elsewhere that adjusted per capita income is indeed a good indicator of future auto ownership. Intuitively it is very reasonable that growth in motor vehicles is reflected by these two variables -- population, to reflect the need for more cars, and per capita income to reflect one's ability to buy cars.

The linear multiple-regression approach for forecasting autos not only allows economic variables to be considered, but it allows economic data specific to the region to be considered. One would certainly expect regional economic activity to be significant in an area's ability to purchase automobiles.

In a similar fashion, commercial vehicles (trucks), motorcycles, and regional gasoline consumption were also projected. Commercial vehicles were projected on the basis of population and total earnings for the region, since commercial vehicles by definition, are used primarily for business purposes and therefore are dependent on the economic activity of the region. (Total earnings, which is the summation of all earnings for the majority of the major industrial and commercial activity, is an accurate indicator of commercial business trends.) Motorcycles were forecast using historical trend data for adjusted per capita personal income. Since motorcycles have traditionally been a luxury item rather than a necessity (except for a small minority), its population growth is dependent on increased buying power. This is attested to by the fact that the majority of motorcycles purchased are for recreational purposes rather than to serve basic transportation needs.

Gasoline consumption was projected from the number of vehicles and California Consumer Price Index. An increase in vehicles would imply more consumption, just as changes in prices would be reflected in the demand for gasoline. This is justified on the grounds that individuals are conscious of gasoline prices, both implicitly as they purchase autos which give better gas mileage, and explicitly as they shop around for the lower-priced gasoline stations.

4. RESULTS OF THE MULTIPLE REGRESSION ANALYSIS

The following regression equations developed for the San Francisco area are accompanied by the coefficient of multiple determination (R^2) and the tests of significance for each coefficient (t-score):

Automobiles = -1696710.8 + 0.85243 (population

R^2 = 0.9590

t-score = 16.78

(per capita income was found to be not significant for this variable)

Motorcycles = 241261.8 + 71.675 (per capita income)

R^2 = .9520

t-score = 15.45

Commercial Vehicles = 155976.5 - 0.12023 (population) + 65.5 (total earnings)

R^2 = .9803

t-score (population) = -3.15

t-score (total earnings) = 8.26

Gasoline Consumption = -456.88 + 0.00078 (no. of vehicles) + 6.806 (price index)

R^2 = .9937

t-score (vehicles) = 9.16

t-score (price index) = 3.12

The resulting projections for all significant variables are presented in Table B-1, together with the historical data used in the development of the regression equations.

Table B-1. San Francisco Bay Area Regression Analysis Results

Year	Price Index	Per Capita Income	Population	Total Earnings $ Millions	Gasoline Million Gal.	Auto Registration	Commercial Vehicles	Motorcycles
				- Historical -				
1960	88.2	3435	3,676,200	7450	1321	1,488,058	198,750	15,205
1961	89.3	3550	3,786,800	7850	1361	1,542,438	206,953	17,029
1962	90.5	3675	3,913,200	8150	1427	1,682,822	227,296	21,818
1963	91.9	3815	4,054,200	8650	1508	1,753,200	218,997	29,640
1964	93.5	3960	4,167,200	9000	1600	1,816,295	251,236	37,738
1965	95.4	4110	4,278,100	9500	1665	1,932,934	270,852	48,360
1966	97.4	4275	4,362,700	9980	1749	1,961,418	284,647	57,196
1967	100.0	4430	4,460,700	10400	1810	1,999,385	295,907	66,555
1968	104.1	4580	4,539,600	10984	1928	2,126,627	318,520	75,022
1969	109.3	4690	4,592,500	11150	2020	2,218,648	339,886	93,141
1970	114.9	4783	4,644,100	11556	2101	2,265,856	354,374	106,631
1971	119.1	4880	4,670,000	12100	2175	2,352,007	370,577	123,770
1972	123.1	5020	4,720,000	12750	2260	2,442,127	440,772	125,678
				- Projected -				
1975	137.8	5487	4,967,700	14761	2460	2,537,906	525,998	152,019
1977	144.5	5800	5,100,000	16000	2594	2,650,682	591,283	174,453
1980	154.7	6233	5,481,900	18262	2916	2,976,226	693,596	205,489

1975, 1977, 1980 values for gasoline consumption, auto registration, commercial vehicles, and motorcycles are calculated by regression equations.

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APPENDIX C

ESTIMATING MODE CHOICE AND VMT REDUCTION

To perform mode choice analyses required by the project within the time constraints, a certain amount of regrouping of existing data had to be done. Trip purposes and traffic zones were aggregated to conserve unnecessary effort. Meanwhile, some disaggregation and experimentation was necessary to get origin/destination patterns grouped in a manner suitable for assessing VMT reduction. Each procedure in part necessitated checking and some modification of BATSC mode choice curves.

1. TRIP PURPOSES

BATSC mode choice curves were developed for three trip purposes. To simplify analyses, the three purposes were reduced to two:

a) Work trips, including BATSC home based work and related business trips; these trips approximate rush hour travel patterns.

b) Non-work trips, including BATSC home based all other except work and school trips and non-home based trips; these trips approximate off-peak or midday travel patterns.

2. ZONES AND SUPERDISTRICTS

BATSC data were tabulated into 291 zones. For analytical purposes, the zones were grouped into 30 larger geographic units, referred to by BATSC as "superdistricts."

3. ORIGIN/DESTINATION COMBINATIONS

BATSC aggregated zonal data into six origin (production)/destination (attraction) combinations as a basis for determining mode choice curves from 1965 data (Figures C-1, C-2, and C-3).

- From low density residential to regional CBD
- From low density residential to other CBD
- From medium density residential to regional CBD
- From medium density residential to other
- From high density residential to regional CBD
- From high density residential to other

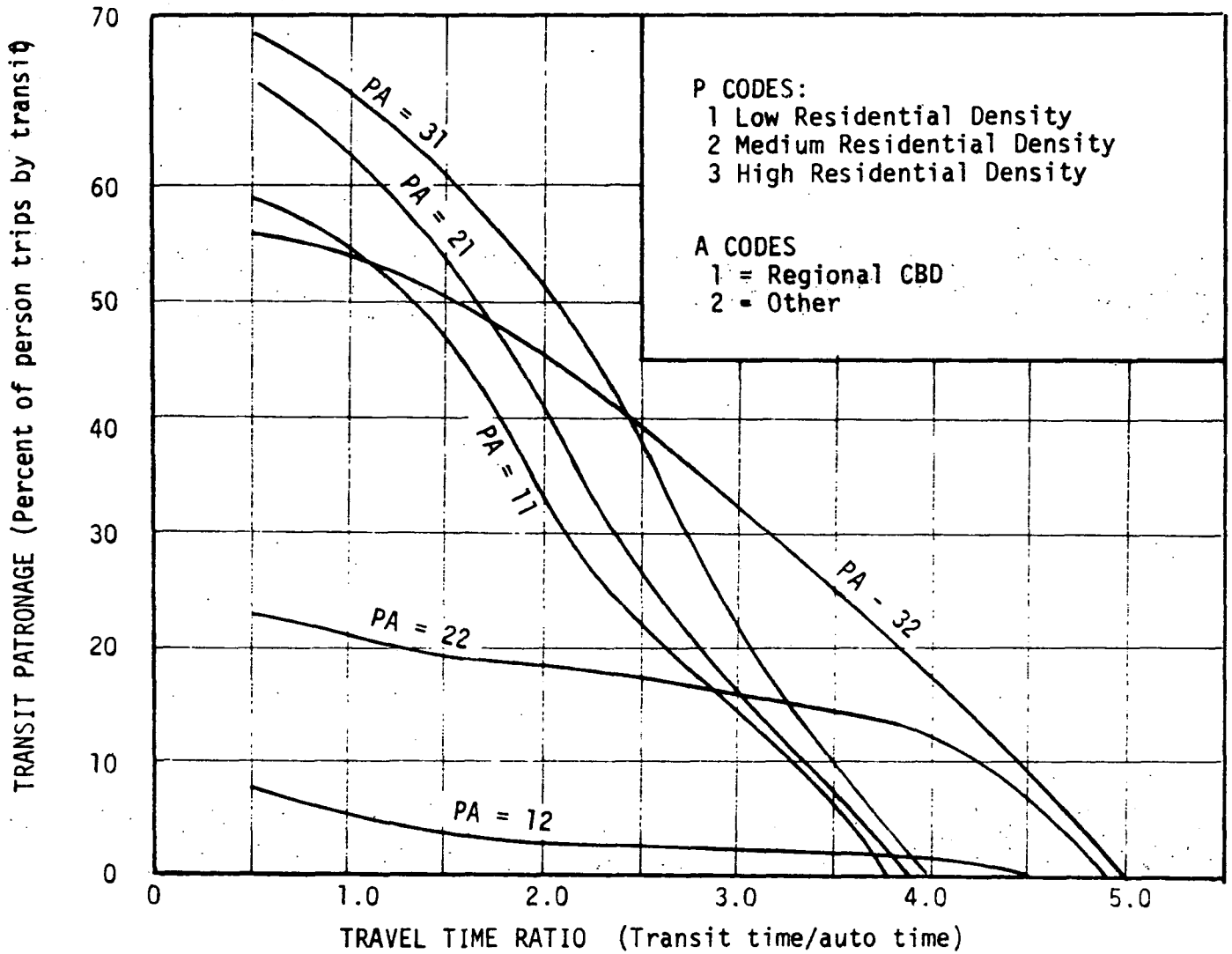

Figure C-1. Bay Area Transportation Study Modal Split Model
Home Based Work and Related Business Trips

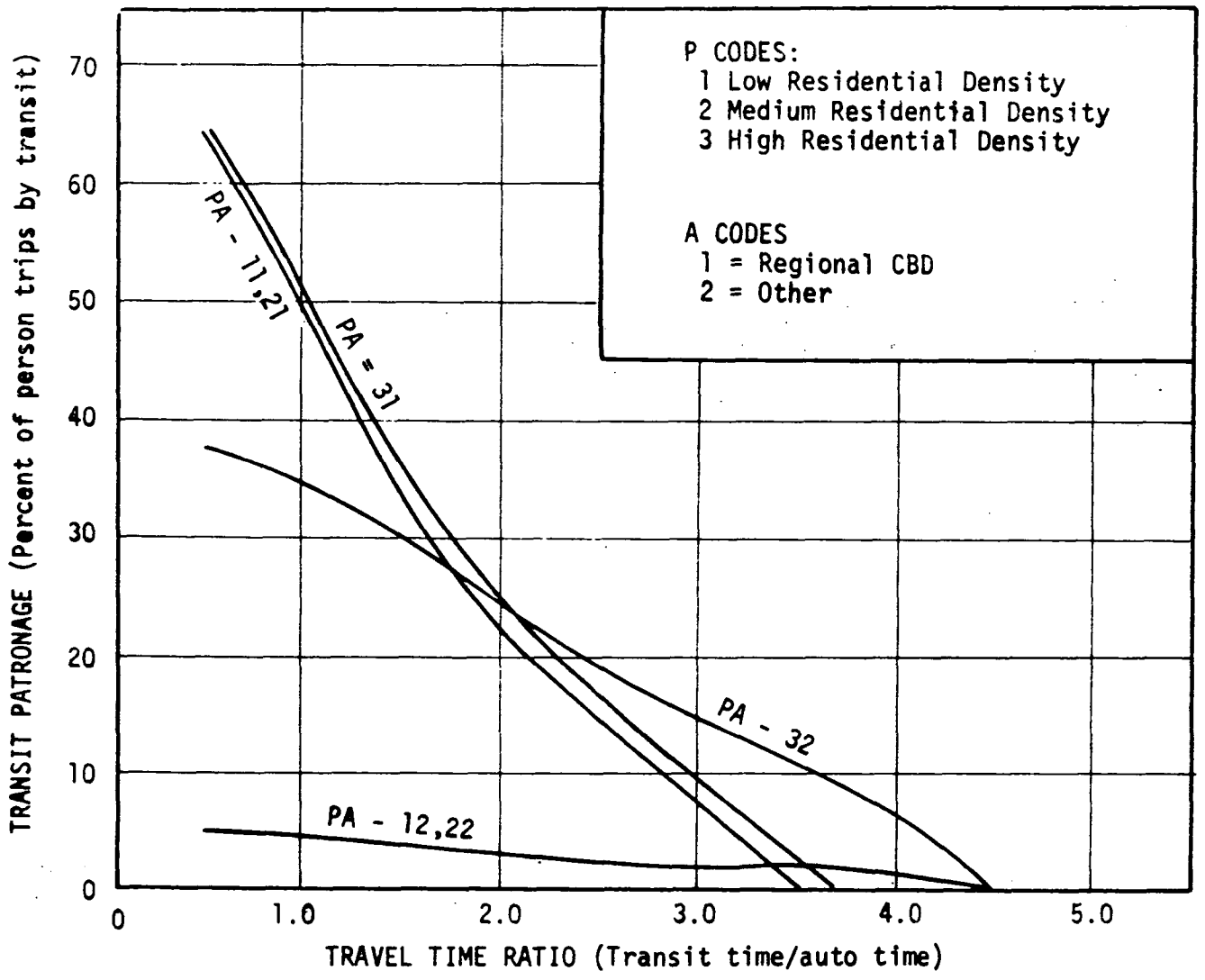

Figure C-2. Bay Area Transportation Study Model Split Model
Home Based All Other Except Work and School Trips

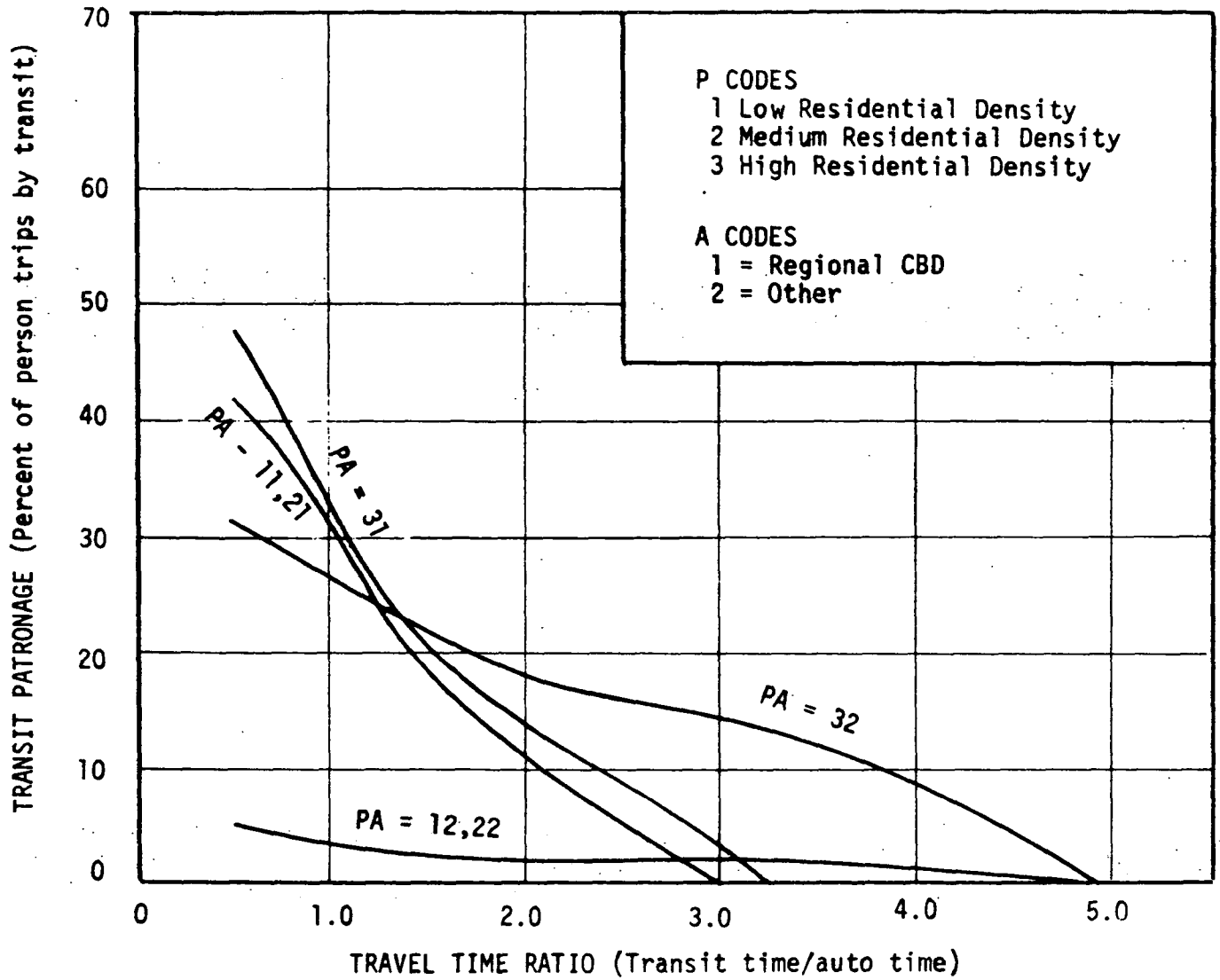

Figure C-3. Bay Area Transportation Study Modal Split Model
Non-Home Based Trips

BATSC defined low density as zones with less than 10 dwelling units per net residential acre, medium density as 10-30 dwelling units per acre and high density as over 30 dwelling units per acre. Only San Francisco, about 50 percent of Oakland and Berkeley and 10 percent of northern San Mateo County and Richmond fall under the definition of medium or high density. This residential density distinction, when applied by superdistrict, separates trips originating in San Francisco from trips originating in remaining low density areas. To avoid losing the distinction between lower and higher density travel characteristics in the East Bay (due to aggregation) trips in and out of Oakland-Berkeley were treated separately from other Alameda-Contra Costa County travel.

The BATSC regional CBD designation included San Francisco and Oakland central business districts, a grouping which underestimates transit usage to the San Francisco CBD and overestimates transit use to downtown Oakland. To test strategies related to control of travel to downtown San Francisco, it was important to separate out the San Francisco CBD. Oakland CBD was aggregated with other Oakland-Berkeley travel.

4. TRIP LENGTH

Intradistrict trips were assumed to be local, whereas interdistrict trips were considered intercity trips.

5. MODIFICATION OF MODE CHOICE CURVES

Once 1965 travel data had been aggregated by work and non-work purposes, by intradistrict and interdistrict orientation, and by destination -- San Francisco CBD, elsewhere in San Francisco, Oakland-Berkeley, and elsewhere in the Bay Area (Tables C-1 and C-2) -- mode choice curves were developed according to the following procedures:

- District to district travel times via transit and automobile were obtained from computer tapes of BATSC 1965 data. Distinction was made between peak hour and midday travel times. A single zone in each district was selected for computing district to district travel times (Tables C-3, C-4, C-5).

- Ratios of district to district auto/transit travel times were plotted against percent of person trips by transit. Separate plots were developed for (1) trips destined to San Francisco CBD, (2) trips destined to the remainder of

Table C-1. 1965 Trip Origins and Destinations, Work Purpose

Destination	Daily Person Trips				Daily Transit Trips				Percent Trips by Transit			
	Origin Within District (Local Travel)	Origin in San Francisco (*Includes Oakland-Berkeley)	Origin Elsewhere (Other Intercity Travel)	Total Person Trips	Origin Within District (Local Travel)	Origin in San Francisco (*Includes Oakland-Berkeley)	Origin Elsewhere (Other Intercity Travel)	Total Transit Trips	Origin Within District (Local Travel)	Origin in San Francisco (*Includes Oakland-Berkeley)	Origin Elsewhere (Other Intercity Travel)	Total Trips
San Francisco CBD	-	241,500[1]	186,800	428,300	-	125,800[1]	69,100	194,900	-	52[1]	37	45
Elsewhere in San Francisco	107,100	89,400	83,800	280,300	20,600	26,500	6,600	53,700	19	30	8	19
Oakland-Berkeley	220,800	75,300*	146,300	442,400	30,600	17,500*	4,300	52,400	14	23*	3	12
Remainder Alameda County	134,400	37,700*	38,700	210,800	2,200	4,100*	100	6,400	2	11*	1	3
Remainder Contra Costa County	134,500	17,100*	52,300	203,900	2,500	1,100*	500	4,100	2	6*	1	2
San Mateo County	64,100	29,400	93,800	187,300	1,300	5,300	2,700	9,300	1	18	3	5
Marin County	39,300	2,800	19,300	61,400	500	600	400	1,500	3	20	2	2
Santa Clara County	261,800	0	276,400	538,200	3,200	0	3,200	6,400	1	-	1	1
Solano County	58,700	0	19,100	77,800	1,200	0	900	2,100	6	-	5	3
Sonoma County	60,600	0	20,800	81,400	200	0	0	200	1	-	0	0
Napa County	22,400	0	6,100	28,500	0	0	0	0	0	-	0	0
TOTAL	1,103,700	493,200	943,200	2,540,300	62,300	180,800	88,100	331,000	5	37	9	13

Source: 1965 BATSC Trip Table, Productions (origins) and Attractions (Destinations)

[1] Includes all trips originating in San Francisco destined to the CBD

Table C-2. 1965 Trip Origins and Destinations, Non-Work Purpose

Destination	Daily Person Trips				Daily Transit Trips				Percent Trips by Transit			
	Origin Within District (Local Travel)	Origin in San Francisco (*Includes Oakland-Berkeley)	Origin Elsewhere (Other Intercity Travel)	Total Person Trips	Origin Within District (Local Travel)	Origin in San Francisco (*Includes Oakland-Berkeley)	Origin Elsewhere (Other Intercity Travel)	Total Transit Trips	Origin Within District (Local Travel)	Origin in San Francisco (*Includes Oakland-Berkeley)	Origin Elsewhere (Other Intercity Travel)	Total Trips
San Francisco CBD	-	534,200[1]	63,400	597,600	-	105,700[1]	12,100	117,800	-	20[1]	19	20
Elsewhere in San Francisco	620,900	247,400	106,100	974,700	60,200	60,000	10,300	130,500	10	24	10	13
Oakland-Berkeley	1,018,700	140,300	149,500	1,308,500	56,000	12,200	12,200	80,400	5	9	8	6
Remainder Alameda County	807,600	66,700	65,200	939,500	31,200	1,700	1,800	34,700	4	3	3	4
Remainder Contra Costa County	922,300	47,700	102,900	1,072,900	57,800	2,300	3,900	64,000	6	5	4	6
San Mateo County	822,000	55,700	180,300	1,058,000	53,000	4,400	8,700	66,100	6	8	5	6
Marin County	256,600	12,100	56,400	325,100	14,400	1,000	1,300	16,700	6	8	2	5
Santa Clara County	1,494,300	0	1,147,600	2,641,900	26,300	0	10,900	37,200	2	-	1	1
Solano County	268,900	0	35,400	304,300	5,100	0	1,200	6,300	2	-	3	2
Sonoma County	331,300	0	69,800	401,100	31,200	0	8,100	39,300	9	-	12	10
Napa County	109,900	0	22,400	132,300	6,900	0	2,100	9,000	6	-	10	7
TOTAL	6,652,500	1,104,100	1,999,000	9,755,900	342,100	187,300	72,600	602,000	5	17	4	6

Source: 1965 BATSC Trip Table, Productions (Origins) and Attractions (Destinations)

[1] Includes all trips originating in San Francisco destined to the CBD

Table C-3. Trips to San Francisco CBS (Superdistrict 1), 1965, Work Purpose

Origin (Superdistrict)	Auto/Transit Travel Time	Total Person Trips	Total Transit Trips	Percent Trips by Transit
1	6.08/4.46 = 1.40	75,500	23,700	31
2	17.6/13.1 = 1.35	83,800	49,900	60
3	33.0/18.4 = 1.80	71,700	35,300	49
4	33.0/23.4 = 1.40	30,600	16,900	55
5	53.5/33.1 = 1.60	35,300	10,600	30
6	63.7/42.5 = 1.50	13,400	6,500	49
7	78.6/60 = 1.30	11,800	6,400	54
16	49.5/34.5 = 1.40	25,700	12,300	48
17	57.5/41.3 = 1.40	12,500	7,370	59
18	67.9/37.4 = 1.80	8,075	3,260	37
15	74.8/51.7 = 1.45	6,910	2,820	43
14	116.4/65.2 = 1.80	780	170	22
20	72.5/57.6 = 1.25	9,850	4,700	48
30	53.2/35.8 = 1.50	14,600	2,920	20
29	56.1/47.6 = 1.20	12,300	3,930	32

Table C-4. Trips to Oakland (Superdistrict 16), 1965, Work Purpose

Origin (Superdistrict)	Auto/Transit Travel Time	Total Person Trips	Total Transit Trips	Percent Trips by Transit
1	42.9/32.5 = 1.30	1,730	1,170	68
2	52.8/35.4 = 1.45	3,900	515	13
3	53.3/32.1 = 1.70	3,340	230	69
4	59.9/42.9 = 1.40	2,060	250	12
5	Poor Connect.	1,150	-	0
13	No Transit	1,590	-	0
14	89.8/45.0 = 2.0	6,810	265	4
15	37.1/33.4 = 1.1*	52,200	3,710	7
16	8.9/5.25 = 1.7	168,500	25,600	15
17	34.3/26.0 = 1.3	30,400	5,960	20
18	58.2/25.1 = 2.3	15,500	990	6
19	No Transit	2,560	-	0
20	46.2/37.2 = 1.2	13,700	1,050	8
22	Poor Connect.	1,000	-	0
29	Poor Connect.	1,015	-	0

*Manual adjustment to 1.3

Table C-5. Trips to Berkeley (Superdistrict 17), 1965, Work Purpose

Origin (Superdistrict)	Auto/Transit Travel Time	Total Person Trips	Total Transit Trips	Percent Trips by Transit
1-4	68.3/42.1 = 1.60	3,860	340	9
15	83.5/41.2 = 2.00	6,330	280	4
16	34.3/26 = 1.30	29,900	4,900	16
17	7.7/4.6 = 1.70	52,300	5,040	10
18	53.5/22.3 = 2.40	24,200	1,550	6
19	119.9/39.9 = 3.00	3,200	280	9
20	97.9/27.2 = 3.60	10,200	150	1

San Francisco, (3) trips destined to Oakland-Berkeley, and trips destined to other areas. Work trip (peak hour) values were plotted separately from non-work trip (midday) values (Figures C-4 and C-5).

