APTD-1442

TRANSPORTATION CONTROLS TO REDUCE MOTOR VEHICLE EMISSIONS IN BOSTON, MASSACHUSETTS

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Water Programs
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

APTD-1442

TRANSPORTATION CONTROLS TO REDUCE MOTOR VEHICLE EMISSIONS IN BOSTON, MASSACHUSETTS

Prepared by

GCA Corporation
GCA Technology Division
Bedford, Massachusetts

Contract No. 68-02-0041

EPA Project Officer: Fred Winkler

Prepared for
ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Water Programs
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

December 1972

The APTD (Air Pollution Technical Data) series of reports is issued by the Office of Air Quality Planning and Standards, Office of Air and Water Programs, Environmental Protection Agency, to report technical data of interest to a limited number of readers. Copies of APTD reports are available free of charge to Federal employees, current contractors and grantees, and non-profit organizations as supplies permit - from the Air Pollution Technical Information Center, Environmental Protection Agency, Research Triangle Park, North Carolina 27711, or may be obtained, for a nominal cost, from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22151.

This report was furnished to the Environmental Protection Agency by GCA Corporation, Bedford, Massachusetts, in fulfillment of Contract No. 68-02-0041. The contents of this report are reproduced herein as received from GCA Corporation. The opinions, findings, and conclusions expressed are those of the author and not necessarily those of the Environmental Protection Agency.

Publication No. APTD-1442

Acknowledgements

Many individuals and several organizations have been helpful in carrying out this study; for these contributions the GCA Technology Division extends its sincere gratitude.

Continued project direction and guidance were given by Mr. Fred Winkler (Project Officer) and Mr. Dave Tamny of the Land Use Planning Branch, EPA, Durham, North Carolina, and Mr. Wallace Woo (Co-Project Officer) of EPA, Region I.

Many members of local and state agencies supplied data and critical analysis to the study.

Alan M. Voorhees, Inc., acted as subcontractors to GCA Technology Division and supplied major input to the study especially in the areas of traffic data, control strategies and implementation obstacles.

TABLE OF CONTENTS

Section	Title	Page

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION AND SUMMARY

A. BACKGROUND

States were required to submit implementation plans by January 30, 1972, that contained control strategies demonstrating how the national ambient air quality standards would be achieved by 1975. Many urban areas could not achieve the carbon monoxide and oxidant air quality standards by 1975 or even 1977 through the expected emission reductions from the 1975 exhaust systems control. Major difficulty was encountered by many states in the formulation of implementation plans that included transportation control strategies (including, for example, retrofit and inspection, gaseous fuel conversions, traffic flow improvements, increased mass transit usage, car pools, motor vehicle restraints, and work schedule changes.) Because of the complex implementation problems associated with transportation controls, states were granted until February 15, 1973, to study and to select a combination of transportation controls that demonstrated how the national air quality standards would be achieved and maintained by 1977.

B. PURPOSE, SCOPE AND LIMITATIONS OF STUDY

The purpose of the study reported on herein was to identify and develop transportation control strategies that will achieve the carbon monoxide and oxidant air quality standards required to be met by Massachusetts in the Metropolitan Boston area by the year 1977. The results of the study were to help determine the initial direction that the State of Massachusetts should take in selecting feasible and effective transportation controls. It was anticipated that the control strategies outlined in this study would be periodically revised in the coming years. State implementation plans were analyzed to verify and assess the severity of the carbon monoxide and oxidant pollutant problems, and the most promising transportation controls and their likely air quality impact were determined. Major implementation obstacles were noted after discussions with those agencies responsible for implementing the controls and, finally, a surveillance review process (January, 1973 - December, 1976, inclusive) was developed for EPA to use in monitoring implementation progress and air quality impact of transportation control strategies.

It should be noted that the study was carried out relying on the best data and techniques available during the period of the study and further, that a large number of assumptions were made as to the nature of future events. It should also be noted that much of the data utilized was in the process of review and revision by the appropriate agencies throughout the course of the study. In order to satisfy contractual requirements, it was necessary that the best available data as of November 10, 1972, be utilized. Any air quality readings taken after August 31, 1972, and any changes in emission estimates after November 10, 1972, are not reflected in this study. The 1977 air quality predictions were based on extant air quality data and on predicted stationary source emissions and predicted traffic patterns, and these predicted parameters themselves were based on anticipated emission control techniques, anticipated growth patterns, and the assumed outcome of unresolved legal and political decisions. (The opening of key major traffic facilities before 1977 was particularly sensitive to the outcome of legal and political decisions.)

Further, the development ranking and selection of transportation controls were based on extant and predicted economic, sociological, institutional and legal considerations. Finally, the surveillance process presented in this report, although showing key checkpoints towards implementation of the recommended controls, is in itself dependent upon the same assumed pattern of future events.

It should be emphasized therefore, that to the extent that the timescale of the recommended program permits, the conclusions and recommendations of this report should not be construed as a program which must be rigidly followed until 1977, but rather it should be regarded first, as a delineation as to what appears at the present time to be a feasible course of action to attain air quality goals, and secondly, as a framework upon which an optimum on-going program can be built as new data and techniques become available, as legal and political decisions are made, and as the assumptions as to future events are, or are not, validated.

C. CONTENT OF REPORT

Section II of this report describes how the pollutant concentration levels which could be expected to occur in 1977 in the Metropolitan Boston area were predicted. These levels were determined by an adaptation of the proportion model using motor vehicle emissions from traffic patterns predicted for 1977 together with predicted non-vehicular emissions for 1977 obtained from state agencies. Comparison of these predicted 1977 air pollutant concentrations with the national air quality standards enabled the computation of the motor vehicle emissions which would result in the air quality standards being met, and therefore, to what extent, if any, reductions in the predicted 1977 motor vehicle emissions would be required. In order to determine the pollutant concentrations which was to serve as the basis for the proportional model, an intensive evaluation of all existing meteorological and air quality data was performed. The final determination as to the concentration value used was made in close cooperation with representatives of local and state agencies and of EPA.

Section III describes how candidate control strategies were developed, evaluated and ranked having regard to technical, legal, institutional, sociological and economic criteria. An important feature of this task was the continuing interaction between, on one hand, the GCA study team, and on the other hand, representatives of local and state environmental planning and transportation agencies, concerned citizen's groups, and EPA representatives.

Section IV presents the rationale for selecting the optimum package of controls necessary to achieve the required reduction in motor vehicle emissions and also presents the confirmed effect on air quality.

Section V deals with the obstacles to the implementation of the selected strategies. Since the obstacles to implementation were important criteria in the evaluation of the feasibility of candidate transportation controls, there is considerable discussion on such obstacles in earlier sections.

Section VI presents the surveillance review process which will enable EPA to monitor the implementation progress and air quality impact of the recommended strategies. A curve showing predicted air quality levels for the years 1973 to 1977 and beyond is presented, based on the implementation of the recommended transportation controls. This will provide a basic indication of the way in which air quality should improve as time passes and as controls are implemented. In addition, important checkpoints are provided delineating the salient actions which must be taken in order to implement the strategies such as the obtaining of the necessary financing and legislation.

It should be noted, however, that the surveillance process thus provided is of necessity based on the problem and the concomitant transportation controls as they are presently perceived. An equally important part of any surveillance process is the continuing reassessment of both the problem itself and the appropriateness of the required controls. As was discussed earlier in this Introduction, the present study employed a whole range of both of extant data and techniques, and also of assumptions about the course of future events. This data base should be continuously reviewed as new information becomes available. Thus, although the key background parameters are called out in the Surveillance Process, a thorough and continuing review of all the data, techniques and assumptions contained in this report will be required to properly update the problem definition and appropriate control measures.

D. SUMMARY OF THE PROBLEM AND RECOMMENDED TRANSPORTATION CONTROLS

1. Carbon Monoxide Air Quality and Emissions

The 8-hour average CO air quality will not be achieved by 1977 in several zones in the inner city of Boston with the CO emission reductions obtained from the Federal Motor Vehicle Control Program. Three zones, Kenmore Square, Haymarket Square-Government Center and Science Park will exceed the standard by a substantial amount, while two others, the East Boston Area by the Sumner-Callahan Tunnel and the Washington Street-Albany Street Area, will exceed it slightly. Tables I-1, I-2 and I-3 summarize the emissions and air quality in the three most critical zones with and without the application of the recommended control strategies. The other two zones will easily attain the air quality when any part of recommended transportation controls is applied.

2. Oxidant Air Quality and Hydrocarbon Emissions

The oxidant problem in Metropolitan Boston is regional and assumed to be uniform within the Route 128 area. A 25% reduction by 1977 in hydrocarbon emissions will be needed in addition to that which is attained by the Federal Motor Vehicle Control Program and the reduction of the stationary sources. Table I-4 summarizes the emissions and air quality in the area within Route 128 with and without the application of the recommended control strategies.

TABLE I-1

CARBON MONOXIDE EMISSIONS (KG/DAY) AND CONCENTRATION (PPM)

KENMORE SQ. WITH AND WITHOUT CONTROL STRATEGIES

	Present 1970	1977 without strategy	1977 with strategy
Vehicular Emissions	13,130	7,164	3,790
Non-Vehicular Emissions	45	54	54
Total Emissions	13,175	7,218	3,844
CO Level (8-hour Average)	22.4	12.3	6.5

	1978	Without Strategies 1979	1981	1984
Vehicular Emissions	5,917	4,852	3,468	2,339
Non-Vehicular Emissions	56	58	63	70
Total Emissions	5,973	4,910	3,531	2,409
CO Level (8-hour Average)	10.1	8.3	6.0	4.1

Area = .471 sq. mi.

TABLE I-2

CARBON MONOXIDE EMISSIONS (KG/DAY) AND CONCENTRATION (PPM) AT HAYMARKET SQ. WITH AND WITHOUT CONTROL STRATEGIES

	Present 1970	1977 without strategy	1977 with strategy	1978 without strategy	1979 without strategy
Vehicular Emissions	12,119	7,837	4,195	6,472	5,306
Non-Vehicular Emissions	45	54	54	55	57
Total Emissions	12,164	7,891	4,249	6,527	5,363
CO Level (8-hour Average)	20.7	13.4	7.2	11.1	9.1

Area = .471 sq. mi.

TABLE I-3

CARBON MONOXIDE EMISSIONS (KG/DAY) AND CONCENTRATION (PPM)

AT SCIENCE PARK WITH AND WITHOUT CONTROL STRATEGIES

	Present 1970	1977 without strategy	1977 with strategy	1978 without strategy	1979 without strategy
Vehicular Emissions	14,148	8,658	4,645	7,238	6,027
Non-Vehicular Emissions	45	54	54	55	57
Total Emissions	14,193	8,712	4,699	7,293	6,084
CO Level (8-hour Average)	24.2	14.8	8.0	12.4	10.4

Area = .471 sq. mi.

TABLE I-4

HYDROCARBON EMISSIONS (KG/DAY) AND OXIDANT LEVELS (PPM)

WITHIN RT. 128 REGION WITH AND WITHOUT CONTROL STRATEGIES

	Present 1972	1977 without strategy	1977 with strategy	1978 without strategy	1979 without strategy
Vehicular Emissions	131,555	72,101	47,800	61,000	52,500
Non-Vehicular Emissions	170,002	51,000	51,000	52,500	54,000
Total Emissions	301,557	123,101	98,830	113,500	106,500
Oxidant Level (1-hour Average)	.20	.10	.074	.089	.081

Area = 243 sq. mi.