- Curves were developed to fit district to district travel data, first trying to utilize zone to zone mode choice curves derived by BATSC, and as a second choice interpolating between curves previously developed by BATSC. Mode choice curves generally take the same shape from one geographic area to another, making extrapolation from limited data less risky than one might otherwise expect. Mode split curve assumptions behind curves shown in Chapter 4 are identified below and are documented in Tables C-6 through C-9.

Work Trips (Interdistrict and Intradistrict):

1. To San Francisco CBD from San Francisco -- BATSC Curve PA = 21
2. To San Francisco CBD from Elsewhere -- Adjusted BATSC PA = 11 Curve
3. To Remainder San Francisco from San Francisco -- Interpolated BATSC Curves PA = 32 and PA = 22
4. To Remainder San Francisco from Elsewhere -- Interpolated BATSC Curves PA = 22 and PA = 12
5. To Oakland-Berkeley from San Francisco-Oakland-Berkeley -- Developed Curve to Fit BATSC Data
6. To Oakland-Berkeley from Elsewhere -- Developed Curve to Fit BATSC Data
7. To Remainder Alameda County from San Francisco-Oakland-Berkeley -- Developed Curve to Fit BATSC Data
8. To Remainder Alameda County from Elsewhere -- BATSC Curve PA = 12
9. To Contra Costa County from San Francisco-Oakland-Berkeley -- Same as No. 7
10. To Contra Costa County from Elsewhere -- BATSC Curve PA = 12
11. To Marin County from San Francisco -- BATSC Curve PA = 22
12. To Marin County from Elsewhere -- BATSC Curve PA = 12
13. To San Mateo County from San Francisco -- BATSC Curve PA = 22
14. To San Mateo County from Elsewhere -- BATSC Curve PA = 12
15. To Santa Clara County -- BATSC Curve PA = 12
16. To Solano County -- BATSC Curve PA = 21
17. To Sonoma County -- BATSC Curve PA = 21
18. To Napa County -- BATSC Curve PA = 21

Non-work Trips (Interdistrict and Intradistrict):

1. To San Francisco from all Locations -- BATSC NBO Curve PA = 11,21
2. To Remainder of San Francisco from All Locations -- Curve to Fit BATSC Data
3. To Oakland-Berkeley from Everywhere -- Curve to Fit BATSC Data
4. To Other Locations -- BATSC HBO Curve PA = 12

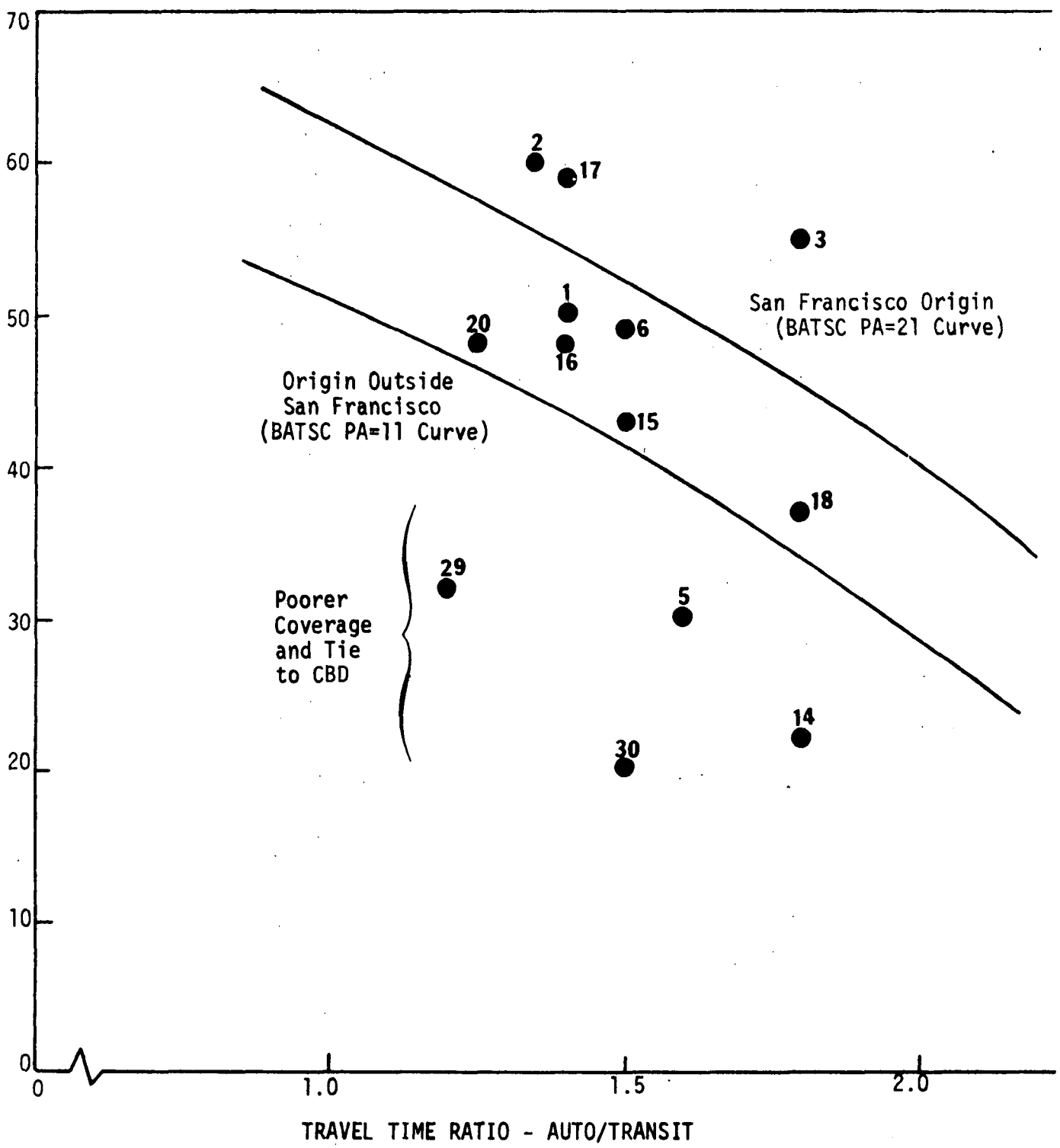

Figure C-4. Percent Person Trips by Transit Versus Auto-Transit Travel Time Ratio -- Example: Work Trips to San Francisco CBD

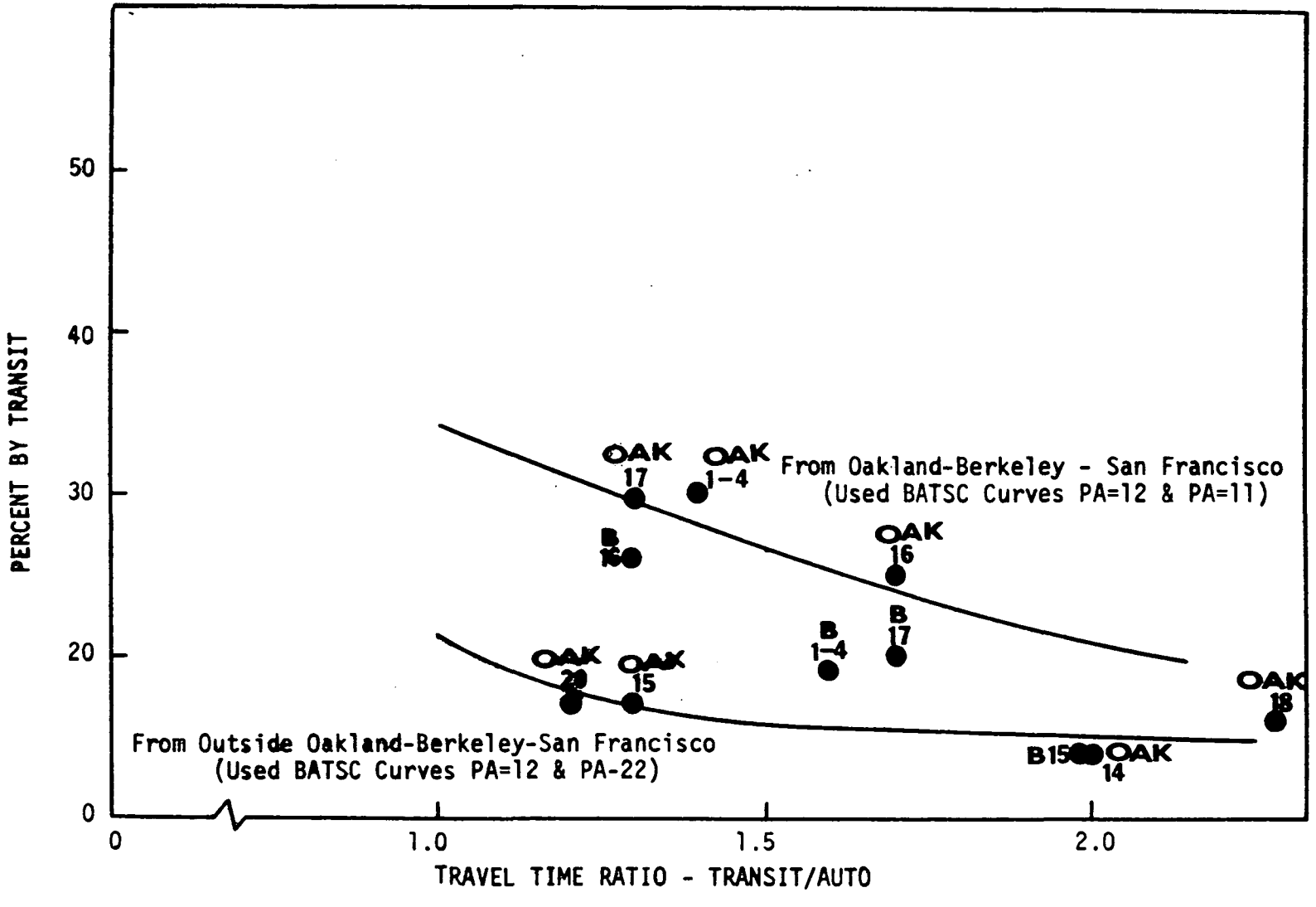

Figure C-5. Percent Person Trips by Transit Versus Auto-Transit Travel Time Ratio -- Example: Work Trips to Oakland-Berkeley

Table C-6. 1980 Trip Origins and Destinations, Work Purpose

Destination	Daily Person Trips				Daily Transit Trips				Percent Trips by Transit			
	Origin Within District (Local Travel)	Origin in San Francisco (*Includes Oakland-Berkeley)	Origin Elsewhere (Other Intercity Travel)	Total Person Trips	Origin Within District (Local Travel)	Origin in San Francisco (*Includes Oakland-Berkeley)	Origin Elsewhere (Other Intercity Travel)	Total Transit Trips	Origin Within District (Local Travel)	Origin in San Francisco (*Includes Oakland-Berkeley)	Origin Elsewhere (Other Intercity Travel)	Total Trips
San Francisco CBD	-	262,000[1]	211,200	473,200	-	161,300[1]	107,900	269,200	-	62[1]	51	57
Elsewhere in San Francisco	108,000	116,300	135,400	359,700	24,400	33,700	12,200[2]	70,300	23	29	09[2]	20
Oakland-Berkeley	234,800	108,800*	254,500	598,100	38,300	24,500*	28,300	91,100	16	22*	11	15
Remainder Alameda County	199,300	58,100*	117,300	374,700	3,900	7,300*	3,700	14,900	2	13*	3	4
Remainder Contra Costa County	185,800	39,200*	122,800	347,800	6,500	5,700*	4,500	16,700	3	15*	4	5
San Mateo County	184,300	57,900	197,600	439,800	6,700	15,300	9,600	31,600	4	26	5	7
Marin County	77,300	7,300	32,600	117,200	1,500	1,800	1,200	4,500	2	24	4	4
Santa Clara County	369,600	0	533,200	902,800	7,500	0	18,000	25,500	2	-	3	3
Solano County	91,400	0	38,500	132,900	4,200	0	2,100	6,300	5	-	6	5
Sonoma County	103,200	0	42,200	145,400	3,800	0	2,300	6,100	4	-	5	4
Napa County	38,300	0	25,400	63,700	1,900	0	1,100	3,000	5	-	5	5
TOTAL	1,595,000	649,600	1,710,700	3,955,300	98,700	249,600	190,900	539,200	6	38	11	14

Source: 1980 BATSC Trip Table, X-2 Transit Network, Productions (Origins) and Attractions (Destinations).

[1] Includes all trips from San Francisco destined to the CBD.

[2] Hand adjustment to compensate for inclusion of Southern Crossing in BATSC 1980 assumptions.

Table C-7. 1980 Trip Origins and Destinations, Non-Work Purposes

Destination	Daily Person Trips				Daily Transit Trips				Percent Trips by Transit			
	Origin Within District (Local Travel)	Origin in San Francisco (*Includes Oakland-Berkeley)	Origin Elsewhere (Other Intercity Travel)	Total Person Trips	Origin Within District (Local Travel)	Origin in San Francisco (*Includes Oakland-Berkeley)	Origin Elsewhere (Other Intercity Travel)	Total Transit Trips	Origin Within District (Local Travel)	Origin in San Francisco (*Includes Oakland-Berkeley)	Origin Elsewhere (Other Intercity Travel)	Total Trips
San Francisco CBD	-	471,500[1]	101,800	573,300	-	158,000[1]	23,000	181,000	-	34[1]	22	32
Elsewhere in San Francisco	47,000	348,200	183,100	578,300	22,600	34,700	6,800[2]	64,100	48	10	4[2]	11
Oakland-Berkeley	998,300	237,200*	356,100	1,591,600	40,000	16,300*	12,800	69,100	4	7*	4	4
Remainder Alameda County	907,600	116,500*	217,000	1,241,100	6,200	3,600*	2,400	12,200	1	3*	1	1
Remainder Contra Costa County	936,400	115,200*	275,600	1,327,200	9,800	4,100*	3,700	17,600	1	4*	1	1
San Mateo County	946,000	142,400	342,900	1,431,300	10,100	8,900	5,900	24,900	1	2	2	2
Marin County	411,000	42,700	102,100	555,800	3,200	1,700	1,200	6,100	1	4	1	1
Santa Clara County	1,573,300	0	963,200	2,536,500	13,900	0	10,500	24,400	1	-	1	1
Solano County	346,200	0	60,100	406,300	2,800	0	700	3,500	1	-	1	1
Sonoma County	422,300	0	69,000	491,300	6,300	0	1,700	8,000	1	-	2	2
Napa County	152,500	0	59,600	212,100	1,900	0	900	2,800	1	-	1	1
TOTAL	6,740,600	1,473,700	2,730,500	10,944,800	116,800	227,300	69,600	413,700	2	15	3	4

Source: 1980 BATSC Trip Table, X-2 Transit Network, Productions (Origins) and Attractions (Destinations)

[1] Includes all trips from San Francisco destined to the CBD

[2] Hand adjustment to compensate for inclusion of Southern Crossing in BATSC 1980 Assumptions

Table C-8. Percentage Breakdown of Bay Area VMT, 1980

Destination	Work Purpose VMT: Origin Within District (Local Travel)	Work Purpose VMT: Origin in San Francisco (*Includes Oakland-Berkeley)	Work Purpose VMT: Origin Elsewhere (Other Intercity Travel)	Work Purpose VMT: Total Work VMT	Non-Work Purpose VMT: Origin Within District (Local Travel)	Non-Work Purpose VMT: Origin in San Francisco (*Includes Oakland-Berkeley)	Non-Work Purpose VMT: Origin Elsewhere (Other Intercity Travel)	Non-Work Purpose VMT: Total Non-work VMT	Total All Purpose VMT
San Francisco CBD	-	0.4[1]	2.9	3.3	-	0.6[1]	1.9	2.5	5.8
Elsewhere in San Francisco	0.2	0.4	3.2	3.8	0.6	1.1	3.2	4.9	8.7
Oakland-Berkeley	0.7	0.9*	4.7	6.3	2.1	1.5*	4.3	7.9	14.2
Remainder Alameda County	0.8	0.7*	2.7	4.2	1.8	1.2*	3.3	6.3	10.5
Remainder Contra Costa County	0.8	0.5*	2.4	3.7	2.0	1.3*	3.4	6.7	10.4
San Mateo County	0.7	0.7	4.2	5.6	2.0	1.2	4.5	7.7	13.3
Marin County	0.4	0.1	0.7	1.2	1.2	0.3	3.4	4.9	6.1
Santa Clara County	1.7	0	8.5	10.2	3.8	0	8.7	12.5	22.7
Solano County	0.5	0	0.9	1.4	0.9	0	1.0	1.9	3.3
Sonoma County	0.3	0	1.0	1.3	0.8	0	1.1	1.9	3.2
Napa County	0.1	0	0.5	0.6	0.3	0	0.9	1.2	1.8
TOTAL	6.2	3.7	31.7	41.6	15.5	7.2	35.7	58.4	100.0

Source: 1980 BATSC travel data, zone to zone vehicle trips multiplied by travel distance and summed.

[1] Includes all trips from San Francisco destined to the CBD

Table C-9. Work Trips by Transit for Selected Control Options

Destination	Origin	A Transit Improvements[1]		B Imposition of 50¢ Toll to S.F.			C Imposition of $2 Toll to S.F.			D Free Fare			E Traffic Restrictions Transit/Auto = 1.0			F Improved Local Transit Transit/Auto = 1.4		
		% by Transit 1980	Increase From 1965	% by Transit 1980	% Increase Over A	% VTM Reduction	% by Transit 1980	% Increase Over A	% VTM Reduction	% by Transit 1980	% Increase Over A	% VTM Reduction	% by Transit 1980	% Increase Over A	% VTM Reduction	% by Transit 1980	% Increase Over A	% VTM Reduction
S.F. CBD	S.F.	62	10	62	-	0	62	-	0	64	2	0.02	62	-	0	62	-	0
	Elsewhere	51	14	53	2	0.12	57	6	0.35	74	23	0.69	51	-	0	51	-	0
Remainder S.F.	Rem. S.F.[2]	23	4	23	-	0	23	-	0	26	3	0.01	23	-	0	37	14	0.07
	S.F.	29	-1	29	-	0	29	-	0	31	2	0.01	36	7	0.04	29	-	0
	Elsewhere	9	1	10	1	0.03	12	3	0.10	16	7	0.30	13	4	0.12	9	-	0
Oak-Berk.	Oak-Berk.[2]	16	2	16	-	0	16	-	0	18	2	0.01	16	-	0	17	1	0.01
	S.F., Oak., Berk.	22	-1	22	-	0	24	2	0.03	25	3	0.04	24	2	0.03	22	-	0
	Elsewhere	11	8	11	-	0	11	-	0	20	9	0.22	11	-	0	11	-	0
Rem. Ala. Co.	Rem-Alameda[2]	2	0	2	-	0	2	-	0	2	0	0	2	-	0	7	5	0.04
	S.F., Oak., Berk.	13	2	13	-	0	15	2	0.01	15	2	0.01	13	-	0	13	-	0
	Elsewhere	3	2	3	-	0	3	-	0	10	7	0.17	5	2	0	7	4	0.04
Contra Costa Co.	Contra Costa[2]	3	1	3	-	0	3	-	0	3	0	0	3	-	0	7	4	0.03
	S.F., Oak., Berk.	15	9	15	-	0	17	2	0.01	17	2	0.01	15	-	0.05	15	-	0
	Elsewhere	4	3	4	-	0	4	-	0	10	7	0.14	5	1	0	6	2	0.05
Marin Co.	Marin Co.[2]	2	1	2	-	0	2	-	0	2	10	0	2	-	0	7	5	0.02
	S.F.	24	4	25	1	0	28	4	0.01	27	3	0	26	2	0.02	24	-	0
	Elsewhere	4	2	4	-	0	4	-	0	10	7	0.07	5	1	0	6	2	0.01
San Mateo Co.	S.M. Co.[2]	4	3	4	-	0	4	-	0	4	0	0	4	-	0	7	3	0.02
	S.F.	26	8	26	-	0	30	4	0.04	28	2	0.01	26	-	0.01	26	-	0
	Elsewhere	5	2	5	-	0	5	-	0	10	5	0.20	5	-	0	6	1	0.04
Santa Clara Co.	S.C. Co.[2]	2	1	2	-	0	2	-	0	2	0	0	2	-	0	7	5	0.08
	Elsewhere	3	2	3	-	0	3	-	0	10	7	0.21	5	2	0	6	3	0.25
Solano Co.	Solano Co.[2]	5	-1	5	-	0	5	-	0	5	0	0	5	-	0	6	1	0
	Elsewhere	6	1	6	-	0	6	-	0	10	4	0.04	6	-	0	6	-	0
Sonoma Co.	Sonoma Co.[2]	4	3	4	-	0	4	-	0	4	-	0	4	-	0	6	2	0.01
	Elsewhere	5	5	5	-	0	5	-	0	10	5	0.05	5	-	0	6	1	0.01
Napa Co.	Napa Co.[2]	5	5	5	-	0	5	-	0	5	-	0	5	-	0	6	1	0
	Elsewhere	5	5	5	-	0	5	-	0	10	5	0.05	5	-	0	6	1	0
Total Bay Area Work Trips		13.6	1.0	13.7	0.1	0.15	14.2	0.6	0.55	18.4	4.7	2.25	14.4	0.7	0.27	14.0	0.4	0.68

[1] Assumes BART fully operational and Santa Clara County Transit District operating with 200 new buses.