3. Control Strategies

The following Transportation Control Strategies are recommended and their impact over the years is shown in Figures I-1 and I-2.

a. A Source Oriented Control Strategy consisting of Inspection-Maintenance and Retrofit estimated to reduce emissions as summarized in Table I-5.

b. A Transportation Oriented Control Strategy consisting of a CBD Parking Management, Peripheral Parking Facilities, moderate Transit Improvements, Road Pricing and Traffic Flow Improvements. These are estimated to reduce emissions in the inner city and throughout the region by the percent shown in Table I-5.

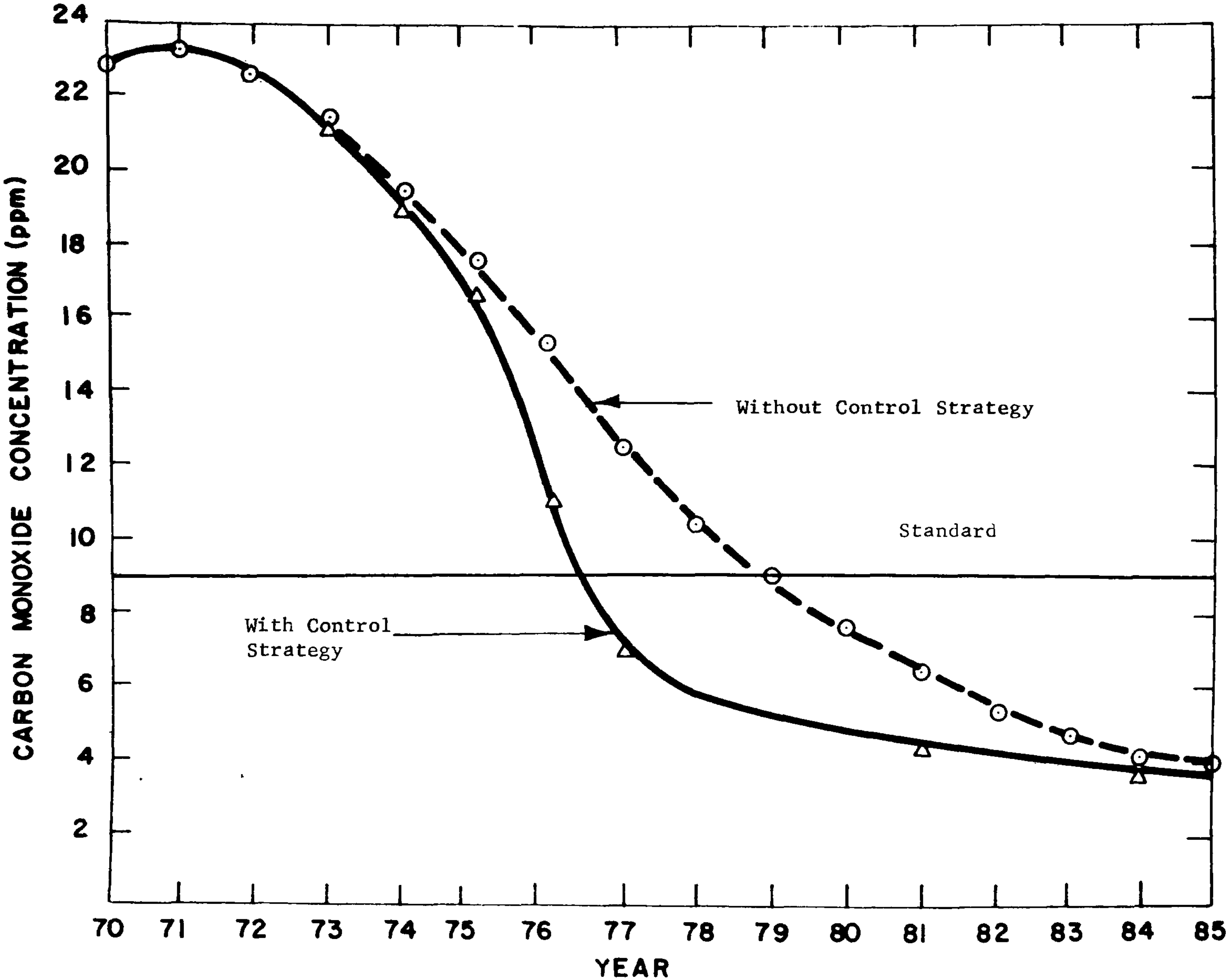


Figure I-1. Carbon Monoxide concentration estimates at Kenmore Sq. with and without control strategies.

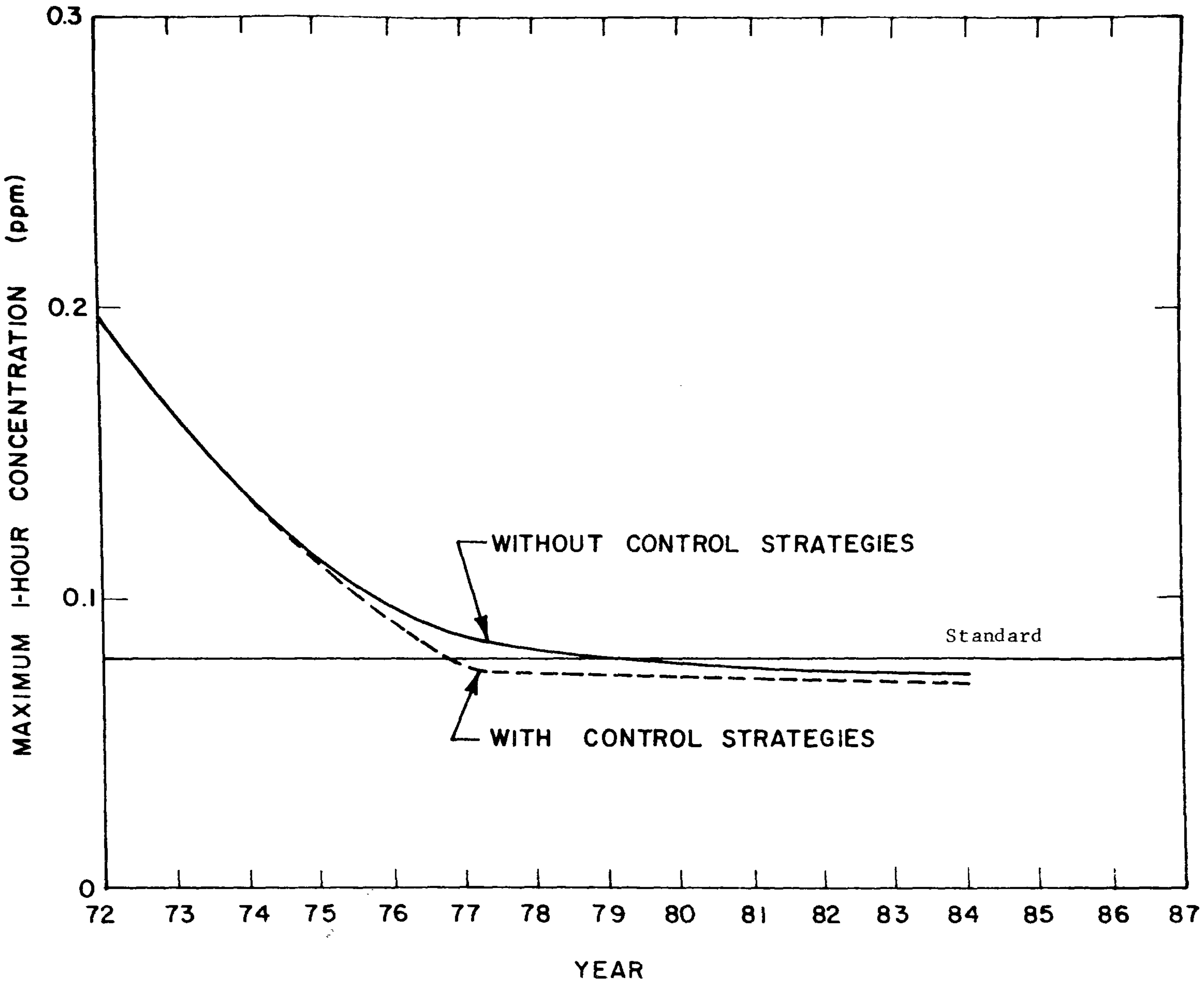


Figure I-2. Oxidant concentration estimates within Route 128 Region with and without control strategies.

TABLE I-5

EMISSION REDUCTIONS WITH RECOMMENDED CONTROL STRATEGIES

Program Element	Program Strategy	Percent Emission Reduction: Inner City HC	Inner City CO	Region HC	Region CO
Source Control	Inspection and Maintenance	10.4	8.7	10.4	8.7
	Retrofit	33.2	43.5	33.2	43.5
Transportation Oriented	CBD Parking Management, Peripheral Parking Facilities, Mass Transit Improvements, Road Pricing	11.1	11.1	3.9	3.9
	Traffic Flow Improvements	1.5	1.5	.3	.3
	TOTAL	56.2	64.8	47.8	56.4

II. VERIFICATION AND ASSESSMENT OF AIR POLLUTION PROBLEM

A. OUTLINE OF METHODOLOGY

The basic procedure employed was to develop pollutant concentration levels which could be expected in 1977 without the application of transportation controls (the potential 1977 levels). Pollutant levels were determined by the proportional model using non-vehicular emissions supplied by state agencies and using vehicular emissions based on traffic data developed during the course of this study. More sophisticated techniques could not be employed due to the lack of suitable extant calibrated diffusion models, and the short time period of the contract which precluded the development of a suitable model and the required inputs. Comparison of potential 1977 air quality levels with the appropriate standard gave the allowable motor vehicle emissions in 1977, which in turn formed the basis for the development of transportation control strategies.

Emissions from non-vehicular sources were obtained from state implementation plans updated as required from information supplied by state agencies. Emissions from vehicular sources were computed following the recommendations given in EPA draft publication An Interim Report on Motor Vehicle Emission Estimation by David S. Kircher and Donald P. Armstrong, dated October 1972. Air quality data for each sensor within the city area was reviewed and evaluated in close cooperation with state and local agencies. The instrumental method and sensor location was studied and records of instrument maintenance and calibration examined so as to identify questionable readings. Meteorological records were then examined and compared with seasonal and diurnal variations in air quality levels. Finally the pollutant concentration which would form the basis for the proportional rollback calculations were decided upon in concert with state and local agencies and EPA representatives. The year in which this concentration level occurred defined the base year for the proportional rollback calculations.

Because of the major differences involved, the detailed methodologies for carbon monoxide and oxidants are presented separately below.

1. Methodology for Carbon Monoxide

Because ambient concentrations of carbon monoxide at any given location appear to be highly dependent on carbon monoxide emissions in the near vicinity, it was felt that some justification existed for a modification of the proportional model. It was felt that in order to reduce ambient CO levels in, for example, a central business district (CBD), it would be more appropriate to roll back CO emissions in the CBD itself, rather than the entire air quality region. The assumption was therefore made that pollutant concentration in any given zone was directly proportional to the emission rate of that pollutant emission within that zone. Accordingly, the city area was divided into traffic zones - about the size of the central business district (CBD) in the center of the city with increasingly larger zones towards the suburban areas. Where traffic data was already available for existing "traffic districts" the traffic zones were either the traffic districts themselves or suitable aggregations thereof. Otherwise the traffic zones were based on rectangular grids.