[2] Local (Intradistrict) trips).

APPENDIX D

MOTOR VEHICLE EMISSIONS

1. INTRODUCTION

Environmental pollution resulting from motor vehicle emissions was investigated by considering separately the contributions from: light duty vehicles, heavy duty gasoline powered vehicles, heavy duty diesel vehicles, and motorcycles. Base year emissions from these vehicle types were estimated by determining the annual mileage by model distribution of the region's vehicle population, the overall mileage traveled by vehicles in the region, and then applying appropriate emission factors which are attributable to the various vehicle age classifications. Consider, for example, a region in which it is known that eight percent of all light-duty vehicle travel is performed by cars of age three years, that the total vehicle miles traveled in the region is five million miles per year, and that the representative hydrocarbon exhaust emission factor for three-year old cars in the region is 4.4 grams per mile. The hydrocarbon exhaust emission contribution by the three-year old light duty vehicle group is

$$(5{,}000{,}000)\ \ 4.4\ (.08) \times \frac{1}{365\ \frac{\text{days}}{\text{yr}}} = 4822 \text{ total grams hydrocarbon per day.}$$

Subsequently, the total light duty emissions for the region may be determined by performing the summation:

$$(VMT)_n \sum_{i=(n-12)}^{h+1} e_{ip}\, m_{in} = \text{total exhaust emissions}$$

where

VMT = total vehicle miles traveled in region for given vehicle type (light duty, heavy duty, etc.). This is determined from transportation study data.

e_{ipn} = emission factor for ith model year for pollutant p during calendar year n in a given region.

m_{in} = weighted annual travel of the ith model year vehicle during calendar year n. (The determination of this variable involves the use of the vehicle model year distribution.)

The factor

e_{ipn} is determined according to the relationship

$$e_{ipn} = c_{ip}\, d_{ipn}\, s_p \text{ (Reference D-1)}$$

where

c_{ip} = the 1975 federal test procedure emission rate for pollutant p (grams per mile) for the ith model year, at low mileage. These values are available from Reference (D-1).

d_{ipn} = the controlled vehicle pollutant p emission deterioration factor for the ith model year at calendar year n. These figures are available from Reference (D-1).

s_p = the speed adjustment factor for exhaust emission for pollutant p. This value is available from Reference (D-1) when the average speed of vehicular travel is known.

The calculation of hydrocarbon emissions also involves evaporative and crankcase hydrocarbon emission rates. These emissions are determined in the same manner as exhaust emissions by using:

$$(VMT)_n \sum_{i=(n-12)}^{n+1} h_i\, m_{in}$$

where

h_i = the combined evaporative and crankcase emission rate for the ith model year,

m_{in} = the weighted annual travel of the ith model year during calendar year n.

The numerical calculations required for estimation of total base year emissions are carried out with the use of a computer program. Values for h_i, c_{ip} and d_{ipn} are taken from Reference (D-1), and s_p, VMT, and m_{in} are determined from vehicle data for the region of interest.

Projected vehicle emissions for the future years 1975, 1977, and 1980 are computed in the same manner as the base year emissions, utilizing anticipated vehicle (VMT) growth rates and expected emission reduction rates as determined from regional data and as provided by Reference (D-1).

The vehicle emissions which are anticipated in future years, based on current scheduled emission control programs, forms the vehicle "baseline emission" profile. The "baseline emissions" may be viewed, therefore, as the nominal emissions which are projected to occur from the base year (the former year in which the maximum ambient pollution peak was observed to occur) to the years 1975, 1977, and 1980. Baseline emissions are calculated in terms of THC, CO, and NO_x. The calculation results for the various types of vehicles are presented in Section of the report.

Implementation of additional controls to reduce vehicle emissions below the nominal baseline emission profile are investigated by adjusting the appropriate mathematical functions which reflect the type of proposed control. For example, the effect of retrofit of catalytic converters on used light duty model vehicles is determined by adjusting the emission and deterioration factors for those models proposed for control, and by carrying out the series of summations in the computer model. If, as another example, a program is implemented to bring about a reduction in total VMT, total emissions, in this case, would be easily determined applying a proportionate decrease in the baseline emissions.

The following sections describe the requirements for manipulation of regional data preparatory to input to the computer model. Emissions are calculated separately for light duty vehicles, heavy duty gasoline powered vehicles, heavy duty diesel vehicles, and motorcycles.

2. LIGHT DUTY VEHICLES

Emissions from light duty vehicles were computed according to the methodology discussed above. This necessitated the determination of 1) weighted annual travel by model, 2) average vehicle speed in the region, 3) emission factors by model, 4) deterioration rates for emission factors by model, and 5) total VMT.

2.1 Weighted Annual Travel

To determine the weighted annual travel of various model year vehicles in the San Francisco Air Basin, the following vehicle distributions were utilized:

- Passenger car model distribution
- Annual mileage distribution by model.

The passenger car model distribution was obtained from data supplied by R. L. Polk and Company (D-2). This data lists registered passenger models by county as of July 1, 1972. The model year data does not include all light duty vehicles (pickups and light trucks are omitted), but its distribution by model year was presumed closely representative of the actual light duty distribution. The passenger car distributions for the base year of 1971 were calculated from the 1972 Polk registration data, truncated at the year 1971. Table D-1 displays the Polk passenger car registration data and the corresponding calculated normalized distribution which was taken as the light duty vehicle model distribution. It is assumed that this distribution reflects very closely the true distribution of model passenger cars actually traveling in the area, although it is recognized that through-trips by cars registered outside the county may influence the true distribution. This effect is considered to be minor, particularly in the San Francisco Basin, because through trips represent a small fraction of the total vehicle mileage.

The annual mileage of the various model year vehicles is determined from data compiled by the California ARB from results of tests by the California Highway Patrol (D-3). The tests were conducted between March 15 and May 30 of 1972, at numerous locations in the state. Odometer readings were recorded for each of the model years. An average age was calculated for each of the model years at the time of the test (for example, the average age of 1972 model cars at the mid-time of the test period was .28 years, the average age of 1971 models was 1.06, of 1970 models 2.06, etc.) and plotted as a function of the average odometer reading. The plot is end of the year average ages of vehicles (i.e., 1972 models have an average age of .75 years at the close of 1972; 1971 models are 1.75 years old, etc.). Table D-2 shows a tabulation of odometer readings versus average vehicle age for test data taken in the City of Sacramento. The difference in

Table D-1. Passenger Car Model Distribution (As of December 1972) for San Francisco Air Basin (Reference D-1)

County	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57	Prior to 57
ALAMEDA	47323	45480	43437	48604	43805	37966	38533	40445	34262	27854	21680	13781	11707	8040	4467	5147	18063
CONTRA COSTA	24671	25033	24539	27146	24807	21415	22112	23633	19251	15602	11880	7701	6453	4586	2505	2926	9498
MARIN	9943	10615	9658	11675	10164	8915	8324	8584	6910	5523	4015	2529	2040	1399	843	843	2914
RAPA	3191	3150	3068	3475	3251	2784	3019	3164	2650	2341	1782	1258	979	708	413	456	1773
SAN FRANCISCO	35619	27959	26746	27105	23557	20134	20074	20913	17658	14299	10851	7106	5574	3619	2068	2327	8375
SAN MATEO	40053	27579	25892	28255	25565	22257	22775	23692	19485	15734	11854	7595	6134	4070	2284	2581	8436
SANTA CLARA	54003	49917	47848	54629	49109	43803	44195	45774	38723	32438	24356	15576	12928	9020	4651	5275	16977
SOLANO	7117	7570	7054	7809	6731	5682	6177	6332	5516	4486	3481	2242	2037	1482	852	957	3060
SONOMA	8077	7997	7818	9018	8257	2423	8426	9236	7901	6822	5522	3551	2866	2156	1216	1359	5012
TOTALS (2205400)	230000*	205300	196060	217716	195246	170379	173635	181773	152356	125099	95421	61339	50718	35080	19299	21871	74108
% TOTAL	10.43	9.30	8.89	9.87	8.85	7.72	7.87	8.24	6.90	5.67	4.32	2.78	2.30	1.59	.875	.991	3.36

* This is an adjusted value (was 171471) based on assumption that 1972 model cars are sold at constant linear rate throughout the marketing season (terminating in October 1972).

Table D-2. Distribution of Average Annual Mileage and Cumulative Mileage by Vehicle Age

Vehicle Age	(End of 1972) Odometer	Miles In Preceeding Year
.750	13,400	13,400
1.750	26,500	13,100
2.750	39,300	12,800
3.750	49,800	10,500
4.750	59,100	9,300
5.750	67,300	8,200

Source: Table I of Reference D-3.

odometer readings between successive model years is equivalent to the miles driven by each of the models in the past year (see Table D-2). The mileage driven in the past calendar year versus the actual vehicle age is plotted in Figure D-1. Since the Highway Patrol tests entailed only models of year 1966 and newer, the mileage driven in the past year by older cars was assumed to be the same as that given for the statewide average annual mileage compiled by the State ARB in Reference (D-3). The overall model mileage distribution was presumed to approximate driving patterns in the base year of the study, consequently data was adjusted accordingly.

The weighted annual travel of the different model year light duty vehicles was calculated by multiplying the vehicle model year distribution by the model annual vehicle mileage. These values are tabulated for San Francisco in Table D-3.

2.2 Average Vehicle Speed in Region

The speed adjustment factor, used in the emission calculation, is determined by the pollutant type and the average vehicle travel speed in the region. The value is given by Figures 1, 2, and 3 of Reference (D-1).

2.3 Emission and Deterioration Factors

The light duty vehicle emission rates must reflect the special case in California where earlier and stricter emission standards have been

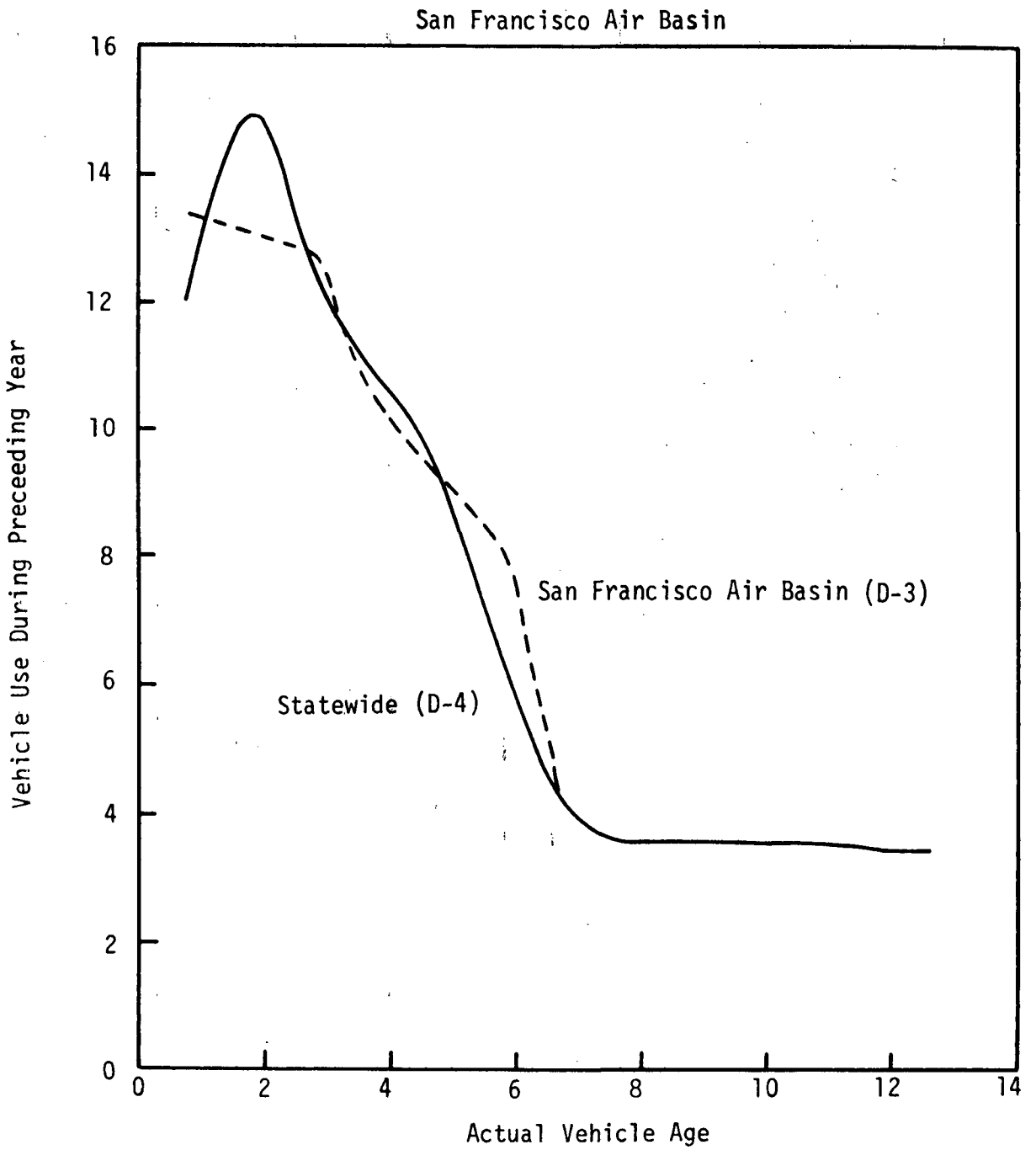

Figure D-1. Vehicle Miles Driven Per Year Versus Age of Vehicle (References D-3 and D-4)

Table D-3. Weighted Annual Travel by Model Year and Total Annual Travel for Light Duty Vehicles San Francisco Air Basin for Base Year 1971

Model Year	Vehicle Age Dist.	Total Cars	Annual VMT in Preceding Year[b]	Weighted Miles Driven In Preceding Year	% Of Total Of All Vehicle Mileage	Total VMT In Preceding Year
71	10.43	293685	13400	1396	.175	3.935×10^{9}
70	9.30	261867	13100	1218	.153	3.430×10^{9}
69	8.89	250322	12800	1136	.143	3.204×10^{9}
68	9.87	277917	10500	1036	.130	2.918×10^{9}
67	8.85	249196	9300	823	.103	2.317×10^{9}
66	7.72	217377	8200	633	.079	1.783×10^{9}
65	7.87	221601	4400	346	.043	9.750×10^{8}
64	8.24	232020	3700	305	.038	8.585×10^{8}
63	6.90	194289	3600	248	.031	6.994×10^{8}
62	5.67	159655	3650	207	.026	5.827×10^{8}
61	5.32	121642	3600	156	.020	4.379×10^{8}
60	2.78	78278	3550	99	.012	2.779×10^{8}
59	2.30	64763	3500	80	.010	2.267×10^{8}
58 & Prior	6.82	192036	3500	238	.030	6.711×10^{8}
TOTAL		2814648 (a)		7921	.993	2.232×10^{10}

(a) State Motor Vehicle Department registration data for automobiles. The data was adjusted to include light duty commercial vehicles not included in the "automobile" registrations.

(b) References D-3 and D-4.

implemented. The essential elements of the California control program include the following:

- Crankcase emission control on all new gasoline-powered vehicles

- Exhaust emission standards on all new vehicles, both diesel and gasoline powered. These controls will be increasingly stringent through the 1975 model year. After 1975, all light duty vehicles must meet strict federal standards.

- Fuel evaporative emissions standards on 1970 and later model gasoline-powered light duty vehicles, and 1973 and later heavy duty vehicles.

- Assembly-line testing of all light duty vehicles to be sold in California after January 31, 1973.

- Crankcase emission control devices required on 1955-1963 model cars upon transfer of ownership in 13 of the state's more populous counties.

- Exhaust control devices required on 1955 to 1965 model year light duty vehicles upon transfer of ownership in the South Coast, San Diego and San Francisco Air Basins (the latter Basin after March 1, 1973). These devices reduce emissions of hydrocarbons and oxides of nitrogen

- Exhaust control devices for oxides of nitrogen will be required on 1966 to 1970 vehicles on an installation schedule starting February 1, 1973.

Exhaust emission factors for the light duty vehicle population in future years or the base year is dependent on the degree to which scheduled emission control programs will have been implemented in the year being considered.

Base year emission factors, by model and pollutant, were determined from results of vehicle emission tests performed according to the 1972 Federal Certification Test Procedure. The exhaust emission factors are shown in Table D-4 for the base year. Table D-5 is a tabulation of exhaust factors effective after July 1974 when all used light duty vehicles of the model years 1966 to 1970 will have been equipped on schedule with exhaust gas recirculation control devices for oxides of nitrogen and a portion of the 1955 to 1965 light duty vehicles will have been equipped

Table D-4. CO, THC, and NO_x Light Duty Vehicle Exhaust Emission Factors for the State of California Base Year 1971 (Reference D-1)

Model Year	Exhaust Emission Factors at Low Mileage (Grams/Mi) CO	THC	NO_x
Pre-1966	87	8.8	3.6
1966	51	6.0	3.4
1967	50	4.6	3.4
1968	46	4.5	4.3
1969	39	4.4	5.5
1970	36	3.6	5.1
1971	34	2.9	3.5

Table D-5. CO, THC, and NO_x Light Duty Vehicle Exhaust Emission Factors for San Francisco Effective After July 1974 (Reference D-1)

Model Year	Exhaust Emission Factors at Low Mileage (Grams/Mi) CO	THC	NO_x
Pre-1966	60.0	6.6	1.9
1966	35.2	5.3	1.8
1967	34.5	4.1	1.8
1968	31.7	4.0	2.2
1969	26.9	3.9	2.9
1970	24.8	3.2	2.7
1971	34.0	2.9	3.5
1972	19.0	2.7	3.5
1973	19.0	2.7	2.3
1974	19.0	2.7	2.3
1975	4.8	.5	2.3
1976 and later	1.8	.23	.31

with the vacuum spark advance disconnect (VSAD) device. These factors are used for calculation of projected baseline emissions. The calculation of emissions for model 1955 to 1965 light duty vehicles must include an adjustment for the fraction of the vehicle fleet which has not been retrofitted by 1975, 1977, and 1980. The retrofit is required upon change of vehicle ownership, assumed to be 25 percent per year (D-5). With the retrofit beginning in early 1973 for all domestic light-duty vehicles (82 percent), by 1975 the fraction of 1955 to 1965 vehicles with the VSAD device will be .82 [.25+.25 (1-.25)] = .36. In 1977 the fraction will be .82 [.44+.25 (1-.44) +.25 (1-.25 (1-.44))] = .56. Similarly in 1980, .70 of the designated model fleet will be retrofitted.

Deterioration factors expressing the rate of increase of the light-duty vehicle emission factors with model age, are available from Reference (D-1). These factors are taken to be constant for the base year as well as the projected years (the operation of the exhaust gas recirculation device add on is presumed not to exhibit a deteriorating characteristic).

The values in Table D-5 are adjusted to reflect the VSAD device scheduled for installation on model 1966 to 1970 light duty vehicles by July 1974. It also reflects a recent revision in standards requirements for CO and THC for 1975 model vehicles.

Reduction of emissions attributed to the VSAD installation were determined from direct communication with the EPA District 9 Office, as were the revised emission standards for 1975 model vehicles.

Crankcase and evaporative emission factors are given in Table D-6 and apply for both the base year and projected years. These values reflect the California standards for evaporative emissions on 1970 and later light duty vehicles and crankcase emission control on all vehicles.

The emission values are given for low mileage non-deteriorated vehicle operation. Deterioration factors by model year and pollutant are used to account for the aging or deterioration of exhaust emission control devices. The deterioration factors also reflect the special case in California where earlier promulgation of emission standards occurred.

Table D-6. Light Duty Crankcase and Evaporative Hydrocarbon Emissions by Model Year in California Base Year and Projected Years (Reference D-1)*

Model Year	LDV Hydrocarbons
Pre-1960	3.0
1961-1963	3.0
1964-1967	3.0
1968-1969	3.0
1970-1971	.5
1972	.2
1973 on	.2

2.4 Total VMT

Total VMT in the region is determined either from: 1) calculation of the product of total registered vehicles by model and VMT per year by model, or 2) transportation studies performed in the area. The calculation of VMT from model and VMT distribution is shown in Table D-3. VMT estimates based on studies performed by the MTC were considered to be the most valid input for VMT (D-6). These figures were available from regional transportation studies performed in the San Francisco Basin. The VMT values were used in calculation of total emissions from light duty vehicles in the San Francisco Basin.

2.5 Computer Calculation of Emissions

The parameters of the foregoing discussion are determined in the context of a specified pollutant, emission type (exhaust, evaporative, or crankcase), and year n, and inserted in the relation

$$s_p \, (VMT)_n \sum_{i=(n-12)}^{n+1} c_{ip} \, d_{ipn} \, m_{in} \quad \text{or} \quad (VMT)_n \sum_{i=(n-12)}^{n+1} h_i \, m_{in}$$

to compute total emissions. Emissions are calculated for

n = base year, 1975, 1977, and 1980.

p = THC, RHC, CO, and NO_x (see Section for discussion of hydrocarbon reactivity).

*The values extracted from this document were adjusted to reflect the installation of PCV crankcase devices on pre-1963 vehicles. The emission factor of 3.0 was obtained by communication with the EPA Region 9 Office.

Computer printout sheets for hydrocarbon, carbon monoxide, and oxides of nitrogen emissions for 1972 are shown in Figures D-2, D-3, and D-4, respectively. These case examples give the exhaust and crankcase/evaporative emissions in the base year for each of the three major pollutants generated by light-duty vehicles for the San Francisco Basin study. The input data for each model year vehicle is shown in table form for each case. The values for average speed and daily vehicle miles traveled are shown along with the output data display at the bottom of the sheet. The emission rate, expressed in grams per mile, is an average rate for all light-duty vehicle model years. The total emission for each case is shown in tons per year and tons per day.

2.6 Projected Emissions in Future Years

The calculation of emissions for future years involves a projection of deterioration factors, emission factors, and weighted annual vehicle travel for future model vehicles, and VMT and average traffic speed in the future years of interest. The deterioration and emission factors in future years are estimated by considering vehicle controls which are scheduled for future implementation, and adjusting the factors accordingly. Since regional projections of vehicle model year distribution and annual mileage by model are not available, the weighted annual vehicle travel distribution for future years was assumed to remain unchanged from that presently used. It is noted that rather constant historical patterns in motor vehicle sales justify this assumption as a feasible estimate. Projected VMT and average traffic speeds are available from transportation studies conducted by the Metropolitan Transportation Commission (D-6). This information has been tabulated and is shown in Table D-7.