An emission density/concentration ratio (e/c ratio) was assigned to each sensor, the e/c ratio being based on the total CO emission density (expressed in Kg/sq. mile/24 hours) for the base year within the zone in which the sensor was located, and the CO concentration value which formed the basis of the proportional rollback computations. Based on the e/c ratios so obtained, the maximum allowable emission density was derived which corresponded to the national air quality level to be achieved (i.e., 9 ppm for an 8-hour average). Maps showing the emission densities for each zone were then prepared for 1977 and other years based on the predicted vehicular and non-vehicular emissions for those years. Vehicular emissions were based on traffic patterns predicted for those years in the absence of any transportation controls imposed in order to meet national air quality standards for CO (the "no strategy case"). Non-vehicular emissions for the years of interest were obtained from state implementation plans and state agencies. These take into account the predicted growth and the predicted control strategies to be applied to those sources. The predicted control strategies were generally those which state agencies considered to be the maximum feasible.

From these maps, the zones in which emissions exceeding the maximum allowable density were identified. On the assumption that the predicted emission densities from non-vehicular sources were to be taken as irreducible, the allowable emissions from motor vehicles in each zone for the year of interest were then determined. For the purposes of evaluating the effects of candidate transportation controls, the maximum allowable emission density for the year 1977 was expressed as a percentage reduction from the 1977 "no strategy" emission density. However, as will be seen in following sections of this report, as each traffic control was developed, emissions were recomputed, using the revised VMT's and speeds resulting from the application of the control measures.

A typical summary sheet of the output of this methodology is shown in Table II-1. It should be noted that the term "without strategy" refers to a transportation strategy, i.e., one which affects only vehicle emissions. The non-vehicular emissions used reflected both the growth expected in such emissions and also the effect of various control strategies for non-vehicular sources as predicted by state agencies. It should also be noted that total emissions rather than emission densities are presented since the summary refers to the rollback in one zone only.

2. Discussion of Methodology for Carbon Monoxide

a. Modified Proportional Model Applications and the limitations of the conventional proportional rollback method have been well documented and reviewed and need not be discussed further here.[21] The

TABLE II-1

SAMPLE SUMMARY SHEET FOR: METROPOLITAN BOSTON

II. CARBON MONOXIDE

A. Zone for which emissions computed.

4-2 Kenmore Square Zone 25

B. Area: .471 sq. miles

C. Carbon Monoxide emissions (Kg/24 hr.) and CO levels (ppm).

	Present 1970	1977 without strategy	1977 with strategy
Vehicular Emissions	13,130	7,164	3,790
Non-Vehicular Emissions	45	54	54
Total Emissions	13,175	7,218	3,844
CO Level (8-hour average)	22.4	12.3	6.5

	WITHOUT STRATEGIES 1978	1979	1981	1984
Vehicular Emissions	5,917	4,852	3,468	2,339
Non-Vehicular Emissions	56	58	63	70
Total Emissions	5,973	4,910	3,531	2,409
CO Level (8-hour average)	10.1	8.3	6.0	4.1

technique used in the present study was an extension of the conventional rollback technique to the extent that it was assumed first, that the constant of proportionality between emissions and concentration may be derived from emissions emanating from the relatively small area around the sensor (the traffic zone) and second, that this constant of proportionality (the emission/concentration ratio) could be applied to determine pollutant concentrations in other zones of comparable area on the basis of the pollutant emissions in those zones.

Some justification of the first assumption can be found, for example, in recent work of Hanna[15] and Gifford[14] who demonstrate the dominance of urban pollution patterns by the distribution of the local area sources. The success of their urban diffusion model, in which concentration is simply directly proportional to the area source strength and inversely proportional to wind speed, is attributed largely to the relatively uniform distribution of emission within an urban area and the rate at which the effect of an area source upon a given receptor decreases with distance. In the proportional model, meteorological effects, such as wind speed, are assumed to be duplicated over one-year periods. The validity of the second assumption depends, in large part, upon the extent to which diffusion and transport parameters are uniform from zone to zone - a factor which could not be investigated because of the constraints of the program. Thus, it was felt that, in the absence of a more sophisticated technique, the use of this extension to the proportional model was justified first, to obtain some assessment as to whether the existing sensors were located in the hotspots, and second, to obtain some assurance that transportation strategies intended to reduce emission densities in one zone (to the level required to meet ambient standards) did not increase emission densities to unacceptable levels in adjacent zones. In Boston, it was decided by the Bureau of Air Pollution Control and EPA to use only one e/c ratio because only one station was operating at the time the maximum occurred.

As might be expected, where an urban area had several sensors, the emission concentration ratios were widely different and this served to underline the fundamental limitations of the technique employed. An implicit assumption in the technique employed was that the air quality in a traffic zone could be fairly represented by one concentration level and that this level depended only upon the average emission density within that zone. The two major factors mitigating against this assumption are:

a) Emission densities are not uniform across even a small traffic zone.

b) Concentration levels are not uniform across the traffic zone partly because of the lack of uniformity of emission density and partly because the point surface concentrations are affected by micrometeorology and microtopography as well as emission density.

Considerable judgement had to be used, therefore, both in the derivation of e/c ratios and in their subsequent use. In heavily trafficked downtown areas the variation was judged not to be too great, so that the single recorded concentration might reasonably be expected to be representative of the zone's air quality and emission density. However, in suburban zones having overall low traffic densities, sensors were often found to be placed at very localized hot spots, such as a traffic circle, so that the recorded concentration levels were neither representative of the overall air quality nor of the overall emission density in the zone.