Baseline emission calculation results are presented in Section 3.3.3 of this report.

Table D-7. Summary of Vehicular Travel, San Francisco Air Basin (Reference D-6)

Vehicle Type	Vehicle Miles of Travel (In Thousands of Miles)			
	1971	1975	1977	1980
Light duty vehicles	57,783	67,311	72,051	79,197
Heavy duty vehicles	4,017	4,679	5,009	5,506
Total, LDV and HDV	61,800	71,990	77,060	84,703
Average speed, mph	39	40.3	41.1	42.0

YEAR	c_{ip}	d_{ipn}	m_{in}	h_i	s_p
1971	2.90	1.00	.176	.50	.63
1970	3.60	1.05	.154	.50	.63
1969	4.40	1.16	.143	3.00	.63
1968	4.50	1.21	.131	3.00	.63
1967	4.60	1.14	.104	3.00	.63
1966	6.00	1.29	.080	3.00	.63
1965	8.80	1.00	.044	3.00	.63
1964	8.80	1.00	.038	3.00	.63
1963	8.80	1.00	.031	3.00	.63
1962	8.80	1.00	.026	3.00	.63
1961	8.80	1.00	.020	3.00	.63
1960	8.80	1.00	.012	3.00	.63
1959	8.80	1.00	.010	3.00	.63
1958	8.30	1.00	.030	3.00	.63

AVERAGE SPEED = 39.00
HYDROCARBON EXHAUST EMISSIONS = 3.51 G/M
CRANKCASE AND EVAP LOSSES = 2.17 G/M
TOTAL = 5.68 G/M
DAILY VEHICLE MILES TRAVELLED = 57783.00 THOUSAND MILES
TOTAL YEARLY HYDROCARBON EMISSIONS = 132070.46 TONS
TOTAL DAILY HYDROCARBON EMISSIONS = 361.84 TONS

Figure D-2. San Francisco Basin - Estimated Hydrocarbon Baseline Emissions from Light Duty Vehicles in 1971

YEAR	c_{ip}	d_{ipn}	m_{in}	s_p
1971	34.00	1.00	.176	.56
1970	36.00	1.18	.154	.56
1969	39.00	1.53	.143	.56
1968	46.00	1.41	.131	.56
1967	50.00	1.29	.104	.56
1966	51.00	1.28	.080	.56
1965	87.00	1.00	.044	.56
1964	87.00	1.00	.038	.56
1963	87.00	1.00	.031	.56
1962	87.00	1.00	.026	.56
1961	87.00	1.00	.020	.56
1960	87.00	1.00	.012	.56
1959	87.00	1.00	.010	.56
1958	87.00	1.00	.030	.56

AVERAGE SPEED = 39.00
CARBON MONOXIDE EMISSIONS = 33.56 G/M
DAILY VEHICLE MILES TRAVELLED = 57783.00 THOUSAND MILES
TOTAL YEARLY CARBON MONOXIDE EMISSIONS = 780137.29 TONS
TOTAL DAILY CARBON MONOXIDE EMISSIONS = 2137.36 TONS

Figure D-3. San Francisco Basin - Estimated Carbon Monoxide Baseline Emissions from Light Duty Vehicles in 1971.

YEAR	c_{ip}	d_{ipn}	m_{in}	s_p
1971	3.50	1.00	.176	1.24
1970	5.10	1.00	.154	1.24
1969	5.50	1.00	.143	1.24
1968	4.30	1.00	.131	1.24
1967	3.40	1.00	.104	1.24
1966	3.40	1.00	.080	1.24
1965	3.60	1.00	.044	1.24
1964	3.60	1.00	.038	1.24
1963	3.60	1.00	.031	1.24
1962	3.60	1.00	.026	1.24
1961	3.60	1.00	.020	1.24
1960	3.60	1.00	.012	1.24
1959	3.60	1.00	.010	1.24
1958	3.60	1.00	.030	1.24

AVERAGE SPEED = 39.00
NITROGEN OXIDES EMISSIONS = 5.12 G/M
DAILY VEHICLE MILES TRAVELLED = 57783.00 THOUSAND MILES
TOTAL YEARLY NITROGEN OXIDES EMISSIONS = 118974.81 TONS
TOTAL DAILY NITROGEN OXIDES EMISSIONS = 325.96 TONS

Figure D-4. San Francisco Basin - Estimated Nitrogen Oxides Baseline Emissions from Light Duty Vehicles in 1971

2.7 Control Measures

Three vehicle emission control measures were investigated for their impact on total light duty vehicle emissions. These were 1) a retrofit of 200 percent of 1966 to 1970 model light duty vehicles, and 75 percent of 1971 to 1974 model light duty vehicles, with an oxidizing catalytic converter, 2) a retrofit of 95 percent (assumed based on expected approval of applicable devices in near future) of the light duty 1955 to 1965 vehicle population by 1975 with a spark advance disconnect (whereas the baseline control provides for retrofit of domestic cars upon change of ownership), and 3) an inspection and maintenance idle test program for all light duty vehicles. The anticipated emission reductions expected for those vehicles targeted for catalytic converter installations is 50 percent for THC and CO, and zero percent for nitrogen oxides (D-7). The revised implementation schedule and coverage for VSAD add-on control for 1955 to 1965 will result in emission reductions (in percent) which are equivalent to the difference between a retrofit population adjustment factor of .95 and that factor which was previously used for each of the baseline years under the prior implementation plan. The inspection/maintenance idle test program is expected to provide a six percent reduction in total hydrocarbons and a three percent reduction in carbon monoxide (D-7). These reductions are based on an expected ten percent initial failure rate occurring during the idle test inspection. The subsequent mandatory maintenance of the vehicles found to be in violation would result in the stated emission reductions.

The overall impact of these two control measures on the baseline emission values are computed by applying the reduction factors to the appropriate model year emission factors. The results are summarized in Section 3.3.3.

3. HEAVY DUTY GASOLINE POWERED VEHICLE EMISSIONS

Heavy-duty gasoline powered vehicle emissions are calculated using the same procedure as that for light-duty vehicle emissions.

3.1 Emission and Deterioration Factors

The heavy-duty vehicle emission rates reflect the special case in California where earlier and stricter standards have been implemented.

Exhaust emission factors are given in Table D-8.

Table D-8. Heavy Duty Gasoline-Powered Vehicle Exhaust Emission Factors, California Only (Reference D-1)

Model Year	Carbon Monoxide Gm/Mi	Exhaust Hydrocarbons Gm/Mi	Nitrogen Oxides Gm/Mi
Pre-1970	140	17.0	9.4
1970-1971	130	16.0	9.2
1972	130	13.0	9.2
1973-1974	130	13.0	9.2
1975	81	4.1	2.8

Crankcase and evaporative emission rates are shown in Table D-9.

Table D-9. Heavy Duty Gasoline-Powered Vehicle Crankcase and Evaporative Hydrocarbon Emissions by Model Year for California (Reference D-1)*

Model Year	Hydrocarbons, (Gm/Mi)
Pre-1960	3.0
1961-1963	3.0
1964-1967	3.0
1968-1969	3.0
1970-1971	3.0
1972	3.0
1973 on	0.8

Due to a lack of actual heavy-duty deterioration information, light-duty deterioration values are used for controlled heavy-duty vehicles, with control by model year offsets. (1968 light-duty figures are used for 1973 and later controlled heavy-duty vehicles). The deterioration factors are tabulated from the light-duty deterioration tables of Reference (D-1).

3.2 Heavy Duty Vehicle Speed and VMT

Average speed and heavy-duty vehicle VMT data are available from transportation studies conducted by the MTC (D-6). Table D-5 of the previous section gives the breakdown of heavy duty VMT and speed for the base year and projected years in the San Francisco Basin. The speed emission adjustment factor is determined using the same technique as for light duty vehicles.

*The values extracted from this document were adjusted to reflect the installation of PCV crankcase devices on pre-1963 vehicles. The emission factor 3.0 was obtained by communication with the EPA Region 9 Office.

3.3 Model Year Distribution

The heavy duty vehicle model year distribution was determined from published vehicle registration data from the Department of Motor Vehicles (D-8). This vehicle data is segregated in terms of automobiles and commercial vehicles. While the commercial vehicle tabulation was known to include a large number of light duty vehicles, such as pickups and vans (and also includes diesel-powered trucks), it's model year distribution was considered to be representative of the heavy duty vehicle distribution. Table D-10 contains the commercial vehicle model distribution for the year 1972. The distribution is calculated for statewide values since a distribution is not available for the particular region under consideration.

The annual mileage distribution of heavy-duty gasoline powered vehicles is shown in Table D-10. The distribution is obtained from the publication "1971 Motor Truck Facts" (D-9). Weighted annual travel by model is determined as indicated in Table D-10.

Heavy duty vehicle mileage data must be manipulated to segregate diesel from gasoline powered motive types (diesel-powered trucks average greater annual mileage and emit at different rates than gasoline-powered trucks). Based on the Motor Vehicle Department Gross Report (D-10), it is determined that 225,653 vehicles were registered as vehicles rated over 6,000 pounds (or "heavy duty") at the end of 1972. Of these vehicles, 66,970 are diesel-powered. Additional information from Motor Vehicle Statements of transactions (D-11) shows another 14,000 diesel vehicles were exempt from state registration (state, county, or government-operated vehicles). It was therefore estimated that a proportionate number

$$\left(\frac{14{,}000}{66{,}970} \times 225{,}653 = 47{,}172\right) \text{ (Reference D-9)}$$

of unlimited heavy-duty gasoline powered vehicles fell within this category.

Those vehicles which come from out-of-state, yet perform their travel within California boundaries, account for 28,000 more commercial vehicles, of which 50 percent are assumed to be diesels. Consequently, total heavy duty diesel vehicles in California (end of 1972) total 94,800, and all heavy duty vehicles (gasoline and diesel) total 300,825. Hence 68.5 percent of all heavy duty vehicles are gasoline-powered.

Table D-10. Commercial Vehicle Model Year Distribution

Model Year	Total Registered Commercial Vehicle [a]	Fraction of Total Vehicles	Miles Driven in Preceding Year [b]	Weighted Miles Driven in Preceding Year	Fraction of Total of all Vehicle Mileage
	California, 1972				
72	182609	.0950	7500	713	.073
71	159155	.0827	10000	827	.0847
70	149022	.0775	10000	775	.0794
69	162294	.0844	10000	844	.0864
68	142569	.0741	10000	741	.0758
67	110410	.0574	10000	574	.0587
66	119853	.0623	10000	623	.0638
65	116632	.0606	10000	606	.062
64	111162	.0578	10000	578	.0592
63	90743	.0472	10000	472	.0483
62	70534	.0367	10000	367	.0375
61	53385	.0278	10000	278	.0284
60	59446	.0309	10000	309	.0316
59 & Prior	395488	.2056	10000	2056	.2105
TOTAL	1923302	1.00		9763	

(a) Reference D-8

(b) Reference D-9

The foregoing relationships were used to adjust the state motor vehicle registration data to determine the gasoline-powered heavy-duty vehicle population model distribution. Total regional VMT for the San Francisco Basin was then calculated as shown on Table D-11.

This value of VMT was then related to that calculated for diesel powered heavy-duty vehicles (see following section) to establish the portion of all heavy-duty VMT (as given by transportation studies in the region) which is diesel or gasoline powered. Using this approach, it was determined that gasoline powered heavy-duty vehicles account for 39.3 percent of all heavy-duty travel miles. This percentage (assumed to be the same in future years) was then applied to VMT estimates for the area, given only in terms of either light or heavy-duty mileage, to establish the miles driven by the gasoline heavy-duty vehicles. Subsequently, this value was incorporated with other pertinent vehicle data (discussed earlier in this section) to calculate baseline emissions. The results of these computations are presented in Section 3.3.3.

3.4 Heavy-Duty Diesel Powered Vehicles

Emissions resulting from operation of heavy-duty diesel powered vehicles are calculated in a similar manner as gasoline powered heavy-duty vehicles.

Emission factors for uncontrolled diesel powered heavy-duty vehicles are available from Table 3-2 of EPA Document AP-42 (D-12). These factors apply to vehicles prior to 1975 models. In 1975 and thereafter, new standards apply. The new standards will limit diesel exhaust emission to 1.05 grams THC per mile, and 2.270 grams CO per mile. Evaporative and crankcase emissions for diesels are considered negligible in the totals.

The effect of deterioration on exhaust emissions from diesel vehicles is considered negligible.

Total VMT is calculated as shown in Table D-12. The value is related to that calculated for heavy-duty gasoline powered vehicle VMT in order to determine the portion of total heavy-duty VMT each vehicle motive-type accounts for. This ratio is computed because VMT data (to be used in

Table D-11. VMT for Heavy Duty Gasoline Powered Vehicles for (Base Year 1971) San Francisco Air Basin

Model Year	Vehicle Model Distribution	(B) Total Vehicles		(C) VMT per Vehicle in Preceding year[b]	B x C Total VMT in Preceding Year
71	.095	3732		7500	27.99×10^6
70	.0827	3249		10000	
69	.0775	3044		10000	
68	.0844	3315		10000	
67	.0741	2911		10000	
66	.0574	2255		10000	
65	.0623	2447		10000	
64	.0606	2380	35599	10000	355.490×10^6
63	.0578	2270		10000	
62	.0472	1854		10000	
61	.0367	1442		10000	
60	.0278	1092		10000	
59 & Prior	.0309	1214		10000	
TOTAL		39281[a]			383.480×10^6

(a) Reference D-8. The commercial vehicle total for this region was adjusted to reflect only heavy duty vehicles which are gasoline powered.

(b) Reference D-9

Table D-12. Calculated VMT for Heavy-Duty Diesel Powered Vehicles - San Francisco Air Basin

	Model Year	Model Distribut.[a]	B Total Vehicles	C VMT per Vehicle in Preceding Year[c]	B X C Total VMT in Preceding Year
Base Year 1971	1972 & 1971	.105	1,897	14,000	26.558×10^6
	1970 and prior	.895	16,172	35,000	566.020×10^6
		TOTAL	18,069[b]		592.578×10^6

(a) Vehicle model distribution assumed same as for heavy-duty gasoline powered vehicles.

(b) Reference D-8. This vehicle data for Sacramento region was adjusted to reflect only heavy-duty vehicles which are diesel-powered.

(c) Reference D-4.

emission calculations) is expressed as overall mileage by all heavy-duty VMT which is generated by diesel type vehicles. The result is that 60.7 percent of all heavy-duty travel is performed by diesels. This value is assumed to remain constant in future years.

Table D-13 demonstrates the organization of pertinent data and calculations required to obtain the baseline hydrocarbon emissions. Projected emissions are calculated based on VMT predictions for heavy-duty VMT provided by MTC studies (D-6). Computations of baseline CO and NO_x emissions were carried out in the same fashion and are given in Section 3.3.3.

4. MOTORCYCLES

Baseline motorcycle emissions for RHC are computed as illustrated in Tables D-14 and D-15. The motorcycle population is segregated into two classifications: two-stroke motorcycles, and four-stroke motorcycles. Two-stroke motorcycles constitute 38 percent of the statewide population of licensed motorcycles (D-13). The overall motorcycle population for a given region is determined from Motor Vehicle Department registration data (D-14). Projected cycle population in future years is determined by a mathematical correlation of cycles with projected personal income in the region (see Appendix B). Neither the projected nor the present population figures reflect the unlicensed off-road motorcycles which number approximately one-third of the registered motorcycle population (D-15). Off-road motorcycles were eliminated from the emission analysis, however, as it was felt that their remote operation in rural areas plays a negligible role in the total air pollution problem.

Emission factors for two-stroke and four-stroke motorcycles were derived from the seven-mode test procedure of California, and are given in Reference D-4. Exhaust, crankcase, and evaporative emission factors were combined together since it was known that the rigor of maintaining separate computations for the emission category would have a minor effect on the outcome of reactive hydrocarbon emissions, and have no effect on CO or NO_x (crankcase and evaporative losses represent hydrocarbon emissions only). This is true for the case of reactive hydrocarbons because: 1) The crankcase and evaporative emissions are

Table D-13. Diesel Baseline RHC Emissions - San Francisco Bay Area

Year Considered	Model Year	(A) % of Total Models[a]	(B) Annual VMT per Vehicle[b]	A x B Weighting Factor for VMT per year	% of all Vehicle Mileage	(A) Total VMT per Day	(D) Hydrocarbon Emission Factor[c] gm/mi	(C) Conversion Factor x Reactivity Factor	(AxBxC) Emissions tons/day
1970	71 & 70	.105	14,000	1,470	.044	108,683	3.36	$1.10 \times 10^6 \times .99$(d)	.402
	67 & prior	.895	35,000	31,325	.955	2,358,938	3.36	$1.10 \times 10^6 \times .99$(d)	8.718
				32,795		2,467,621			9.120
1975	76 & 75	.105	14,000	1,470	.044	147,753	1.05	$1.10z10^6 \times .99$(d)	.147
	75 & prior	.895	35,000	31,325	.955	2,757,925	3.36	$1.10 \times 10^6 \times .99$(d)	10.193
						2,905,678			10.340
1977	78 & 77	.105	14,000	1,470	.044	136,262	1.05	$1.10 \times 10^6 \times .99$(d)	.158
	76 & 75	.168	35,000	5,880	.179	554,338	1.05	$1.10 \times 10^6 \times .99$(d)	.640
	75 & prior	.727	35,000	25,445	.775	2,400,066	3.36	$1.10 \times 10^6 \times .99$(d)	8.870
				32,795		3,090,666			9.668
1980	81 & 80	.105	14,000	1,470	.044	150,080	1.05	$1.10 \times 10^6 \times .99$(d)	.173
	79 75	.380	35,000	13,300	.405	1,381,149	1.05	$1.10 \times 10^6 \times .99$(d)	1.595
	74 & prior	.515	35,000	18,025	.549	1,872,223	3.36	$1.10 \times 10^6 \times .99$(d)	6.920
						3,403,422			8.688

(a) Calculated in Table D-1.

(b) Total VMT based on transportation studies by Division of Highways (D-6). These values are in terms of all heavy duty vehicles and must be adjusted (60.7% diesel) to reflect only diesel population.

(c) EPA preliminary issue of emission factors to be incorporated in revision of EPA document AP-42 (D-7).

(d) .99 = reactivity factor obtained from verbal communication with EPA (D-16).

Table D-14. Motorcycle (2 Stroke) RHC Baseline Emissions - San Francisco Air Basin

Year	(A) Motorcycle Population[a]	(B) Miles per Year[b]	(C) Emission Factor gm/mi[c]	(D) Conversion Factor tons/year gm/day	(E) Reactivity Factor[d]	Overall Factor (CxDxE)	Total Miles per Year	Emissions tons/day
1971	47,032	4000	15.35	3.02×10^{-9}	.96	44.5×10^{-9}	188×10^{6}	8.36
1975	57,767	4000	15.35	3.02×10^{-9}	.96	44.5×10^{-9}	231×10^{6}	10.3
1977	66,292	4000	15.35	3.02×10^{-9}	.96	44.5×10^{-9}	265×10^{6}	11.8
1980	78,085	4000	15.35	3.02×10^{-9}	.96	44.5×10^{-9}	312×10^{6}	13.9

(a) Based on MVD data (D-14), and projections based on TRW regression-correlation with regional personal income (see Appendix E).

(b) Reference D-17.

(c) Emission Factor of 4.35 is made up of 3.3 exhaust, .7 crankcase, and .35 evaporative emissions (D-4).

(d) Private communication with EPA (D-16), during which preliminary reactivity factors for motorcycle hydrocarbon emissions were issued.

NOTE: 4 strokes constitute 62% of cycle population (based on EPA tech support document for metrop. L.A. region)

Table D-15. Motorcycle (4 Stroke) RHC Baseline Emissions - San Francisco Air Basin

Year	(A) Motorcycle Population[a]	(B) Miles per Year[b]	(C) Emission Factor gm/mi[c]	(D) Conversion Factor tons/year gm/day	(E) Reactivity Factor[d]	Overall Factor (CxDxE)	Total Miles per Year	Emissions tons/day
1971	76,738	4000	4.35	3.02×10^{-9}	.86	11.3×10^{-9}	306×10^{6}	3.5
1975	94,252	4000	4.35	3.02×10^{-9}	.86	11.3×10^{-9}	377×10^{6}	4.3
1977	108,161	4000	4.35	3.02×10^{-9}	.86	11.3×10^{-9}	433×10^{6}	4.9
1980	127,404	4000	4.35	3.02×10^{-9}	.86	11.3×10^{-9}	510×10^{6}	5.8

(a) Based on MVD data (D-14), and projections based on TRW regression-correlation with regional personal income (see Appendix E).

(b) Reference D-17.

(c) Emission Factor of 4.35 is made up of 3.3 exhaust, .7 crankcase, and .35 evaporative emissions.

(d) Private communication with EPA (D-16), during which preliminary reactivity factors for motorcycle hydrocarbon emissions were issued.

Note: 4 strokes constitute 62% of cycle population (based on EPA tech support document for metropolitan L. A. region).

relatively small in comparison to exhaust emissions, and 2) the reactive factors for crankcase, evaporative, and exhaust hydrocarbons are not substantially different (D-16).

Since exhaust emissions from motorcycles are uncontrolled, and no controls are scheduled, the effect of deterioration on exhaust emissions was considered negligible.

The miles driven per year were estimated to be the same for all models at 4,000 (D-17) and were assumed to remain unchanged in future years.

Based on the information above, two-stroke and four-stroke motorcycle emissions were computed for the case of hydrocarbon, CO, and NO_x pollutants. The overall results are tabulated in Section 3.3.3.

5. REFERENCES

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D-15. Automotive Environmental Systems, "Uncontrolled Vehicle Emission Study for the California Air Resources Board," Interim Report.

D-16. Private communication with EPA regarding preliminary reactivity factors for motorcycle and diesel hydrocarbon emissions.

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APPENDIX E

AIRCRAFT EMISSIONS

1. GENERAL APPROACH

The basic equation used for calculating aircraft emissions of total hydrocarbon, carbon monoxide, and oxides of nitrogen for a specific aircraft class is as follows:

Emissions of a specific pollutant =

emission factor for the aircraft class	x	number of engines on aircraft in the class	x	number of LTO cycles performed by the aircraft class

Emission factors are documented by the EPA (E-1) in terms of pounds of pollutant emitted per engine per Landing Takeoff (LTO) cycle and are presented in Table E-1. If types of aircraft within a class have different numbers of engines, an average number for the class may be used, or the LTO for the class may be segregated according to engine number.

The number of LTO cycles performed by each type of aircraft within a region must be known or estimated for the base year associated with that region. The aircraft classes designated by EPA are shown in Table E-2.

One special case of base year emission calculations differs from EPA emission factor documentation. This special case involves Aircraft Class 3 only, and results from the fact that aircraft in this class (primarily Boeing 727's, 737's, and Douglas DC-9's) underwent a burner can retrofit program from 1970 to 1972. Although the object of this program was to reduce the exhaust smoke from these aircraft, additional effects were the reduction of hydrocarbon and carbon monoxide emissions, and the increase of oxides of nitrogen emissions. The emission factors before and after the program were as follows (E-2):

	THC	CO	NO_x
Pre-retrofit	4.9 lb/engine/LTO	20.0 lb/engine/LTO	10.2 lb/engine/LTO
Post-retrofit	3.5 lb/engine/LTO	17.0 lb/engine/LTO	12.2 lb/engine/LTO

Table E-1. Emission Factors Per Landing-Takeoff Cycle for Aircraft (Lbs/Engine and Kg/Engine) (Reference E-1)

Aircraft Class	Total Hydrocarbons		Carbon Monoxide		Nitrogen Oxides	
	Lb	Kg	Lb	Kg	Lb	Kg
1	12.2	5.5	46.8	21.2	31.4	14.2
2	41.2	18.7	47.4	21.5	7.9	3.6
3	4.9[a]	2.2[a]	20.0[a]	9.0[a]	10.2[a]	4.6[a]
4	2.9	1.3	6.6	3.0	2.5	1.1
5	3.6	1.6	15.8	7.17	1.6	.73
6	1.1	.5	3.1	1.4	1.2	.54
7	0.40	.18	12.2	5.5	0.047	.021
8	40.7	18.5	304.0	138.0	.40	.18
9	.52	.24	5.7	2.6	.57	.26
10	2.7	1.2	5.7	2.6	2.2	1.0
11	9.93	4.5	15.1	6.85	3.29	1.49
12	20.4	9.3	152.0	69.0	.20	.09

[a] This value describes emissions prior to burner can retrofit.

Table E-2. EPA Aircraft Classification
(Reference E-1)

Aircraft Class Number	Aircraft Class Name	Example Aircraft and Number of Events	Engines Most Commonly Used
1	Jumbo Jet	Boeing 747 (4) Lockheed L-1011 (3) McDonald Douglas DC-10 (3)	Pratt & Witney JT-9D
2	Long Range Jet	Boeing 707 (4) McDonald Douglas DC-8 (4)	Pratt & Witney JT-3D
3	Medium Range Jet	Boeing 737, 727 McDonald Douglas DC-9 (2)	Pratt & Witney JT-8D
4	Air Carrier Turboprop	Convair 580 (2) Electra L-188 (4) Fairchild Hiller FH-227 (2)	Allison 501-D13
5	Business Jet	Lockheed Jetstar (2)	General Electric CJ610 Pratt & Witney JT-12A
6	General Aviation Turboprop	----------	Pratt & Witney PT-6A
7	General Aviation Piston	Cessna 210 (1) Piper 32-300 (1)	Teledyne-Continental Ø-200 Lycoming Ø-320
8	Piston Transport	Douglas DC-6 (4) CONV 440 (2)	Pratt & Witney R-2800
9	Helicopter	Sikorsky S-61 (2) Vertol 107 (2)	General Electric CT-58
10	Military Transport	Lockhead (C-130) (4)	Alliston T56A7 (T-PROP)
11	Military Jet	----------	General Electric J-79 Continental J-69
12	Military Piston	----------	Curtiss-Wright R-1820

It was assumed, for simplicity, that the program proceeded at a constant rate through the three year period. Thus, in mid-year 1970, for example, the program was 1/6 complete, and the average emission factors for this base year were:

THC: 4.9 lb/engine/LTO - 1/6 x (4.9 - 3.5) lb/engine/LTO = 4.7 lb/engine/LTO

CO: 20.0 - 1/6 x (20.0 - 17.0) = 19.5

NO_x: 10.2 - 1/6 x (10.5 - 12.2) = 10.5

The emission factors for all three base years of concern in this study are given in Table E-3 for Class 3 aircraft.

Table E-3. Emission Factors for Class 3 Aircraft

Pollutant	(Units: lb/engine/LTO)		
	1970	1971	1972
THC	4.7	4.2	3.7
CO	19.5	18.5	17.5
NO_x	10.5	11.2	11.9

The equations and data used for projecting aircraft emissions to 1975, 1977, and 1980 are shown in Table E-4. The reader will note that this table does not include information for military aircraft. In some cases, growth data was obtained for particular military air bases; in most cases, however, insufficient data was available for reasonably accurate projections of military aircraft emissions, and operations growth and emission reduction effects in future years were ignored.

The first data column in the table provides estimates (E-2) of engine life for turbines (15 years) and pistons (20 years). The second column lists the equations derived for estimating future emissions from known base year emissions (E_{BY}), growth rate (G), and emission reductions (R). E_{BY} is expressed in terms of tons/day of the pollutant from the indicated aircraft class. G is the fraction increase of base year emissions, except when used in calculating E_{80}, the emissions for 1980, where E_{78} is the synthetic base year, and growth is expressed as a fraction increase

Table E-4. Data for Computation of Projected Civil Aircraft Emissions

Aircraft Class	Engine Life, L (yr)	Emission Equations E (tons/yr)	B.Y.:	Emission Reductions, R (Fraction of Base Year Emissions) HC '70	HC '71	HC '72	HC '78	CO '70	CO '71	CO '72	CO '78	NO_x '70	NO_x '71	NO_x '72	NO_x '78
1. Jumbo Jet	15	$E_{75} = E_{BY}\ (1+G)$		0	0	0	-	0	0	0	-	0	0	0	-
		$E_{77} = E_{BY}\ (1+G)$		0	0	0	-	0	0	0	-	0	0	0	-
		$E_{78} = E_{BY}\ (1+G)$		0	0	0	-	0	0	0	-	0	0	0	-
		$E_{80} = E_{78}\ (1+G\ \ (1-R) - R\ (\frac{2}{L}))$		-	-	-	0.70	-	-	-	0.60	-	-	-	0
2. Long Range Jet	15	$E_{75} = E_{BY}\ (1+G)\ (1-R)$		0.06	0.06	0.06	-	0.015	0.015	0.015	-	(See Class 1)			
		$E_{77} = E_{BY}\ (1+G)\ (1-R)$		0.33	0.33	0.33	-	0.077	0.077	0.077	-				
		$E_{78} = E_{BY}\ (1+G)\ (1-R)$		0.39	0.39	0.39	-	0.093	0.093	0.093	-				
		$E_{80} = E_{78}\ (1+G\ (1-R) - R\ (\frac{2}{L}))$		-	-	-	0.70	-	-	-	0.60				
3. Medium Range Jet	15	$E_{75} = E_{BY}\ (1+G)\ (1-R)$		0.26	0.17	0.05	-	0.13	0.08	0.03	-	-0.03	-0.09	-0.16	-
		$E_{77} = E_{BY}\ (1+G)\ (1-R)$		0.26	0.17	0.05	-	0.13	0.08	0.03	-	-0.03	-0.09	-0.16	-
		$E_{78} = E_{BY}\ (1+G)\ (1-R)$		0.26	0.17	0.05	-	0.13	0.08	0.03	-	-0.03	-0.09	-0.16	-
		$E_{80} = E_{78}\ (1+G\ (1-R) - R\ (\frac{2}{L}))$		-	-	-	0.70	-	-	-	0.60	-	-	-	0
4. Air Carrier Turboprop	15	(See Class 1)		(See Class 1)				(See Class 1)				(See Class 1)			
5. Business Jet	15	(See Class 1)		(See Class 1)				(See Class 1)				(See Class 1)			
6. General Aviation Turboprop	15	(See Class 1)		(see Class 1)				(See Class 1)				(See Class 1)			
7. General Aviation Piston	20	(See Class 1)		0	0	0	-	0	0	0	-	(See Class 1)			
				0	0	0	-	0	0	0	-				
				0	0	0	-	0	0	0	-				
				-	-	-	0.50	-	-	-	0.50				
8. Piston Transport	20	(See Class 1)		-	-	-	-	-	-	-	-	(See Class 1)			
				-	-	-	-	-	-	-	-				
				-	-	-	-	-	-	-	-				
				-	-	-	-	-	-	-	-				
9. Helicopter[a]	15	(See Class 1)		(See Class 1)				(See Class 1)				(See Class 1)			

[a] It is assumed that all have turbine engines.

in emissions from 1978. Similarly, emission reduction is expressed as a fraction decrease of base year emissions for the indicated projection year. The reduction is based on 1978 emissions for calculating projected 1980 emissions. The derivation of values for G and R will be discussed later.

The equations used for Aircraft Class 1 and Classes 4 through 9 are identical. Emissions in 1975, 1977, and 1978 are calculated by simply applying the appropriate growth factor to the base year emissions for each class. Here, 1978 emissions are calculated only for use in projecting 1980 emissions. The expression for E_{80} differs from the preceding equations in the table because of proposed Federal aircraft emission regulations which affect all new engines produced after 1 January 1979 (E-3). This expression contains essentially three terms and was derived as follows:

	1.		2.		3.
1980 Emissions =	1978 emissions	+	emissions increase due to growth in operations	-	emissions reduction due to engine replacement

Term 1: 1978 Emissions = E_{78}, as previously calculated

Term 2: Emissions increase due to growth in operations = $G \times (1-R) \times E_{78}$

(NOTE: Since this growth occurs after the proposed emission regulations come into effect, the growth must be modified by the application of an appropriately reduced emission rate, ergo the (1-R) factor.)

Term 3: Emissions reduction due to engine replacement = $R \times \left(\frac{1980-1978}{L}\right) \times E_{78}$

$$= R \times \left(\frac{2}{L}\right) \times E_{78}$$

where L is the life of the engine. The fraction 2/L represents the fraction of the aircraft engines of a particular class in 1978 which will be replaced with new engines by 1980. This fraction effects a proportionate reduction in emissions, since the replacement engines must comply with the 1 January 1979 emission standards.

Thus, the emissions equation for 1980 reduces to the following:

$$E_{80} = E_{78} \left(1 + G\,(1-R) - R\left(\frac{2}{L}\right)\right)$$

Classes 2 and 3 are special cases as one may observe from Table E-4, because of burner can retrofit programs which effectively reduce hydrocarbon and carbon monoxide emissions and increase (for Class 3) the oxides of nitrogen emissions. These programs affect emissions in 1975 and 1977, and the respective emission equations must show this.

For Class 2, the retrofit program is assumed (E-2) to be planned for the three-year period from 1975 through 1977. It is estimated (E-2) to have the following effect on emission factors:

	THC	CO	NO_x
Pre-retrofit	41 lb/engine/LTO	47.4 lb/engine/LTO	7.9 lb/engine/LTO
Post-retrofit	25 lb/engine/LTO	43.0 lb/engine/LTO	7.9* lb/engine/LTO

The equations used for estimating 1975, 1977, and 1978 emissions were derived as follows, taking the projection year 1975 for the purpose of illustration.

	1.		2.		3.
1975 emissions =	base year emissions	+	emissions increase due to growth in operations	-	emissions reduction due to portion of retrofit program complete by mid-1975

Term 1: Base year emissions = E_{BY}, as calculated for each region

Term 2: Emissions increase due to growth in operations = $G \times E_{BY}$

Term 3: Emissions reduction due to portion of retrofit program complete by mid-1975 =

$$R \times (1+G) \times E_{BY}$$

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* The effect on NO_x emissions is difficult to estimate at this time and is assumed to be negligible.

Where:

R is the appropriate reduction factor for 1975 (discussed later in this text).

Thus,

$$E_{75} = E_{BY} + (G \times E_{BY}) - R \times (1+G) \times E_{BY}$$

$$= E_{BY} (1+G) (1-R)$$

Emissions for 1977 and 1978 are calculated similarly.

For Class 3 aircraft, similar logic leads to identical equations, this time because the retrofit program, as described previously in this text, was at a different stage of completion for each base year used, whether 1970, 1971, or 1972. Thus, the effective reduction in emissions from the base year to 1975, 1977, or 1978 depends on the base year selected.

Emission reductions are shown in Table E-4 for each base year, each projected year, each pollutant, and each aircraft class. Emission reductions effective in 1975, 1977, and 1978 result from the burner can retrofit programs involving Class 2 and Class 3 aircraft, described earlier in the text. All Class 2 aircraft had the same (pre-retrofit) emission factor, regardless whether the base year was 1970, 1971, or 1972. However, the future emission factor depends on the projected year, since the retrofit program is planned for 1975 through 1977. Thus, since the pre-retrofit total hydrocarbon emission factor for Class 2 aircraft was 41 lb/engine/LTO and the post-retrofit emission factor will be 25 lb/engine/LTO, the average emission factor in 1975 will be:

$$41 \text{ lb/engine/LTO} - 1/6 \times (41 - 25) \text{ lb/engine/LTO}$$

and the reduction factor R will be:

$$1/6 \times \frac{(41 - 25)}{41} = 0.06 \qquad \text{(in other words, 6\%)}$$

Reductions for 1977 and 1978 were calculated similarly and appear in Table E-4.

For Class 3 aircraft, the reduction depends on the base year, since the burner can retrofit program was carried out from 1970 through 1972. The emission factors for Class 3 aircraft are shown in Table E-3 for all three base years. Thus, since the post-retrofit total hydrocarbon emission factor is (as was indicated earlier) 3.5 lb/engine/LTO, and the 1970 emission factor was 4.7 lb/engine/LTO, the reduction R for 1975, 1977, and 1978 (i.e., any year after the retrofit program was completed but before new standards come into effect) is:

$$\frac{4.7 \text{ lb/engine/LTO} - 3.5 \text{ lb/engine/LTO}}{4.7 \text{ lb/engine/LTO}} = 0.26$$

Reductions corresponding to the other two base years are shown on Table E-4.

Emission reductions for all classes of aircraft between 1978 and 1980 are a result of the proposed Federal emission standards, to be effective on new turbine and piston aircraft engines starting 1 January 1979. The emissions from each new engine (i.e., each engine manufactured on or after 1 January 1979) will be lower than the emissions from its older (i.e., pre-1979) counterpart by the estimated (E-2) reduction values shown in Table E-4. A reliable estimate for the reduction to be expected for oxides of nitrogen has not yet been developed, and is assumed to be zero for the time being.

The following sections describe how the aircraft emissions were estimated for civilian airports and military air bases, respectively, in the San Francisco Bay Area.

2. CIVILIAN AIRPORTS

The San Francisco Bay Area APCD Study, entitled "The Aviation Effect on Air Quality,"(E-4) is the source of base year and projected data for the three major airports and other smaller airports in the San Francisco Air Basin. The airports represented are San Francisco International, Oakland International, San Jose Municipal, Livermore, Sonoma County, Hayward, Buchanan, Napa County, San Carlos, Palo Alto, Reid-Hillview, and the other small air fields totalled.

The APCD Study provides a description of each airport in terms of Air Carrier and General Aviation activities, and includes an identification of aircraft types within these activities. In order to compute emissions generated by the various aircraft at San Francisco Bay Area airports, each aircraft type has been re-classified (in the analysis of this report) to comply with the EPA aircraft classification. The EPA emission factors were then directly applied to these aircraft classifications (i.e., Classes A, B, and C in the APCD Study are interpreted as equivalent to EPA Class 7 aircraft).

The census data is presented in number of operations per aircraft. The EPA emission factors are expressed in terms of pounds of pollutant per engine per landing-takeoff cycle. In order to apply EPA emission factors directly to census data, two data adjustments are made:

1) Since the data is given in terms of number of operations, where an operation is defined as either a landing or a takeoff, it is therefore divided by 2 to give the number of LTO cycles.

2) Operations data for aircraft with more than one engine is multiplied by the number of engines for complete representation of all engines.

As described in the APCD Study, the present aircraft activity census for each airport is given for the period April 1969 to March 1970. Forecasted aircraft activity is given for the years of 1975, 1980, and 1985. The forecast is made in terms of two types of aviation: general

and commercial air carrier. The basis for the APCD forecast of general aviation activity is the ABAG Technical Memorandum 11-1 (E-5) which provides estimates of future maximum capacity for the San Francisco Bay Area airports. Future commercial air carrier operations are forecasted by reference to the BASAR Aviation Forecast (E-6). In each case, the aviation projections have been provided for the years 1975, 1980, and 1985.

Table E-5 shows the listed general aviation and air carrier operations activity for each airport and for each aircraft class at these airports. The values for 1970, 1975, and 1980 are extracted from the APCD Study (with appropriate conversions to the EPA aircraft classification types). Linear interpolations are performed to determine the aircraft class operations totals for 1971 (the base year), 1977, and 1978.

Table E-5 also shows the activity growth factors, from the designated base year, for each airport and class for 1975, 1977, 1978, and 1980. Growth factors were computed by taking each airport-class operations figures for 1975, 1977, and 1978 and dividing by the 1971 activity figure for each case. One is then subtracted from the quotient to yield growth in terms of the fraction of the base year (1971) operations. The growth factor 1980 is computed on the basis of growth from the 1978 projected activity. The 1978 base was used to accommodate the format for emission projections dictated by the equations of Table E-4, Data for Computation of Projected Civil Aircraft Emissions.

Total hydrocarbon, carbon monoxide, and oxides of nitrogen emissions for the base year 1971 are computed by using the interpolated 1971 operations activity for each class at each airport, and emission factors from a preliminary revision of EPA document AP-42 (E-1). The procedure for calculation is given by:

$$E_{BY} = \frac{\left(A\ \frac{\text{operations}}{\text{year}}\right)\left(\begin{array}{l}\text{pollutant emission factor}\\ \text{in lb/engine/LTO}\end{array}\right)\left(N\ \text{engines}\right)}{\left(365\ \frac{\text{days}}{\text{yr}}\right)\left(2000\ \frac{\text{lbs}}{\text{ton}}\right)\left(2\ \frac{\text{operations}}{\text{LTO cycle}}\right)}$$

where E_{BY} is the base year emission in tons/day for a specified aircraft class, A is the operations activity for the specified aircraft class in

Table E-5. Aircraft Operations Activity for San Francisco Air Basin Base Year and Projected Years (Page 1 of 4)

Airport	Aircraft Class	Total Operations Per Year 1970	1971 Base Year	1975	G, Growth in 75 (fraction of base year value)	Operations Per Year 1977	G, Growth in 77 (fraction of base year value)	Operations Per Year 1978	G, Growth in 78 (fraction of base year value)	Operations Per Year 1980	G, Growth in 80 (fraction of 1978 value)
San Francisco International Airport	1	8.4	22.4	78.6	2.51	96.8	3.32	106.0	3.73	124.2	.17
	2	149.1	145.8	132.8	-0.10	131.2	-0.11	130.4	-0.12	128.8	-.02
	3	148.5	144.5	128.4	-0.13	128.8	-0.12	129.1	-0.12	129.5	.01
	4	68.9	62.0	34.6	-0.79	36.2	-0.71	37.0	-0.68	38.6	.04
	5	0.1	0.1	0.1	0	0.1	0	0.1	0	0.1	.00
	6	0.1	0.1	0.1	0	0.1	0	0.2	1	0.2	.00
	7	2.7	2.7	2.9	0.07	3.0	0.11	3.0	0.11	3.1	.03
	8	0.1	0.1	0.1	0	0.1	0	0.1	0	0.1	.00
	9	26.1	26.1	26.1	0	26.1	0	26.1	0	26.1	.00
Oakland International Airport (South & North)	1			17.6	0	33.2	0.89[a]	41.1	1.34[a]	57.3[a]	.39
	2	30.8	30.6	29.8	-0.03	41.6	0.36	47.5	0.55	59.3	.25
	3	35.6	34.2	28.8	-0.21	41.1	0.18	47.3	0.36	59.7	.26
	4	16.0	14.3	7.3	-0.51	10.3	-0.28	11.9	-0.17	14.9	.25
	5	1.1	1.6	3.5	1.19	5.1	2.19	5.9	2.69	7.5	.27
	6	2.8	5.3	15.5	1.93	22.6	3.27	26.2	3.94	33.3	.27
	7	277.5	302.8	404.2	0.34	463.2	0.53	492.6	0.63	551.6	.12
	8	5.7	6.7	10.5	0.57	12.3	0.84	13.2	0.97	15.0	.14
	9	23.1	24.0	27.4	0.14	30.3	0.26	31.7	0.32	34.6	.09

Table E-5. Aircraft Operations Activity for San Francisco Air Basin Base Year and Projected Years (Page 2 of 4)

Airport	Aircraft Class	Total Operations Per Year 1970 (Base Year)	1971	1975	G, Growth in 75 (fraction of base year value)	Operations Per Year 1977	G, Growth in 77 (fraction of base year value)	Operations Per Year 1978	G, Growth in 78 (fraction of base year value)	Operations Per Year 1980	G, Growth in 80 (fraction of 1978 value)
San Jose Municipal Airport	1			12.5	0	23.0	0.84[a]	28.3	1.26	38.8[a]	.37
	2	8.9	11.4	21.1	0.85	28.7	1.52	32.6	1.86	40.2	.23
	3	38.6	35.0	20.4	-0.42	28.4	-0.19	32.3	-0.08	40.3	.25
	4	34.8	33.6	28.9	-0.14	40.5	0.21	46.3	0.38	62.4	.35
	5	1.3	1.6	2.7	0.69	3.2	1.0	3.5	1.19	4.0	.14
	6	3.3	5.0	11.6	1.32	14.3	1.86	15.7	2.14	18.4	.17
	7	336.7	330.0	303.1	-0.08	291.9	-0.12	286.3	-0.13	275.1	.34
	8	7.0	7.1	7.6	0.07	7.8	0.10	7.8	0.10	8.0	.02
	9	5.0	5.3	6.3	0.19	7.1	0.34	7.6	0.43	8.4	.10
Livermore	5	1.1	1.5	3.2	1.13	3.8	1.53	4.1	1.73	4.8	.17
	6	2.7	5.0	14.0	1.80	17.2	2.44	18.8	2.76	22.0	.17
	7	256.5	278.3	365.6	0.31	360.6	0.30	358.2	0.29	353.2	-.01
	8	5.7	6.4	9.2	0.44	9.4	0.47	9.4	0.47	9.6	.02
	9	4.1	4.8	7.6	0.58	8.6	0.79	9.0	0.88	10.0	.11
Sonoma County	5	0.4	0.6	1.4	1.33	2.0	2.33	2.4	3.00	3.0	.25
	6	1.0	2.0	6.1	2.05	9.1	3.55	10.5	4.25	13.5	.29
	7	97.8	129.4	158.1	0.22	181.7	0.41	193.6	0.50	217.2	.12
	8	2.2	2.6	4.0	0.54	4.7	0.81	5.1	0.96	5.9	.16
	9	1.5	1.9	3.3	0.74	4.5	1.37	5.0	1.63	6.2	.24

Table E-5. Aircraft Operations Activity for San Francisco Air Basin Base Year and Projected Years (Page 3 of 4)