The e/c ratio derived from the sensor in prediction of 1977 concentration levels, gave air quality levels which were generally representative of the suburban zone. However, it must be realized that control strategies based on this procedure, while they may ensure that the overall air quality in a suburban zone will not exceed ambient standards, do not preclude the occurence of higher concentrations in very localized hot spots such as might occur in the immediate vicinity of a major traffic intersection.

b. Seasonal and Diurnal Variations

The carbon monoxide concentration level chosen as the basis for the base year e/c ratio was the highest valid eight-hour average observed during the base year. The one-hour average either never exceeded the standard or was very much closer to the standard than the eight-hour average, so that controls required to meet the 8-hour standard would also result in the 1-hour standard being met. Motor vehicle emissions over 24 hours, 12 hours and max. eight-hour periods were compared with sensor readings and the most appropriate period of time selected on which to base calculations of emission density. Although seasonal variations in readings were noted, traffic data was not available on a seasonal basis, so that vehicle emissions were based on annual average work day traffic data.

c. Background Concentrations

Background concentration levels of CO were not taken into account. Where a zone was located near a large point source, simple "worst case" diffusion calculations were performed to assess the effect of the point source on the zone. In all cases, it was found that this contribution negligible. Where a zone actually contained a large point source, its emissions were found to be much greater than automotive emissions within the zone and any problem in that zone was regarded as due entirely to the stationary source.

3. Methodology and Discussion for Oxidants

The technique employed for oxidants was basically the same as has just been described for CO with the major difference that only one, the region within Route 128, was used as the basis for the proportional rollback. Because of the length of time required for the formation of oxidants from hydrocarbon emissions, the relatively small areas used as the basis for CO could not be justified. The region within Route

128 was largely a matter of judgement and the decision was made in concert with state and local officials and EPA. In general, it was about the size of the metropolitan area.

The reductions in hydrocarbon emissions necessary to achieve oxidant ambient standards were obtained from Appendix J, Federal Register of August 14, 1971.

B. DISCUSSION OF BASELINE AIR POLLUTION LEVELS

1. Natural Features of the Metropolitan Boston Area

a. Topography

The region is a flat coastal basin surrounded by a semicircle of low hills to the south, west and north, and by Massachusetts Bay on the east. These topographical features, while not of major consequence, are of significance in confining the ventilation of the occasional sea breezes.

Elevations vary from zero to 620 feet above sea level and average 100 feet above sea level. The region is drained by several rivers. The close proximity of the ocean greatly influences local climatology and meteorology.

b. Meteorology

Climatological statistics for the Metropolitan Boston area are based principally on observations from Logan Airport, at the city center near the ocean.

The Metropolitan Boston Interstate Air Quality Control Region experiences a coastal temperature climate with a normal annual temperature of 51.4^{o}F and a normal annual precipitation of 43 inches.

The data indicates that the prevailing northwesterly winter wind has an average velocity of 12-15 mph with a resultant direction of 300 degrees and a resultant wind speed of 7-10 mph. The information shows that the wind in the summer season, the prevailing southwesterly wind, has an average velocity of 10-12 mph, a resultant velocity of 3-5 mph and a resultant direction of 240 degrees.

The spring and fall seasons show a transition in wind direction and average temperature, witha variation in resultant wind direction and resultant wind speed. The wind and the transition-weather variations in spring and fall has changeable and less predictable weather patterns during these seasons.

The months of December, March, June, and September further complicate the weather patterns since these months are truly transitional and, in most instances, do not follow the calendar seasonal weather patterns.

The annual average morning mixing depth is 650 meters and the annual average afternoon mixing depth is 1100 meters. The seasonal averages vary from 475 meters for summer mornings to 800 meters for winter mornings and from 1000 meters in autumn and winter afternoons to 1200 meters in spring and summer afternonns. The wind speeds vary from 8.8 meters/second in spring afternoons to 5.5 meters/second in summer mornings with annual averages of 7 meters/second for morning, and 8 meters/second for afternoons. This data is summarized in Table 1.

Generally the area has fewer stable periods relative to the typical Eastern United States meteorology. Periods of stable, stagnant weather conditions (persisting 3 to 5 days) occur infrequently

TABLE II-2

AVERAGE MIXING DEPTH AND WIND SPEEDS FOR METROPOLITAN BOSTON

TIME PERIOD	MIXING DEPTH (meters)	WIND SPEED (meters/second)
MORNING		
Winter	800	8.0
Spring	750	7.0
Summer	475	5.5
Fall	650	6.5
Annual	650	7.0
AFTERNOON		
Winter	1000	8.5
Spring	1200	8.8
Summer	1200	7.5
Fall	1000	7.8
Annual	1100	8.0

during the summer and fall. Such periods occur only about once or twice a year.

2. Location and Type of Instrumentation

a. Instrumentation and Sampling Locations

Metropolitan Boston presently monitors carbon monoxide and oxidants at Kenmore Square and at Wellington Circle as part of its air quality monitoring network. Carbon monoxide was also sampled at Science Park until May, 1972, when the station ceased operation. The University of Massachusetts has monitored oxidants at its Surburban Experimental Station, Waltham, Mass. for several years. The Environmental Protection Agency monitored carbon monoxide and ozone at the University of Massachusetts field station in Waltham, Massachusetts for a two-month period in the summer of 1971. Data was also collected at two sites operated during the summer of 1972 as part of a study by the Boston Transportation Planning Review. Table II-3 is a brief summary of the operation of the situations.