Airport	Aircraft Class	Total Operations Per Year 1970 (Base Year)	1971	1975	G, Growth in 75 (fraction of base year value)	Operations Per Year 1977	G, Growth in 77 (fraction of base year value)	Operations Per Year 1978	G, Growth in 78 (fraction of base year value)	Operations Per Year 1980	G, Growth in 80 (fraction of 1978 value)
Hayward	5	1.1	1.5	3.2	1.13	3.8	1.53	4.2	1.8	4.8	.14
	6	2.8	5.0	14.0	1.80	17.2	2.44	18.8	2.76	22.0	.17
	7	269.7	288.9	365.6	0.27	360.6	0.25	358.2	0.24	353.2	-.02
	8	6.0	6.6	9.2	0.39	9.4	0.43	9.4	0.43	9.6	.02
	9	4.3	5.0	7.6	0.52	8.6	0.72	9.0	0.80	10.0	.11
Buchanan	5	1.4	1.8	3.2	0.78	3.8	1.11	4.2	1.33	4.8	.14
	6	3.4	5.5	14.0	1.55	17.2	2.13	18.8	2.42	22.0	.17
	7	324.9	333.0	365.6	0.10	360.6	0.08	358.2	0.08	353.2	-.02
	8	7.2	7.6	9.2	0.21	9.4	0.24	9.4	0.24	9.6	.02
	9	5.1	5.6	7.6	0.36	8.6	0.54	9.0	0.61	10.0	.11
Napa County	5	0.8	1.2	2.6	1.17	3.5	1.92	3.9	2.25	4.8	.23
	6	1.9	3.8	11.2	1.95	15.5	3.08	17.7	3.66	22.0	.24
	7	180.5	202.9	292.5	0.44	316.8	0.56	328.9	0.62	353.2	.07
	8	4.0	4.7	7.4	0.58	8.3	0.77	8.7	0.85	9.6	.10
	9	2.9	3.5	6.1	0.74	7.7	1.20	8.4	1.40	10.0	.19
San Carlos	5	1.2	1.6	3.2	1.0	3.8	1.38	4.2	1.63	4.8	.14
	6	3.0	4.8	14.0	1.92	17.2	2.58	18.8	2.92	22.0	.17
	7	285.0	301.1	365.6	0.22	360.6	0.20	358.2	0.19	353.2	-.01
	8	6.3	6.9	9.2	0.33	9.4	0.36	9.4	0.36	9.6	.02
	9	4.5	5.1	7.6	0.49	8.6	0.69	9.0	0.77	10.0	.11

Table E-5. Aircraft Operations Activity for San Francisco Air Basin Base Year and Projected Years (Page 4 of 4)

Airport	Aircraft Class	Total Operations Per Year 1970 (Base Year)	1971	1975	G, Growth in 75 (fraction of base year value)	Operations Per Year 1977	G, Growth in 77 (fraction of base year value)	Operations Per Year 1978	G, Growth in 78 (fraction of base year value)	Operations Per Year 1980	G, Growth in 80 (fraction of 1978 value)
Palo Alto	5	0.8	1.2	2.6	1.17	3.5	1.92	3.9	2.25	4.8	.23
	6	1.9	3.8	11.2	1.95	15.5	3.08	17.7	3.66	22.0	.24
	7	181.4	203.8	293.4	0.44	317.3	0.56	329.3	0.62	353.2	.07
	8	4.0	4.7	7.4	0.58	8.3	0.77	8.7	0.85	9.6	.10
	9	2.9	3.5	6.1	0.74	7.7	1.20	8.4	1.40	10.0	.19
Reid Hillview	5	0.9	1.3	3.0	1.31	3.7	1.85	4.1	2.15	4.8	.17
	6	2.2	4.4	13.2	2.0	16.7	2.80	18.5	3.21	22.0	.05
	7	212.8	239.2	344.6	0.44	348.0	0.46	349.8	0.46	353.2	.10
	8	4.7	5.5	8.7	0.58	9.1	0.66	9.2	0.67	9.6	.04
	9	3.4	4.2	7.2	0.72	8.3	0.98	8.9	1.12	10.0	.12
Others	5	3.1	5.7	16	1.81	28	3.91	34	4.97	46	.35
	6	7.7	20.0	69	2.45	126.2	5.3	154.8	6.74	212	.37
	7	726.8	942.0	1803	0.92	2445.0	1.60	2766.0	1.94	3408	.23
	8	16.1	21.9	45	1.06	63.8	1.91	73.2	2.34	92	.26
	9	11.5	16.6	37	1.23	60.6	2.65	72.4	3.36	96	.33

[a]Calculated using 1975 as base year

operations per year, and N is the number of engines for the specified aircraft class. Table E-6 shows a sample calculation for San Jose Municipal Airport for the base year 1971 emissions. From the example it can be seen that all class 3 and 7 aircraft do not possess the same number of engines. Hence, class 3 and 7 have been segregated by aircraft engine number to account for the total number of "engine LTOs."

Table E-7 shows the projected total hydrocarbon, carbon monoxide, and oxides of nitrogen emissions in tons/day for the years 1971, 1975, 1977, and 1980 for each aircraft class and for each airport. This table is generated by computations according to the equations specified in Table E-4, and using the growth factors, G (see Table E-5) which are calculated for the Bay Area only. An example of such a computation is illustrated below.

Consider the projected hydrocarbon emissions at San Jose Municipal Airport for class 2 aircraft in 1977. According to Table E-4 , the expected emissions in 1977 will be

$$E_{77} = E_{BY}\ (1+G)\ (1-R)$$

where E_{BY} = class 2 HC emissions in base year (1971) = 1.287 tons/day (Table E-6)
G = growth in fraction increase of base year = 1.52 (Table E-5)
R = expected emission reduction, in fraction of base year emission = .33 (Table E-4)

substituting values,

$$E_{77} = 1.287\ (1+1.52)\ (1-.33) = 2.173 \text{ tons/day in 1977}$$

In 1980,

$$E_{80} = E_{78}\left[1+G\ (1-R) - \frac{2R}{L}\right]$$

L = engine life = 15 years
G = growth in fraction increase of year 1978 - .23
R = emission reduction in fraction of year 1978 = .70

where

$$E_{78} = E_{BY}\ (1+G)\ (1-R) = 1.287\ (1+1.86)\ (1-.39) = 2.245$$

$$E_{80} = 2.245\left[1+.23\ (1=.7) - \frac{2(17)}{15}\right] = 2.191 \text{ tons/day in 1980}$$

Table E-6. Base Year Aircraft Emissions at San Jose Municipal Airport

Aircraft Class	Total Operations in 1971 (Thousands)	Number of Engines Per Aircraft	Engine LTO Cycles[a] (Thousands)	1971 Emissions (Tons/Day) THC	CO	NO_x
1	0	-	-	-	-	-
2	11.4	4	22.8	1.287	1.479	.247
3	15.6 19.4	2 3	44.7	0.257	1.123	.686
4	33.6	2	33.6	0.133	0.304	.115
5	1.6	2	1.6	0.008	0.035	.004
6	5.0	2	5.0	0.008	0.021	.008
7	286.5 21.8	1 2	165.1	0.090	0.551	.011
8	7.1	2	7.1	0.395	2.959	.004
9	5.3	1	2.65	0.002	0.005	.002
			TOTAL =	2.180	6.477	1.077

[a] LTO Cycles = $\frac{\text{Operations}}{2}$ X Number of Engines

The emission factors are shown in Table E-1. Future emissions for Hamilton were calculated by reducing the total LTO cycles by the negative growth factor and by applying the projected class distribution factor for future years. The emissions for all airports in the San Francisco Bay Area are shown in Table E-7.

Table E-7. Base Year and Projected Aircraft Emissions for San Francisco Bay Area Civilian Airports (Page 1 of 4)

Airport	Aircraft Class	THC (Tons/Day) 1971	1975	1977	1980	CO (Tons/Day) 1971	1975	1977	1980	NO_x (Tons/Day) 1971	1975	1977	1980
San Francisco International Airport	1	0.749	2.629	3.236	3.400	2.871	10.077	12.398	13.838	1.926	6.760	8.320	10.651
	2	16.493	13.953	9.896	7.966	18.973	16.829	15.747	14.229	3.160	2.844	2.812	2.718
	3	1.164	0.840	0.850	0.774	8.501	6.800	6.885	6.545	2.781	2.637	2.667	2.698
	4	0.246	0.137	0.071	0.068	0.560	0.313	0.162	0.168	0.212	0.045	0.061	0.070
	5	0.000	0.000	0.000	0.000	0.002	0.002	0.002	0.002	0.000	0.000	0.000	0.000
	6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	7	0.002	0.002	0.002	0.002	0.048	0.051	0.043	0.049	0.000	0.000	0.000	0.000
	8	0.005	0.005	0.005	0.004	0.042	0.042	0.042	0.040	0.000	0.000	0.000	0.000
	9	0.009	0.009	0.009	0.008	0.102	0.102	0.102	0.096	0.010	0.010	0.010	0.010
Total		18.668	17.575	14.069	12.222	31.099	34.216	35.381	34.967	8.089	12.296	13.870	16.147
Oakland International Airport (North & South)	1		0.588	1.111	1.470		2.256	4.264	5.843		1.514	2.861	4.921
	2	3.473	3.160	3.165	3.369	3.997	3.819	5.028	5.916	0.666	0.646	0.906	1.292
	3	0.284	0.187	0.278	0.333	0.877	0.693	1.035	1.149	0.674	0.580	0.867	1.260
	4	0.057	0.028	0.041	0.048	0.186	0.091	0.134	0.162	0.049	0.024	0.035	0.051
	5	0.008	0.018	0.026	0.031	0.038	0.083	0.121	0.149	0.004	0.009	0.013	0.019
	6	0.008	0.023	0.034	0.041	0.022	0.064	0.094	0.115	0.009	0.026	0.038	0.057
	7	0.082	0.110	0.125	0.134	2.530	3.390	3.870	4.175	0.010	0.013	0.015	0.018
	8	0.373	0.586	0.686	0.735	2.855	4.482	5.253	5.681	0.004	0.006	0.007	0.009
	9	0.008	0.009	0.010	0.010	0.095	0.108	0.120	0.125	0.009	0.010	0.011	0.013
Total		4.293	4.709	5.476	6.171	10.600	14.986	19.919	23.314	1.425	2.828	4.753	7.640
San Jose Municipal Airport	1		0.417	0.767	0.959		1.603	2.949	3.868		1.075	1.978	3.322
	2	1.287	2.235	2.173	2.191	1.479	2.695	3.446	3.890	0.247	0.457	0.622	0.869
	3	0.257	0.124	0.173	0.193	1.123	0.600	0.837	0.966	0.686	0.433	0.603	0.857
	4	0.133	0.115	0.161	0.185	0.304	0.261	0.368	0.444	0.115	0.099	0.139	0.214
	5	0.008	0.013	0.016	0.017	0.035	0.059	0.070	0.075	0.004	0.007	0.008	0.010
	6	0.008	0.018	0.023	0.024	0.021	0.049	0.172	0.065	0.008	0.019	0.023	0.029
	7	0.090	0.083	0.079	0.086	0.551	0.507	0.485	0.529	0.011	0.010	0.010	0.013
	8	0.395	0.424	0.435	0.395	2.959	3.166	3.255	3.018	0.004	0.004	0.004	0.004
	9	0.002	0.002	0.003	0.003	0.005	0.006	0.007	0.007	0.002	0.002	0.003	0.003
Total		2.180	3.431	3.830	4.053	6.477	8.946	11.589	12.862	1.077	2.106	3.390	5.321

Table E-7 Base Year and Projected Aircraft Emissions for San Francisco Bay Area Civilian Airports (Page 2 of 4)

Airport	Aircraft Class	THC (Tons/Day) 1971	1975	1977	1980	CO (Tons/Day) 1971	1975	1977	1980	NO_x (Tons/Day) 1971	1975	1977	1980
Hayward	5	0.007	0.015	0.018	0.019	0.033	0.070	0.083	0.090	0.003	0.006	0.008	0.010
	6	0.008	0.022	0.027	0.029	0.021	0.058	0.072	0.078	0.008	0.022	0.027	0.035
	7	0.075	0.095	0.094	0.088	2.582	3.279	3.228	3.042	0.008	0.010	0.010	0.010
	8	0.368	0.511	0.526	0.505	2.748	3.820	3.930	3.772	0.004	0.005	0.006	0.006
	9	0.002	0.003	0.003	0.003	0.020	0.030	0.034	0.035	0.004	0.006	0.007	0.008
Total		0.460	0.646	0.668	0.644	5.404	7.257	7.347	7.017	0.027	0.049	0.058	0.069
Buchanan	5	0.009	0.016	0.019	0.020	0.039	0.069	0.082	0.089	0.009	0.016	0.034	0.024
	6	0.008	0.020	0.025	0.026	0.023	0.059	0.072	0.077	0.009	0.023	0.028	0.036
	7	0.098	0.108	0.106	0.101	2.979	3.277	3.217	3.056	0.002	0.002	0.002	0.002
	8	0.424	0.513	0.526	0.505	3.166	3.831	3.926	3.663	0.004	0.005	0.005	0.005
	9	0.002	0.003	0.003	0.002	0.022	0.030	0.040	0.034	0.003	0.004	0.005	0.005
Total		0.541	0.660	0.679	0.654	6.229	7.266	7.337	6.919	0.027	0.050	0.074	0.072
Napa County	5	0.006	0.013	0.019	0.019	0.026	0.056	0.076	0.086	0.033	0.006	0.009	0.012
	6	0.006	0.018	0.245	0.027	0.016	0.047	0.065	0.076	0.006	0.018	0.024	0.035
	7	0.060	0.086	0.094	0.096	1.821	2.622	2.841	2.906	0.006	0.008	0.009	0.010
	8	0.262	0.414	0.464	0.485	1.957	3.095	3.467	3.548	0.002	0.003	0.003	0.004
	9	0.001	0.002	0.002	0.002	0.014	0.024	0.031	0.033	0.002	0.003	0.004	0.004
Total		0.335	0.533	0.822	0.629	3.834	5.844	6.480	6.649	0.019	0.038	0.049	0.065
San Carlos	5	0.008	0.016	0.019	0.020	0.035	0.070	0.083	0.090	0.004	0.008	0.009	0.012
	6	0.007	0.020	0.025	0.026	0.020	0.058	0.072	0.077	0.008	0.023	0.029	0.037
	7	0.092	0.112	0.110	0.105	2.695	3.288	3.234	3.047	0.009	0.011	0.011	0.011
	8	0.385	0.512	0.524	0.531	2.875	3.824	3.910	3.753	0.004	0.005	0.005	0.006
	9	0.002	0.003	0.003	0.003	0.020	0.030	0.034	0.034	0.004	0.006	0.007	0.008
Total		0.494	0.663	0.681	0.685	5.645	7.270	7.333	7.001	0.029	0.053	0.061	0.074
Palo Alto	5	0.006	0.013	0.017	0.019	0.026	0.056	0.076	0.086	0.003	0.007	0.009	0.012
	6	0.006	0.018	0.024	0.027	0.016	0.042	0.065	0.076	0.006	0.018	0.024	0.035
	7	0.060	0.086	0.094	0.096	1.821	2.622	2.841	2.906	0.006	0.009	0.009	0.010
	8	0.262	0.414	0.464	0.485	1.957	3.092	3.464	3.620	0.000	0.000	0.000	0.000
	9	0.001	0.002	0.002	0.002	0.014	0.024	0.031	0.033	0.002	0.004	0.004	0.004
Total		0.335	0.533	0.601	0.629	3.834	5.841	6.477	6.721	0.017	0.038	0.046	0.061

Table E-7. Base Year and Projected Aircraft Emissions for San Francisco Bay Area Civilian Airports (Page 3 of 4)

Airport	Aircraft Class	THC (Tons/Day) 1971	1975	1977	1980	CO (Tons/Day) 1971	1975	1977	1980	NO_x (Tons/Day) 1971	1975	1977	1980
Livermore	5	0.007	0.015	0.018	0.018	0.033	0.070	0.083	0.089	0.003	0.006	0.008	0.010
	6	0.007	0.020	0.024	0.025	0.021	0.059	0.072	0.078	0.008	0.022	0.028	0.035
	7	0.082	0.107	0.107	0.100	2.492	3.264	3.240	3.040	0.008	0.010	0.010	0.010
	8	0.356	0.513	0.523	0.502	2.726	3.925	4.007	3.844	0.004	0.006	0.006	0.006
	9	0.002	0.003	0.003	0.003	0.019	0.030	0.031	0.034	0.003	0.005	0.005	0.006
Total		0.454	0.658	0.675	0.648	5.291	7.348	7.433	7.085	0.026	0.049	0.057	0.067
Sonoma County	5	0.003	0.007	0.010	0.008	0.013	0.030	0.044	0.036	0.001	0.002	0.003	0.003
	6	0.003	0.009	0.014	0.011	0.008	0.024	0.036	0.031	0.003	0.009	0.014	0.013
	7	0.038	0.046	0.054	0.050	1.164	1.420	1.641	1.536	0.004	0.005	0.006	0.005
	8	0.145	0.223	0.262	0.222	1.083	1.668	1.960	1.657	0.001	0.002	0.002	0.001
	9	0.001	0.002	0.002	0.002	0.007	0.012	0.016	0.013	0.001	0.002	0.002	0.002
Total		0.190	0.287	0.342	0.293	2.275	3.154	3.697	3.273	0.010	0.020	0.027	0.024

Table E-7. Base Year and Projected Aircraft Emissions for San Francisco Bay Area Civilian Airports (Page 4 of 4)

Airport	Aircraft Class	THC Tons/Day) 1971	1975	1977	1980	CO (Tons/Day) 1971	1975	1977	1980	NO_x (Tons/Day) 1971	1975	1977	1980
Reid-Hillview	5	0.007	0.0162	0.0200	0.021	0.028	0.0647	0.0800	0.087	0.003	0.0069	0.0086	0.011
	6	0.007	0.0210	0.0266	0.027	0.019	0.0570	0.0722	0.075	0.007	0.0210	0.0266	0.031
	7	0.062	0.0893	0.0905	0.091	1.883	2.7115	2.7492	2.749	0.007	0.0101	0.0102	0.011
	8	0.307	0.4851	0.5096	0.497	2.292	3.6214	3.8047	3.713	0.003	0.0047	0.0050	0.005
	9	0.001	0.0017	0.0020	0.002	0.016	0.0275	0.0317	0.033	0.003	0.0052	0.0059	0.007
Total		0.384	0.6133	0.6487	0.638	4.238	6.4821	6.7378	6.657	0.023	0.0479	0.0563	0.065
Others	5	0.047	0.1025	0.2308	0.284	0.206	0.4491	1.0115	1.304	0.021	0.0458	0.1031	0.169
	6	0.030	0.1035	0.1890	0.236	0.085	0.2933	0.5355	0.703	0.033	0.1139	0.2079	0.350
	7	0.277	0.5318	0.7202	0.867	8.440	16.2048	21.9440	26.426	0.028	0.0538	0.0730	0.101
	8	1.222	2.5173	3.5560	4.408	9.124	18.7954	26.5508	32.912	0.012	0.0247	0.0349	0.051
	9	0.006	0.0134	0.0219	0.026	0.065	0.1450	0.2373	0.298	0.011	0.0245	0.0402	0.064
Total		1.582	3.2685	4.7179	5.821	17.920	35.8876	50.2791	61.643	0.105	0.2627	0.4591	0.735
TOTAL - ALL AIRPORTS		29.91	33.58	33.21	33.09	102.8	144.5	170.0	184.1	10.88	17.84	22.30	30.34

3. MILITARY AIR BASES

There are five military air bases in the San Francisco Bay Area. These bases are shown in Table E-8, along with the respective number of operations in 1970. A military aircraft operation is defined as either a landing or a takeoff; thus, to derive a figure for Landing Takeoff (LTO) cycles, each value in Table E-8 is divided by two.

The LTO cycles are listed in Table E-9 for both military and civilian operations at each base. Although the operations data used was actually for the year 1970, it was assumed that no significant changes in military or civilian operations occurred between 1970 and the base year for this area, 1971. Estimated LTO cycle growth is shown on the table for military and civilian operations at each base. All these values, except one set, have been assumed to be zero because of the uncertainty in predicting operations changes at military bases. The one exception is Hamilton Air Force Base, where the military aircraft operations have been estimated to decrease 50% in 1975 compared to operations in 1971. The basis for this decrease is that Hamilton will phase out Air Force fighter plane operations and convert completely to reserve operations, which made up about 20% of the operations in 1971(E-7).

The distribution of operations by aircraft class at each base is also shown on Table E-9, in terms of fractions of the military and civilian LTO cycles for each year indicated. Civilian operations are estimated to be in all cases single-engine general aviation piston planes (E-7, E-8). The distributions at all bases, except Hamilton, are assumed to remain the same in future years as they were in 1971. At Hamilton, the future distributions reflect the increased reserve operations, which involve primarily helicopters and C-130's.

The emissions in tons/day of total hydrocarbon, carbon monoxide, oxides of nitrogen for each aircraft class at each base are shown in Table E-10. The values in this table are calculated as follows:

emissions per class	=	EPA emission factor	x	number of engines on aircraft in the class	x	number of LTO cycles for the class	x	distribution factor for the class

Table E-8. Aircraft Operations at Military Air Bases in the San Francisco Bay Area (Reference E-9)

Air Base	Operator	Number of Aircraft Operations[a] in 1970	
		Military	Civilian
Alameda Oakland, Ca.	Navy	42,655	14,756
Crows Landing Oakland, Ca.	Navy	21,436	766
Moffett Mountain View, Ca.	Navy	34,939	6,445
Hamilton San Francisco, Ca.	Air Force	39,978	18,906
Travis Fairfield, Ca.	Air Force	76,020	13,535

[a] A Military Aircraft Operation is defined as either a landing or a takeoff.

Table E-9. Distribution and Growth of Aircraft Activity at Military Air Bases in the San Francisco Bay Area

Air Base	Operations Type	Total LTO (1970)	Estimated Growth, as Fraction Increase of Total 1971 LTO			Aircraft Class	Aircraft Type	Number of Engines	Estimated Distribution as Fraction of LTO Cycles of Indicated Year			
			1975	1977	1980				1971	1975	1977	1980
Alameda	Military	21,332	0	0	0	11	A-3	2	1.00	1.00	1.00	
	Civilian	7,378	0	0	0	7	Single	1	1.00	1.00	1.00	1.00
Crows Landing	Military	10,718	0	0	0	11	Trainer	1	1.00	1.00	1.00	1.00
	Civilian	383	0	0	0	7	Single	1	1.00	1.00	1.00	1.00
Moffett	Military	17,470	0	0	0	4	P-3	4	0.50	0.50	0.50	0.50
						11	A-7	1	0.50	0.50	0.50	0.50
	Civilian	3,222	0	0	0	7	Single	1	1.00	1.00	1.00	1.00
Hamilton	Military	19,989	-.50	-.50	-.50	9	HH3 HH53	2				
						10	C-130	4	0.10	0.50	0.50	0.50
						11	F-106 Thunderbirds ETC	1.5	0.80	0	0	0
	Civilian	9,453	0	0	0	7	Single	1	1.00	1.00	1.00	1.00
Travis	Military	38,010	0	0	0	11	C-141	4	0.70	0.70	0.70	0.70
						1	C-5	4	0.30	0.30	0.30	0.30
	Civilian	6,768	0	0	0	7	Single	1	1.00	1.00	1.00	1.00

Sources: U.S. Air Force and U.S. Navy Representatives, Los Angeles, California.

Table E-10. Aircraft Emissions From Military Air Bases in the San Francisco Bay Area

Aircraft Emissions (Tons/Day)

THC				CO				NO_x			
1971	1975	1977	1980	1971	1975	1977	1980	1971	1975	1977	1980
0.5802	0.5802	0.5802	0.5802	0.8822	0.8822	0.8822	0.8822	0.1922	0.1922	0.1922	0.1922
0.0002	0.0002	0.0002	0.0002	0.1232	0.1232	0.1232	0.1232	0.0004	0.0004	0.0004	0.0004
0.1457	0.1457	0.1457	0.1457	0.2216	0.2216	0.2216	0.2216	0.0482	0.0482	0.0482	0.0482
0.0002	0.0002	0.0002	0.0002	0.0063	0.0063	0.0063	0.0063	0.0000	0.0000	0.0000	0.0000
1.387	1.387	1.387	1.387	0.3159	0.3159	0.3159	0.3159	0.1196	0.1196	0.1196	0.1196
0.1188	0.1188	0.1188	0.1188	0.1807	0.1807	0.1807	0.1807	0.0394	0.0394	0.0394	0.0394
0.0017	0.0017	0.0017	0.0017	0.0539	0.0539	0.0539	0.0539	0.0002	0.0002	0.0002	0.0002
0.0014	0.0071	0.0071	0.0071	0.0156	0.0780	0.0780	0.0780	0.0002	0.0078	0.0078	0.0078
0.0147	0.0739	0.0739	0.0739	0.0312	0.1561	0.1561	0.1561	0.0120	0.0602	0.0602	0.0602
0.1631	0	0	0	0.2481	0	0	0	0.054	0	0	0
0.0051	0.0051	0.0051	0.0051	0.1579	0.1579	0.1579	0.1579	0.0006	0.0006	0.0006	0.0006
1.4477	1.4477	1.4477	1.4477	2.2015	2.2015	2.2015	2.2015	0.4796	0.4796	0.4796	0.4796
0.7623	0.7623	0.7623	0.7623	2.9242	2.9242	2.9242	2.9242	1.9619	1.9619	1.9619	1.9619
0.0037	0.0037	0.0037	0.0037	0.1130	0.1130	0.1130	0.1130	0.0004	0.0004	0.0004	0.0004
4.63	4.53	4.53	4.53	7.48	7.41	7.41	7.41	2.91	2.91	2.91	2.91

4. REFERENCES

E-1. EPA, "Aircraft," Revision to AP-42, 1973.

E-2. Private communication with Mr. Robert Sampson, EPA, Ann Arbor, Michigan, May 1973.

E-3. EPA, Federal Register, December 1972.

E-4. Bay Area Air Pollution Control District, "Aviation Effect on Air Quality," Regional Airport Systems Study, February 1971.

E-5. "ABAG Technical Memorandum 11-1," December 17, 1970.

E-6. Systems Analysis and Research Corporation, "BASAR Aviation Forecast," Cambridge, Los Angeles, New York, Washington, May 1970.

E-7. Private communication with U. S. Air Force Representative, Los Angeles, California, May 1973.

E-8. Private communication with U. S. Navy Representative, Los Angeles, California, May 1973.

E-9. Department of Transportation, Federal Aviation Administration, Military Air Traffic Activity Report, Calendar Year 1970.

APPENDIX F

AIRCRAFT EMISSIONS CONTROL

In this appendix are presented the data and calculations used to estimate the emission reductions to be expected from modification of ground operations at the major airports in the San Francisco Bay Area. The taxi-idle procedure will be modified by reducing the number of engines used by multi-engines turbine aircraft and by increasing the thrust setting at which they operate. San Francisco International (SFO), Oakland International (North and South) (OAK) and San Jose International (SJC) are dealt with separately in this appendix, and the total aircraft emissions reductions for the Bay Area are summarized at the end.

1. SAN FRANCISCO INTERNATIONAL AIRPORT

Table F-1 shows the projected Landing Takeoff (LTO) cycles for each combination of aircraft class and engine number. It will be necessary to calculate for each combination the emissions to be expected in 1975, 1977, and 1980 from the current or "standard" method used for the taxi-idle mode and to compare these estimated emissions with the expected emissions from the modified method hypothesized for taxi-idle. The procedure used to develop these estimates is nearly the same for each of the three airports; San Francisco International will be discussed in detail, and the other two will be presented in a parallel manner but will be discussed more briefly.

The modal emission factors designated by EPA will be used to translate the LTO data into emissions estimates. However, these factors must be first modified to reflect the reductions due to the burner can retrofit program planned for the three-year period from 1975 through 1977. This program is discussed more fully in Appendix E. These reductions are presented in Table F-2.

Table F-1. Projected Commercial Air Carrier LTO Cycles at San Francisco International Airport (Reference E-1)

Class	Number Engines Per Plane	LTO (in thousands) 1975	1977[a]	1980
1	4	6.0	7.52	9.8
1	3	33.4	41.0	52.3
2	4	66.4	65.6	64.4
3	2	21.4	20.6	19.3
3	3	42.8	43.8	45.4

[a]Interpolated from 1975 and 1980 data.

Table F-2. Reductions Due to Class 2 Burner Can Retrofit

	1975[a]	1977[a]	1978[a]
THC	6%	33%	39%
CO	1.5%	7.7%	9.3%

[a]As percent of base year emissions

Another modification results from the fact that emission factors will be reduced between 1978 and 1980 due to the Federal program for new turbine aircraft engines, which takes effect with all engines produced after 1 January 1979. This program is discussed in more detail in Appendix E. The relationship between 1978 and 1980 modal emission factors is as follows:

$$EF_{80} = EF_{78} \left(1 - \frac{2}{L} + (1-R) \left(\frac{2}{L} + G\right) \right)$$

where EF_{80} = modal emission factor to be used for 1980 emissions

EF_{78} = modal emission factor used for 1978 emissions

L = estimated life of turbine aircraft engine = 15 years

R = reduction in emissions due to new engine emission standards

G = growth in LTO from 1978 to 1980 for the aircraft combination

The values for R are discussed in Appendix E and are 0.70 for THC, and 0.60 for CO. The growth values are also discussed in Appendix E and, for San Francisco International, are:

Class 1: G = 0.17

Class 2: G = -0.02

Class 3: G = 0.01

The modal emission factors for the standard taxi-idle method are shown in Table F-3.

Table F-3. Standard Taxi-Idle Emission Factors (Units: LB/Engine/Hr) (Reference E-2)

	1975		1977		1978		1980	
	THC	CO	THC	CO	THC	CO	THC	CO
1	27.3	102	27.3	102	27.3	102	26.2	101
2	92.7	107	87.1	105	53.1	95.2	47.8	86.6
3[a]	6.99	33.4	6.99	33.4	6.99	33.4	6.4	31.1

[a]Smokeless JT8D; Emission Factors include reductions due to burner can retrofit.

Standard taxi-idle emissions were calculated as follows:

$$\text{Taxi-idle emissions} = \text{Taxi-idle emission factor} \times \text{Time in taxi-idle mode} \times \text{LTO} \times \text{Number of engines per plane}$$

The time in the taxi-idle mode is 26 minutes (E-2) for each of the three classes. Estimates for standard taxi-idle emissions for 1975, 1977 and 1980 are shown in Table F-4 for each class-engine combination.

Table F-4. Standard Taxi-Idle Emissions - SFO
(Units: Tons/Day)

Aircraft Class	Number of Engines Per Plane	1975		1977		1980	
		THC	CO	THC	CO	THC	CO
1	4	.3859	1.442	.4837	1.807	.6050	2.3321
1	3	1.6113	6.0202	1.9779	7.3901	2.4214	9.3345
2	4	14.5028	16.7406	13.4626	16.2293	7.2530	13.1404
3	2	.1762	.8420	.1696	.8106	.1455	.7071
3	3	.5287	2.5261	.5410	2.5852	.5135	2.4951

To calculate the emission reduction per engine due to the higher thrust setting, Figure F-1 was assumed to be typical (E-3) of turbine engines used on aircraft in Classes 1, 2, and 3. According to this curve, the emission reductions which result from reducing the number of engines from four to two or from two to one (i.e., doubling the thrust per operating engine) correspond to points A and C for CO and B and D for THC. Thus, the percent reductions are as follows, reading data points from the curve:

For THC, $\frac{90 - 38}{90} = 58\%$

For CO, $\frac{109 - 70}{109} = 37\%$

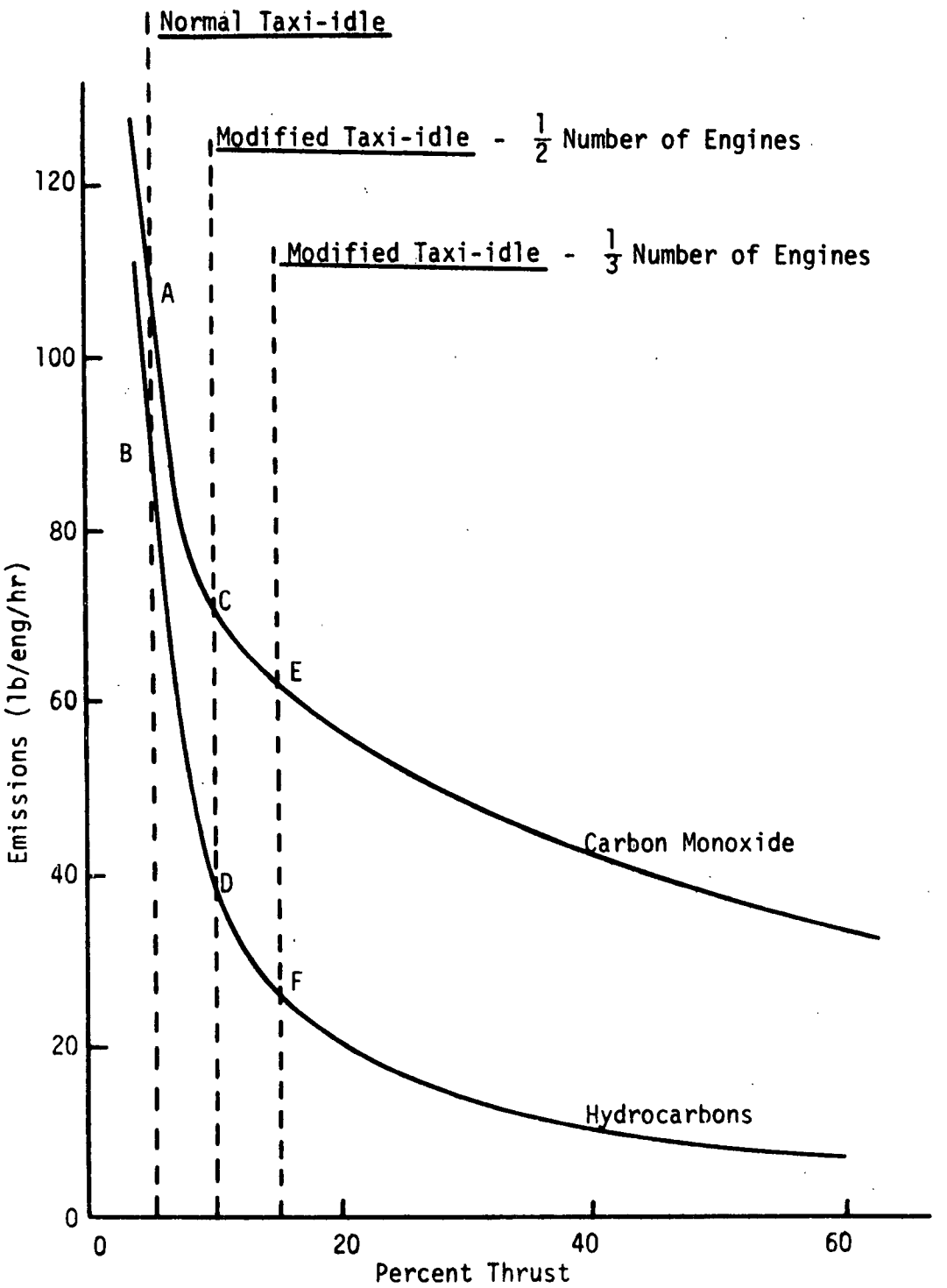

Figure F-1. Hydrocarbon and Carbon Monoxide Emissions From a Typical Aircraft Turbine Engine (JT3D) (Reference E-3)

Reducing the number of operating engines from three to one corresponds to moving from points A to E for CO and B to F for THC. Thus,

For THC, $\frac{90 - 26}{90} = 71\%$

For CO, $\frac{109 - 62}{109} = 43\%$

Table F-5 shows the development of modal emission factors for the modified taxi-idle mode, using these percent reductions per operating engine. In Table F-6, the effects of the higher thrust setting and the reduction in number of operating engines are combined in the estimates for emissions for aircraft operating in this mode. These emissions were calcualted as follows:

Modified taxi-idle emissions	=	Modified taxi-idle emission factor	X	Time in taxi-idle mode	X LTO	X	Number of engines used for modified taxi-idle

The time in the taxi-idle mode is assumed to be the same as in standard taxi-idle -- 26 minutes.

Table F-7 shows the difference in emissions between the standard taxi-idle and the modified taxi-idle at San Francisco International Airport.

Table F-5. Development of Modified Taxi-Idle Emission Factors - SFO

Aircraft Class	No. Engines Per Plane	No. Engines For Mod. Taxi-idle	Reduction Per Engine Due to Mod. Taxi-idle[a]		Modified Taxi-idle Emission Factors					
					1975		1977		1980	
			THC	CO	THC	CO	THC	CO	THC	CO
1	4	2	58%	37%	11.466	64.26	11.466	64.26	11.00	63.0
1	3	1	71%	43%	7.917	58.14	7.917	58.14	7.917	58.14
2	4	2	58%	37%	38.934	67.41	36.582	66.15	20.076	54.558
3	2	1	58%	37%	2.936	21.042	2.936	21.042	2.688	19.593
3	3	1	71%	43%	2.027	19.038	2.027	19.038	1.856	17.727

[a] From Figure F-1.

Table F-6. Modified Taxi-Idle Emissions - SFO

Aircraft Class	No. Engines Per Plane	1975		1977		1980	
		THC	CO	THC	CO	THC	CO
1	4	.0810	.4542	.1016	.5693	.1270	.7273
1	3	.1557	1.124	.1912	1.3800	.2439	1.7911
2	4	3.0456	5.2731	2.8271	5.1122	1.5231	4.1415
3	2	.0370	.2652	.0356	.2553	.0306	.2227
3	3	.0511	.4800	.0523	.4912	.0496	.4741

Time in Taxi-idle Mode = 26 Min., all 3 classes (Reference E-2).

Table F-7. Reductions in Taxi-Idle Emissions Due to Modified Taxi-Idle at San Francisco International (Units: Tons/Day)

Aircraft Class	No. Engines Per Plane	1975 THC	1975 CO	1977 THC	1977 CO	1980 THC	1980 CO
1	4	.3049	.9878	.3821	1.2387	.4780	1.6048
1	3	1.4556	4.8962	1.7867	6.0101	2.1775	7.5434
2	4	11.4572	11.4675	10.6355	11.1171	5.7299	8.9989
3	2	.1392	.5768	.1340	.5553	.1149	.4844
3	3	.4776	2.0461	.4887	2.0940	.4639	2.0210
Totals		13.8	20.0	13.4	21.0	9.0	20.6

2. OAKLAND INTERNATIONAL AIRPORT (NORTH AND SOUTH)

The effectiveness of modified ground operations at Oakland International was analyzed exactly the same way as San Francisco International, with the exception that the time in the taxi-idle mode was assumed to be 13 minutes rather than 26 minutes for each class. The reason for this is that Oakland does not have enough passenger departures to be classified as a large air traffic hub or a "Class A" airport as designated by EPA (E-4). One criterion for this EPA-proposed classification is that an airport have at least one million enplaned passengers per year. A similar criterion seems also to have been used for the designation of a typical large airport for which time-in-mode data was developed by EPA (E-2). Thus, since Oakland International has approximately half the number of enplaned passengers as the criterion specified (E-5), it seems likely (E-6) that the time-in-mode for taxi-idle at Oakland would be approximately half the time-in-mode at a typical large airport.

Tables F-8 through F-11 show data calculated for the Oakland International Airport.

Table F-8. Standard Taxi-Idle Emissions - OAK
(Units: Tons/Day)

Aircraft Class	No. Engines Per Plane	1975 THC	1975 CO	1977 THC	1977 CO	1980 THC	1980 CO
1	4	.0438	.1637	.0847	.3166	.1496	.5873
1	3	.1814	.6777	.3440	1.2853	.6020	2.364
2	4	1.6423	1.8957	2.1542	2.5969	1.8382	3.4240
2	3	.3968	.4580	.5002	.6030	.4138	.7708
3	3	.0598	.2859	.0881	.4212	.1285	.6391

Table F-9. Development of Modified Taxi-Idle Emission Factors - OAK

Aircraft Class	No. Engines Per Plane	No. Engines For Mod. Taxi-idle	Reduction Per Engine Due to Mod. Taxi-idle[a] THC	Reduction Per Engine Due to Mod. Taxi-idle[a] CO	Modified Taxi-Idle Emission Factors (lb/Engine/Hr) 1975 THC	1975 CO	1977 THC	1977 CO	1980 THC	1980 CO
1	4	2	58%	37%	11.466	64.26	11.466	64.26	12.579	69.155
1	3	1	71%	43%	7.917	58.14	7.917	58.14	8.686	62.569
2	4	2	58%	37%	38.934	67.41	36.582	66.15	21.899	61.186
2	3	1	71%	43%	2.027	19.038	2.027	19.038	1.995	19.50
3	3	1	71%	43%	2.027	19.038	2.027	19.038	1.995	19.5

[a]From Figure F-1

Table F-10. Modified Taxi-Idle Emissions - OAK
(Units: Tons/Day)

Aircraft Class	No. Engines Per Plane	1975 THC	1975 CO	1977 THC	1977 CO	1980 THC	1980 CO
1	4	.0092	.05158	.01779	.09971	.03365	.18501
1	3	.05260	.38627	.09976	.73261	.18707	1.3475
2	4	.68978	1.1943	.90475	1.6360	.77205	2.1571
2	3	.00868	.08149	.01164	.10934	.01583	.15477
3	3	.01735	.16299	.02556	.24006	.03727	.36432

Table F-11. Reductions in Taxi-Idle Emissions Due to Modified Taxi-Idle - OAK (Units: Tons/Day)

Aircraft Class	No. Engines Per Plane	1975 THC	1975 CO	1977 THC	1977 CO	1980 THC	1980 CO
1	4	.0346	.1121	.0669	.2169	.1160	.4023
1	3	.1288	.2914	.2442	.5527	.4149	1.0165
2	4	.9525	.7014	1.2495	.9609	1.0662	1.2669
2	3	.3881	.3765	.4886	.4937	.3980	.6160
3	3	.0425	.1329	.0625	.1811	.0912	.2748
Totals		1.5	1.6	2.1	2.4	2.1	3.6

3. SAN JOSE MUNICIPAL AIRPORT

The same calculation procedure was used for San Jose as was used for San Francisco and Oakland airports. The time-in-mode for taxi-idle was estimated to be 13 minutes, using similar reasoning to that described for Oakland. These data are presented in Tables F-12 through F-15.

Table F-12. Standard Taxi-Idle Emissions - SJC
(Units: Tons/Day)

Aircraft Class	No. Engines Per Plane	1975 THC	1975 CO	1977 THC	1977 CO	1980 THC	1980 CO
1	4	.11848	.44268	.11069	.41357	.10078	.39515
1	3	.12903	.48210	.94656	.88415	.40520	1.5887
2	4	.86526	.99874	1.3205	1.5918	1.2385	2.3030
3	3	.04239	.20254	.06072	.29011	.08366	.41150
3	2	.01413	.06751	.01845	.08817	.02365	.11632

Table F-13. Development of Modified Taxi-Idle Emission Factors - SJC

Aircraft Class	No. Engines Per Plane	No. Engines For Mod. Taxi-idle	Reduction Per Engine Due to Mod. Taxi-idle[a] THC	Reduction Per Engine Due to Mod. Taxi-idle[a] CO	Modified Taxi-Idle Emission Factors (Lb/Engine/Hr) 1975 THC	1975 CO	1977 THC	1977 CO	1980 THC	1980 CO
1	4	2	58%	37%	11.466	64.260	11.466	64.260	11.872	68.645
1	3	1	71%	43%	7.917	58.14	7.917	58.14	8.059	62.107
2	4	2	58%	37%	38.93	67.41	36.582	66.150	21.764	60.707
3	3	1	71%	43%	2.027	19.038	2.027	19.038	1.989	19.426
3	2	1	58%	37%	2.936	21.042	2.936	21.042	2.881	21.470

[a]From Figure F-1

Table F-14. Modified Taxi-Idle Emissions - SJC
(Units: Tons/Day)

Aircraft Class	No. Engines Per Plane	1975		1977		1980	
		THC	CO	THC	CO	THC	CO
1	4	.04976	.27889	.04649	.26055	.04305	.24895
1	3	.03742	.27480	.06863	.50396	.11751	.90556
2	4	.36337	.62920	.55459	1.0029	.52015	1.4509
3	3	.01229	.11545	.01761	.16536	.02510	.24513
3	3	.00593	.04253	.00775	.05554	.01028	.07659

Table F-15. Reductions in Taxi-Idle Emissions Due to Modified Taxi-Idle - OAK (Units: Tons/Day)

Aircraft Class	No. Engines Per Plane	1975		1977		1980	
		THC	CO	THC	CO	THC	CO
1	4	.06872	.16379	.0642	.15302	.05773	.1462
1	3	.09161	.2073	.87793	.38019	.28769	.68314
2	4	.50189	.36964	.76591	.5889	.71835	.8521
3	3	.0301	.08709	.04311	.12475	.05856	.1664
3	2	.0082	.02498	.01070	.03263	.01337	.03973
Totals		0.7	0.8	1.8	1.3	1.1	1.9

4. TOTAL AIRCRAFT EMISSION REDUCTIONS

The reductions to be expected at each airport are listed and summed in Table F-16. These values are the differences between the estimates for emissions from the standard taxi-idle procedure and emissions from the modified taxi-idle procedure.

Table F-16. Total Emission Reductions Due to Modified Taxi-idle (Units: Tons/Day)

Airport	1975 THC	1975 RHC	1975 CO	1977 THC	1977 RHC	1977 CO	1980 THC	1980 RHC	1980 CO
San Francisco International	13.8	12.4	20.0	13.4	12.1	21.0	9.0	8.1	20.6
Oakland International	1.5	1.4	1.6	2.1	1.9	2.4	2.1	1.9	3.6
San Jose Municipal	0.7	0.6	0.8	1.8	1.6	1.3	1.1	1.0	1.9
Total Reductions	16.0	14.4	22.4	17.3	15.6	24.7	12.2	11.0	26.1

Values shown are the differences between the standard taxi-idle emissions and the modified taxi-idle emissions.

5. REFERENCES

F-1. Bay Area Air Pollution Control District, "Aviation Effect on Air Quality," Regional Airport Systems Study, February 1971.

F-2. EPA, "Aircraft," Revision to AP-42, 1973.

F-3. EPA, "Aircraft Emissions: Impact on Air Quality and Feasibility of Control," 1973.

F-4. EPA, "Ground Operation of Aircraft to Control Emissions," Federal Register, December 12, 1972.

F-5. Department of Transportation, Federal Aviation Administration, FAA Statistical Handbook of Aviation, 1970 Edition.

F-6. Private communication with EPA, May 1973.

APPENDIX G

PUBLIC ATTITUDE SURVEY
SAN FRANCISCO BAY AQCR

Responses from Attitudinal Questionnaires sent to households in the San Francisco-Oakland metropolitan area in the San Francisco Bay Air Quality Control Region were comprised of the following distributions by annual family income and autos per household.

Annual Family Income	Number of Respondents	Percent of Sample
Less than $8,000	80	20.8
$8,000 to $15,000	167	43.5
More than $15,000	137	35.7
Total	384	100.0
Autos Per Household		
None	12	3.1
One	158	41.2
Two	182	47.4
Three or more	20	5.2
Unknown	12	3.1
Total	384	100.0

The locations of the respondents' households were:

San Francisco	85
Oakland	32
Richmond	21
San Mateo	21
Concord	19
Walnut Creek	14
Hayward	12
Other Cities	180
Total	384

Questionnaire responses were tabulated by income level and car ownership status of each panel member's family. A summary of the results of the survey follows.