1. Kenmore Square

The Kenmore Square air quality monitoring station has monitored CO and Oxidants since December 1970. The station is presently located at the intersection of three major roads in Boston: Commonwealth Avenue, Beacon Street, and Brookline Avenue. The sampling port is less than three meters from the road and approximately four meters above the

TABLE II-3

STATIONS MONITORING CARBON MONOXIDE OR OXIDANTS IN METROPOLITAN BOSTON

LOCATION	POLLUTANT	METHOD	DATES OF OPERATION	OPERATING AGENCY
Kenmore Square	Carbon Monoxide Oxidants Oxidants	NDIR Mast KI Chemiluminescence	12/70-Present 12/70 - 11/71 4/72 - Present	Mass. Bureau of Air Pollution Control
Science Park	Carbon Monoxide	NDIR	4/71 - 5/72	Mass. Bureau of Air Pollution Control
Wellington Circle	Carbon Monoxide Oxidants	NDIR Chemiluminescence	1/72 - Present 4/72 - Present	Mass. Bureau of Air Pollution Control
Waltham	Carbon Monoxide Oxidants Oxidants	NDIR Chemiluminescence Mast KI	9/71 - 10/71 7/71 - 8/71	U. S. Environmental Protection Agency University of Mass.
A Street South Boston	Carbon Monoxide Oxidants	NDIR Chemiluminescence	6/72-7/72 6/72-7/72	Boston Transportation Planning Review
D Street South Boston	Carbon Monoxide Oxidants	NDIR Chemiluminescence	6/72 - 7/72 6/72 - 7/72	Boston Transporation Planning Review

road. The station is in the midst of several blocks of five story row houses, which impede the circulation of air in the area. An east-west channeling of wind currents is expected in this area along the roadways. Due to this circulation problem and the proximity of the station to the street (less than 3 meters), the data collected at this site may be more affected by traffic pecularities of the region than actual ambient conditions. The station is so sensitive to local traffic that a small change in the CO levels can be detected with every traffic light change.

2. Wellington Circle

The air quality monitoring trailer at Wellington Circle, Medford, Mass., has been in operation since February 1972. It is approximately three miles north of Boston within the traffic circle. Three major arteries circulate traffic around the rotary. The inlet port is approximately 20 meters from the road on two sides and an estimated 40 meters on the other two. The inlet port is approximately 3 meters above the ground. The site is relatively open and should benefit from good circulation from all directions.

3. Science Park

The Science Park station is presently not in operation. It has monitored CO since early 1971 and will soon be back in operation at a nearby site. It was located at the entrance of the Boston Museum of Science and Storrow Drive. It was moved because a parking garage was built on the site. The trailer was located approximately 10 meters above the McGrath Highway and 10 to 15 meters back from the road.

The site was relatively open and near the ocean, although the western side is blocked by the Science Museum. The site sits on a bridge overlooking the Charles River.

4. Waltham Site

The Suburban Experimental Station operated by the University of Massachusetts in Waltham, Mass. is approximately 8 miles from downtown Boston. The sampling site is approximately 60 meters from the nearest roadway. Route 128, a major expressway, is approximately 1 mile to the east and Waltham Square is one-half mile south of the station. The University of Massachusetts has monitored oxidants for over 4 years using a Mast KI instrument. In addition EPA monitored carbon monoxide and oxidants at this site during the summer of 1971.

5. BTPR Sites

The Boston Transportation Planning Review operated two sites in Boston during the summer of 1972. The first station was located on Albany Street in the Massachusetts Department of Public Works yard, about 2 miles south of the downtown area and near the southeast expressway.

The second BTPR site was on D Street in South Boston at another Massachusetts DPW yard. D Street is about 1 mile east of the downtown area and a mile south.

b. Type of Instrumentation

1. CO Analyzers

The Kenmore Square, Wellington Circle and Science Park stations all use an Intertech URAS II NDIR carbon monoxide analyzer and have used them throughout the observation period. The other three stations have all used the EPA reference method although the actual models are not known.

2. Oxidant Analyzers

The Wellington Circle and Kenmore Square stations both use a Bendix Chemiluminescence instrument and the BTPR sites soth used a McMillan Chemiluminescence instrument. The EPA's data from the Waltham site also used a Chemiluminescence instrument. The University of Massachusetts data at Waltham and the Kenmore Square data previous to 1972 used a Mast KI Oxidant monitor. All data were collected with the EPA reference method or approved alternate.

3. Review of Air Quality Data

a. General

CO and total oxidant concentrations observed in the Metropolitan Boston area during the one-year period from 1 July 1971 through 31 July 1972 have been reviewed and the maximum values compared to those reported in the implementation plan for 1970.

The data are not yet summarized in a format that allows for facile review. The EPA data handling system will be implemented soon but is not yet in operation. Statistical summaries have been prepared for the maximum 1 and 8-hour CO periods and 1-hour oxidant periods. No 8-hour summaries are available unless the levels rose above 8 ppm. Due to changes in the equipment and some maintenance problems, the stations did not operate for a portion of the time. The number of days with observations has also been summarized. Tables II-4, 5 summarize the maximum levels monitored at the various stations for CO and oxidants.

b. 1-hour Carbon Monoxide Levels

Tables II-(6-10) summarize the maximum 1-hour levels observed at the sampling stations.