1. All autos made in 1975 and thereafter will be equipped with emission control devices to reduce air pollution. If in 1975 you owned a car built before that year, how would you feel about a law requiring you to put emission control equipment which might cost $125 on your car? ("X" BELOW)

2. How would you feel about this law if the cost was reduced by government subsidy to about $50? ("X" BELOW)

Feeling Toward Law:	1. Cost $125	2. Cost $50
Very much in favor of law..	16.1%	40.8%
Somewhat in favor of law...	18.3	22.0
Somewhat against law.....	22.4	12.8
Very much against law.....	43.2	24.5

3a. Even cars properly equipped with emission control equipment might still pollute the air if the equipment was not properly maintained. How would you feel about a law requiring periodic inspection of the emission control system to assure that it was working properly? ("X" ONE ONLY)

Very much in favor of law	Somewhat in favor of law	Somewhat against law	Very much against law
46.1%	28.3%	11.8%	13.9%

3b. Assuming you had to have your car inspected at least once a year, what would you consider a reasonable cost for the inspection? (WRITE IN AMOUNT)

$ 7.40 Average

3c. Assuming you had to have your car inspected at least once a year, where do you think the inspection should be made? ("X" ONE ONLY)

At state-operated inspection centers..... 41.1%
At city-operated inspection centers..... 11.1
At local service stations or garages..... 42.4
At some other place (Specify): 5.5

4a. Even if all autos were equipped with properly maintained emission control systems, some cities might still have auto air pollution problems due to the large number of cars either on the streets at the same time or concentrated in particular areas. Listed below are several possible ways to reduce pollution under one or both of these conditions. Please tell me how you feel about each of these proposals. ("X" ONE ON EACH LINE)

Proposal	To Me This Plan Is: Very Acceptable (+2)	Somewhat Acceptable (+1)	Neither Acceptable Nor Unacceptable (0)	Somewhat Unacceptable (-1)
a. Closed no rationing	5.0%	19.6%	7.7%	15.1% ▲
b. Very high ($200) registration fee per auto	0.8	2.1	4.0	11.0
c. Very high ($200) registration fee per auto but only for the second, third, etc., auto	12.4	17.0	4.3	15.4 ▲
d. Prohibit traffic and parking in central business districts	29.0	27.4 ▲	10.9	14.4
e. A tax on all day parking in central business districts	21.4	20.1 ▲	11.9	13.8
f. A tax on parking in central business districts regardless of whether a person parked only one hour or all day	7.8	13.2	12.4	21.0 ▲
g. Tolls on exit ramps of major freeways and expressways	1.9	6.1	8.2	13.3
h. Tolls on exit ramps of major freeways and expressways but only when traffic was heavy	3.7	6.4	9.1	13.1
i. Mandatory car pooling--allowing only cars carrying at least three persons to use freeways during rush hours	14.2	17.4	7.6	15.5 ▲
j. Turn some existing lanes into "bus only" and "car pool only" lanes on major expressways and streets	43.7	27.6 ▲	6.1	10.3

▲- Indicates the weighted mean for each answer.

- Which of the proposals listed above would be the most acceptable? (Give Letter:) J 44.4%
  D 26.6%

- Which would be most unacceptable? ..... (Give Letter:) B 50.1%
  A 29.0%

QUESTIONS 5-6 ASK FOR INFORMATION RELATING TO OTHER HOUSEHOLD MEMBERS. CONSULT THEM, IF NECESSARY, FOR THE ANSWERS.

- How often do the various members of your household travel by public transportation? (For example, by bus, subway, or commuter train.)

	Husband	Wife	Children (Over 16 Years Old)
Three or more times a week.	10.7%	8.4%	6.4%
One or two times a week.....	3.4	6.5	2.7
Once a month.....	4.8	9.4	1.7
Once every three months	9.6	13.5	3.4
Never	64.0	61.7	23.5
No household member	7.6	0.5	62.4

5b. Please rate each household member's reason for using public transportation. (Rate the most important reason "1", the next most important "2", the next "3", etc. If a household member never uses public transportation, "X" the "never use" box at the bottom of the list.)

5c. Please rate each household member's reasons for traveling by auto. Follow the same procedure as in Question 5b. (WRITE IN BELOW UNDER 5c)

	5b. Public Transportation			5c. Auto Transportati		
Reasons	Husband	Wife	Children (Over 16 Years Old)	Husband	Wife	Childı (Over Years
a. Cheaper	1	1	1	6	6	7
b. Faster	5	9	7	3	3	2
c. More comfortable	4	7	6	5	5	5
d. Safer for passenger	6	10	2	8	8	8
e. Less congested	2	2	9	7	7	6
f. More available	8	5	2	2	1	3
g. More flexible (I can come and go as I please)	9	8	10	1	2	1
h. More relaxing (able to read while traveling)	3	4	8	Not Applicable		
i. Need car during the day	Not Applicable			4	4	4
j. I do not have a driver's license	10	6	5	Not Applicable		
k. Car is not available when I need it	7	3	4	Not Applicable		
l. Other (Specify): _____	Negligible Response			Only transportation avail		
m. Never use ("X" Box)	225/329	220/369	67/112	15/329	19/369	24/1

Again, consulting other members of your household, please rate in order of effectiveness which items below you feel would be most effective in encouraging the use of public transporation. (Rate the most effective item a "1", the next most effective "2", the next "3", etc.)

Items:	Husband	Wife	Children (Over 16 Years Old)
Cleaner and newer vehicles..	7	8	7
Faster travel	4	4	4
Air-conditioned vehicles	9	9	9
More frequent service	1	1	1
Lower fares	2	2	2
Parking facilities at stops or stations	5	6	8
Shelters against bad weather at stops or stations	8	7	6
Better security to assure personal safety.....	6	5	5
More conveniently located stops and stations	3	3	3
Other (Specify):		Negligible	

6a. *How would you or other household members feel about traveling to and from work in a car pool?* ("X" ONE ONLY)

Very interested	16.4%
Somewhat interested	25.3
Not at all interested	34.7
Already in car pool	8.9
Do not travel to and from work by car	14.5

6b. *If it became necessary to restrict the number of cars on expressways and streets in order to reduce pollution and car pools became necessary, how difficult do you think it would be to get into one an existing one or organize one amongst your friends, neighbors and/or work associates.* ("X" ONE ONLY)

Extremely difficult	33.6%
Very difficult	14.9
Somewhat difficult	25.5
Somewhat easy	12.2
Very easy	4.6
Extremely easy	1.4
Already in car pool	7.9

- One of the major causes of areas of high pollution is traffic congestion. Pollution could be reduced if traffic congestion and stop-and-go traffic was reduced. Listed below are several ideas for reducing traffic congestion. Please tell me how effective you think each of these ideas would be in reducing congestion and pollution. ("X" ONE BOX FOR EACH IDEA)

Idea:	Very Effective (+2)	Somewhat Effective (+1)	Not Effective At All (0)	Would Increase Congestion (0 -)
a. Prohibit parking, loading and unloading on busy streets	53.5% ▲	35.7%	8.9%	1.9%
b. Increase the number of one-way streets	22.4	49.9 ▲	22.7	5.0
c. Establish reversible lanes on busy streets to be used during rush hours	24.8	40.6 ▲	17.7	16.9
d. Prohibit turns at busy intersections during rush hours	54.7 ▲	34.6	8.5	2.2
e. Widen major streets	34.9	43.0 ▲	16.5	5.6
f. Widen major streets at intersections only	5.8	35.3	42.6	16.3 ▲
g. Provide pedestrian underpasses and/or overpasses	47.0 ▲	38.5	12.7	1.7
h. Improve timing of traffic signals	60.3 ▲	34.1	5.0	0.6
i. Increase the number and frequency of radio traffic reports	19.1	51.3 ▲	27.9	1.7
j. Turn some existing lanes into "bus only" and "car pool only" lanes on expressways and busy streets	43.3 ▲	38.0	11.3	7.4

Your ideas (Please List):

- Prohibit parking in central business district
- Restrict truck deliveries to nighttime or off-peak hours
- Improve traffic law enforcement
- Tax suburban cars entering central business district
- Provide bicycle lanes

▲- Indicates the weighted mean for each answer.

Since traffic congestion is most severe at times when people are going to or coming from work, one alternative for reducing congestion would be to have people start and stop work at different times of the day. That is, some people would start work at 5:00 AM and quit at 2:00 PM, others would work from 7:00 AM to 4:00 PM, others from 10:00 AM to 7:00 PM, etc. How do you feel about this idea? ("X" ONE ONLY)

Very much in favor	39.6%
Somewhat in favor	28.7
Indifferent	14.1
Somewhat opposed	9.8
Very much opposed	7.7

Along with the air pollution problem, the country may also be faced with a gasoline shortage. The following methods have been suggested as ways to both combat air pollution and conserve gasoline. How do you feel about each of these proposals? ("X" ONE ON EACH LINE)

Proposal	To Me This Plan Is: Very Acceptable (+2)	Somewhat Acceptable (+1)	Neither Acceptable Nor Unacceptable (0)	Somewhat Unacceptable (0)	Very Unacceptable (-1) (-2)
a. Gasoline rationing with drivers being allowed to purchase during a year:					
about 90 percent of the fuel now used	20.3%	25.1%	14.2%	▲12.0%	28.4%
b. about 80 percent of the fuel now used	5.4	25.5	18.1	▲20.9	30.1
c. about 2/3 of the fuel now used	8.4	10.8	15.7	18.6	▲46.5
d. An "Emissions" or "Smog" tax based on the number of miles driven during a year:					
at $10 per thousand miles	6.1	11.6	12.7	16.3	▲53.2
e. at $15 per thousand miles	3.5	6.4	11.8	14.2	▲64.2
f. Doubling the price of gasoline and using the additional revenue to improve mass transit	6.2	8.1	8.4	12.2	▲65.0

▲- Indicates the weighted mean for each answer.

Please record the model year of each car owned in your household. (WRITE IN BELOW UNDER 10a)

Please estimate the number of miles each car was driven in the last year. (WRITE IN NUMBER OF MILES UNDER 10b BELOW)

10c. For each car, please estimate what percentage of last year's mileage was accounted for by driving outside your local metropolitan area. (For example, vacation, business trips, short weekend trips, etc.) (WRITE IN BELOW UNDER 10c)

	10a Model Year	10b Last Year's Mileage	10c Percentage of Mileage Outside Local Area
Car #1	1968	11,370	29
Car #2	1968	9,320	26
Car #3	1967	8,130	21
Car #4	1965	3,790	20

10d. How many licensed drivers are there in your household? (WRITE IN)

Number of Licensed Drivers: 1.91 Average

10e. If better public transportation were available, would you consider disposing of any of the cars you own?

Yes	10.5%
Maybe	18.0
No	71.5

10f. How many? (WRITE IN) 1.03 cars
Average of Yes and Maybe

1a. Overall, how serious a problem do you think auto air pollution is in your city? ("X" ONE BOX UNDER 11a BELOW)

1b. Overall, how serious a problem do you think auto air pollution is nationwide? ("X" ONE BOX UNDER 11b BELOW)

	11a. City	11b. Nationwide
Very serious problem	22.6%	37.0%
Serious problem	26.3	47.5
Slightly serious problem...	42.8	14.1
No problem at all	8.2	1.4

12. If you have any views or comments regarding any questions or idea, please record them.

- Provide safe, cheap, fast and reliable transit
- Develop more efficient (better mileage) engines
- Factories are the cause of the air pollution problem
- Trucks, aircraft, buses and old, improperly maintained autos are the major polluters
- Poor people hit hardest by auto pollution controls
- Develop new energy sources
- Too many taxes already
- Improve gas mileage on new automobiles
- Limit auto and/or engine size
- Speed up development of pollution-free automobiles
- Limit the number of autos
- Curtail teenage driving
- Encourage use of bicycles--provide bicycle lanes
- Provide incentives--such as tax deductions instead of added taxes--to reduce auto travel (car pools, fewer cars per family, smaller engines or cars, etc.)

APPENDIX H

RECENT CALIFORNIA AIR POLLUTION LEGISLATION

This appendix discusses several California air pollution bills which are up for consideration during the current legislative session. The status of these bills is presented as of June 14, 1973. Included here, are the bills comprising the "nine-bill" program which is sponsored by Assembly Speaker, Bob Moretti. Of the fourteen bills presented, it appears that only about six of them stand any chance of becoming law in their present form.

Assembly Constitutional Amendment 16 - Motor Vehicle Taxation and Revenues
Foran

This bill authorizes highway revenues to be used for construction of public transit systems, control of environmental pollution caused by motor vehicles, and payments of bonds issued for such purposes, as well as for highway purposes, including enforcement of law thereon and registration of motor vehicles.

Status: This bill is in the Senate Transportation Committee and will probably die there.

Assembly Bill 266 - Inspection Maintenance: Passenger Vehicles South Coast Air Basin
Foran

This act requires the State Air Resources Board to adopt passenger vehicle emissions test procedures and standards for the South Coast Air Basin and authorizes the Department of Consumer Affairs to be responsible for operating inspection and testing stations.

Certificates of compliance will be issued by the Department of Consumer Affairs when a vehicle meets the adopted emissions standards and when a standard fee, as determined by the Department, is paid. These fees will be deposited in the Air Pollution Control Fund. Upon initial registration or renewals thereafter, the Department of Motor Vehicles will require a Certificate of Compliance in the South Coast Air Basin. Motorcycle owners are exempt.

Status: This bill has been approved by the Assembly Committee on Transportation, May 30, 1973, and sent to the Assembly Ways and Means Committee. It will probably die in the Senate.

Assembly Bill 380 - Inspection, Maintenance in the SCAB
Deddeh

This bill requires the Department of Consumer Affairs, with the cooperation of the State Air Resources Board, the Department of the California Highway Patrol, and the Department of Motor Vehicles, to plan and operate an experimental annual motor vehicle inspection, diagnostic, and repair system, which is to be designed for the South Coast Air Basin. It declares that an effective system of periodic inspection, maintenance, and consumer education will reduce the level

of vehicular air pollution, noise emission levels, improve safety, and provide motorists with objective motor vehicle maintenance information.

Status: This bill was approved by the Assembly Committee on Transportation, May 30, 1973, and sent to the Assembly Ways and Means Committee. It will probably be passed by both houses and be signed by the Governor. It has been endorsed by the Administration.

Assembly Bill 1074 - Motor Vehicle Air Pollution Control
Diddeh/Papan/Wood

The State Air Resources Board would be required to establish standards for accrediting exhaust emission devices which: (1) reduce hydrocarbons, carbon monoxide, and nitrogen oxide emissions from motor vehicle exhaust to specified levels (hydrocarbons -- 350 ppm, CO -- 2 percent, nitrogen oxides -- 800 ppm); and (2) achieve a reduction of hydrocarbon, CO, and NO_x emissions substantially below the standards for any two pollutants set forth in specified sections of the Health and Safety Code. If an exhaust emission device meets two out of the three maximum levels, or if a device substantially reduces the emission of any two of the three pollutants, the State Air Resources Board may accredit such a device, provided that the emission level of the third pollutant is not increased above the level it was before installation of the device.

The Board is prohibited from requiring the installation of more than one exhaust emission device or any vehicle even if two or more devices are accredited. After at least one device is accredited, accreditation of a device, unless it is as effective as any device previously accredited, is prohibited. It specifies that any subsequent accreditation of a more effective device shall not affect the accreditation of a previously accredited device.

Status: This bill is ready for the third reading in the Assembly Transportation Committee and will probably be passed by the Assembly. If it passes the Senate, the Governor will probably sign it.

Assembly Bill 1279 - Gasoline Additives
Sieroty

The State Air Resources Board would be authorized, under specified conditions, to establish standards for composition or chemical or physical

properties of motor vehicle fuel additives and to adopt regulations thereon. It authorizes injunctive relief to be brought by the Attorney General. It imposes various agreement conditions upon any manufacturer of motor vehicle fuel additive found by the Board to result in significant and beneficial reduction in emission of air pollution and authorizes the Board to conduct tests, or to engage independent laboratories to conduct tests, to establish standards for motor vehicle fuel additives.

Status: This bill has been revised and approved and the Governor will probably sign it.

Assembly Bill 2283 - Los Angeles Basinwide APCD
Moretti

This bill creates the Los Angeles Basinwide Air Pollution Control District to encompass the area of the South Coast Air Basin. It specifies the duties, functions, and powers of the district, and limits, with respect to air pollution, the powers of boards of supervisors of counties included in the district.

It authorizes the district board, by resolution, to impose upon distributors an additional license fee of 0.1 cent per gallon of motor vehicle fuel for the privilege of distributing motor vehicle fuel in the district, with the net revenues transmitted to the district. The district board would also be authorized to impose a fee on stationary sources, as defined, of $1 per 100 tons of emission of air contaminants therefrom. The State Air Resources Board would be authorized to exercise the powers of the district under specified circumstances.

Status: This bill will be passed by the Assembly and killed in the Senate.

Assembly Bill 2284 - Air Pollution Violation Fine
Moretti

This act changes civil penalty for certain air pollution violations for each day in which the violation occurs from not to exceed $500, to $500 for a first offense, $1,000 for a second offense, $2,000 for a third offense, $3,000 for a fourth offense, $4,000 for a fifth offense, $5,000 for a sixth offense, and $10,000 for a seventh offense and each succeeding offense, during a 12-month period.

It makes provisions applicable to a violation of rules and regulations of the Bay Area Air Pollution Control District and prescribed provisions

regarding nonvehicular pollution control, including such provisions enforced by regional air pollution control districts created under the Mulford-Carrell Air Resources Act.

Status: This bill is in the Assembly Transportation Committee. It will be substantially modified by the Senate. The Governor will not sign it in its present form.

Assembly Bill 2285 - Gasoline Marketing Control
Berman/Moretti

This bill prohibits any person from holding or storing any volatile organic compound having a vapor pressure of 1.5 pounds per square inch absolute or greater, under actual storage conditions, in any stationary tank, reservoir, or other container of more than 250 gallons capacity, unless such tank, reservoir, or other container is either a pressure tank maintaining working pressures sufficient to prevent hydrocarbon vapor or gas loss to the atmosphere or is designed and equipped with a vapor loss control device or system, as prescribed. Pressure tanks may be equipped with one-way automatic pressure relief valves necessary to meet any other requirements of law.

Status: This bill will probably be killed in the Senate or be revised beyond recognition.

Assembly Bill 2286 - Stationary Source Controls
Montoya/Moretti

This bill requires, on January 1 and July 1 of each year, every air pollution control district to make public a list naming the person operating, and the location of, each stationary source located within the district emitting 25 or more tons annually, or in the case of the Bay Area Air Pollution Control District or such districts located in the San Diego Air Basin or the South Coast Air Basin, as designated by the State Air Resources Board, emitting 100 or more tons annually, of specified air contaminants and stating the amount of each such air contaminant emitted to at least the nearest 0.1 of a ton. It appropriates an unspecified amount to the State Controller for allocation and disbursement to local agencies for costs incurred by them pursuant to this act.

Status: This bill is in the Assembly Transportation Committee. It will pass both houses and probably be signed by the Governor.

Assembly Bill 2287 - Listing of Top Ten Stationary Source Categories
Ingalls/Moretti

This bill requires each air pollution control district, in which the state's ambient air quality standard for a particular air contaminant has been exceeded during the year in the district, to release and disseminate to the public a list naming the person operating, and the location of, the 10 stationary sources located within the district emitting the greatest amount of the particular air contaminant, if the source emits 25 tons or more annually of the air contaminant. The stationary sources would be required to be listed in decreasing order of the amount of their emissions of the air contaminant in tons per day. The list would also include such sources listed in decreasing order of their emissions in tons per day of hydrocarbons or reactive hydrocarbons where the state's ambient air quality standard for oxidant is exceeded.

The bill appropriates an unspecified amount to the State Controller for allocation and disbursement to local agencies for costs incurred by them pursuant to this act.

Status: This bill is in the Assembly Ways and Means Committee. It will probably pass both houses and be signed by the Governor.

Assembly Bill 2288 - Retrofit Devices
Ingalls/Moretti

Requires that the Department of Motor Vehicles, in addition to any other requirements relating to renewal of registration, require, upon 1975 renewal of registration of every 1966-70 model year motor vehicle subject to specified provisions of the Vehicle Code, a valid certificate of compliance from a licensed motor vehicle pollution control device installation and inspection station indicating that such vehicle is properly equipped with a motor vehicle pollution control device with which the vehicle was required, when new, to be equipped, as a condition of first sale and registration in this state.

Status: This bill is being heard in the Assembly Transportation Committee. The Governor will probably veto it this year, because it is felt that the DMV will not, at this time, enforce a certificate of compliance.

Senate Bill 479 - Exhaust Test, Tune-Up: Motor Vehicles South Coast Air Basin
Biddle and Coombs

Every registered automotive repair dealer in the South Coast Air Basin would be required to perform specified exhaust emission control system and device maintenance when he does a tuneup, or any portion thereof, on a motor vehicle with such a system or device, or both.

This bill requires such maintenance to be performed on all motor vehicles so equipped that are registered within the basin, except when the principal garage of the vehicle is located outside of the basin, at least once in 1974 and in 1975, under a schedule adopted by the Chief of the Bureau of Automotive Repair, after consultation with the State Air Resources Board and the Department of the California Highway Patrol.

Status: After first reading, this bill was sent to Senate Committee on Government Organization. It will probably die in the Assembly.

Senate Bill 549 - Motor Vehicle Air Pollution Control Devices
Wedworth

This bill requires the Bureau of Automotive Repair, the Department of the California Highway Patrol, the State Air Resources Board, and all local law enforcement agencies to enforce specified provisions prohibiting the installation, sales, offering for sale, or advertisement, of motor vehicle air pollution control devices which are not certified or accredited by the State Air Resources Board. Violation of these provisions and of specified provisions of the Vehicle Code regarding air pollution control devices, is a misdemeanor.

An unspecified amount is appropriated from the General Fund to the State Controller for allocation and disbursement to local agencies for costs incurred by them pursuant to this act.

Status: The bill is in the Senate Finance Committee. It will probably pass both houses and be signed.

Senate Bill 675 - Fleet Vehicle Conversion or Specification Type System
Beilenson

This bill requires every 1968 to 1973, inclusive, year model fleet vehicle, as defined, and with specified exception, registered under the

Vehicle Code and operating within any one or more of the Counties of Los Angeles, Orange, Riverside, Santa Barbara, San Bernardino, and Ventura, to be equipped with a specified fuel system or other device, in accordance with a schedule prescribed by the State Air Resources Board. Requires that all such vehicles comply no later than December 31, 1974. Makes provision for proof of compliance and certain exemption, and for the issuance of a windshield sticker.

The Department of Motor Vehicles, on and after January 1, 1975, would require, upon initial registration, transfer of ownership and registration, and, upon renewal of registration for the 1975 calendar year and each calendar year thereafter, of vehicles subject to such provisions, a valid certificate of compliance from a licensed motor vehicle pollution control device installation and inspection station indicating that such vehicle is equipped as required.

Status: This bill was read for the first time and sent to the Senate Committee on Government Organization. It will probably die in the Senate.

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