There were no readings in excess of the maximum one-hour standard of 35 ppm (40 milligrams/cubic meter) at any time from any station during the period from June 1, 1971 to July 31, 1972. The standard was equalled on one occasion at the Science Park station, but second highest one-hour reading was 26 ppm. Not much can be said about the diurnal variation from the available data. As Figure II-1 illustrates the Kenmore Square station suffers from moderately high levels throughout the day with noticeably lower levels recorded only in the early morning hours. Wellington Circle (Figure II-2 seems to have two rush hour periods with a fairly high evening residual, perhaps the result of local effects such as a nearby drive-in movie. Science Park (Figure II-3 with the exception of one peak which occurred on a Sunday afternoon just previous to a

TABLE II-4

HIGHEST AND SECOND HIGHEST CO LEVELS (IN PPM) OBSERVED IN METROPOLITAN BOSTON

	8-Hour Average			1-Hour Average	
	Highest	2nd Highest*	2nd Highest**	Highest	2nd Highest
Kenmore Square	16.9	16.0	15.6	26	23.8
Science Park	18.9	18.4	14.3	35	26
Wellington Circle	17.1	16.9	14.9	24	20
Waltham	9.2	9.2	8.8	13	12.5
BTPR 1	N.A.	N.A.	N. A.	12.3	12.0
BTPR 2	N.A.	N.A.	N. A.	19.7	17.6
Implementation Plan (1970 Kenmore Square Data)	22.4		16.9	42	

* 2nd Highest average following the maximum

** 2nd Highest average independent of the maximum

N.A. - Data not available

TABLE II-5

MAXIMUM OXIDANT LEVELS RECORDED IN METROPOLITAN BOSTON

	Maximum 1 hr Oxidant Level (ppm)
KENMORE SQUARE	
Chemiluminescence	.095
Mast KI	.150
WELLINGTON CIRCLE	.110
WALTHAM	.179
Chemiluminescence	
Mast KI	.142
BTPR 1	.186
BTPR 2	.219

TABLE II-6

MAXIMUM 1-HOUR CO CONCENTRATION OBSERVED AT KENMORE SQUARE IN PPM DURING THE PERIOD 1 JUNE 1971 - 31 JULY 1972

HOUR	1971 JUNE	JULY	AUG	SEP	OCT	NOV	DEC	1972 JAN	FEB	MAR	APR	MAY	JUNE	JULY	MAXIMUM
1	8	10	10	10		8	14	25		8.5	12	7.7	7.9	10.7	25
2	5	9	8	7		7	9	20		8.5	12	7.5	8.1	11.6	20
3	5	7	5	6		6	8	8		6.5	10	5.9	4.9	5.6	10
4	2	3	4	4		5	6	8		4.5	9	5.0	3.6	3.6	9
5	2	3	3	2		4	5	7		4	6	5.1	3.4	2.9	[illegible]
6	3	3	3	2		4	5	8		5.5	5	4.8	3.3	2.7	8
7	4	4	3	5		5	8	10		7	6	4.3	4.3	4.2	10
8	9	12	8	16		6	16	14		10.5	10	8.2	8.2	9.7	16
9	10	15	10	17		8	15	17		12	12	12.1	9.4	7.7	17
10	10	10	10	16		8	12	20		12	12	12.4	14.7	23.8	23.8
11	9	11	8	16		8	12	18		12	10	11.3	7.9	9.1	18
12	8	12	8	13		10	14	16		13	12	9.9	10.4	8.5	16
13	8	11	12	15		8	14	12		12	10	9.7	18.4	9.3	18.4
14	9	16	13	13		10	15	11		12	13	13.6	8.4	9.4	16
15	11	14	13	22		10	20	12		10	14	10.1	9.7	8.0	22
16	9	14	13	19		9	16	14		16	11	8.5	9.6	8.2	19
17	10	18	14	20		12	14	22		16	18	15.6	16.3	8.9	22
18	10	16	10	16		12	16	20		15	16	15.9	12.1	10.4	20
19	8	16	14	18		10	10	13		13	16	10.0	10.3	8.0	18
20	9	15	12	16		6	10	17		8	17	9.3	10.9	9.3	17
21	8	15	14	11		10	10	26		9	16	9.9	8.4	8.6	26
22	12	15	13	13		10	12	17		10	17	9.2	11.8	14.7	[illegible]
23	13	15	19	15		12	13	10		9	13	11.9	9.5	16.9	19
24	13	13	14	10		10	10	15		10	16	8.9	10.1	14.4	16
MAXIMUM	13	18	19	22		12	20	26		16	18	15.9	18.4	23.8	
DAYS WITH OBS.	30	31	31	15	0	12	26	7	0	23	30	22	28	20	

TABLE II-7

MAXIMUM 1-HOUR CO CONCENTRATION OBSERVED AT WELLINGTON CIRCLE (IN PPM)
DURING THE PERIOD 1 FEBRUARY 1972 - 31 JULY 1972

HOUR	1971 JAN	FEB	MARCH	APR	MAY	JUNE	JULY	MAXIMUM
1		10	10	14	6	6	6	14
2		7	11	13	5	5	6	13
3		6	13	12	6	5	4	13
4		4	12	11	5	5	3	12
5		4	12	8	5	5	2	12
6		4	11	8	6	7	3	11
7		16	9	9	9	8	7	16
8		16	12	14	9	8	7	16
9		16	12	9	7	7	7	16
10		11	10	8	8	6	6	11
11		10	9	7	7	6	7	10
12		7	10	7	6	6	6	10
13		8	13	8	7	5	4	13
14		9	11	8	7	5	5	11
15		10	10	9	7	6	7	10
16		8	12	8	10	9	7	12
17		14	15	13	13	14	10	15
18		16	12	17	15	13	10	17
19		20	12	12	10	10	6	20
20		20	11	12	9	9	7	20
21		17	10	12	10	9	6	17
22		17	10	13	8	7	6	17
23		24	9	14	8	7	7	24
24		19	7	13	10	6	7	19
MAXIMUM		24	15	17	15	14	10	24
DAYS WITH OBS.		15	31	30	30	25	10	

TABLE II-8

MAXIMUM OBSERVED 1-HOUR CO CONCENTRATIONS (IN PPM) AT SCIENCE PARK
DURING THE PERIOD 1 JUNE 1972 - 8 MAY 1972

HOUR	1971 JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	1972 JAN	FEB	MAR	APR	MAY	MAXIMUM
1	8	6	5	7	22	6	6	15	6	6	5.4	5	22
2	7	4	4	7	16	5	6	6	4	6	6.4	4	16
3	7	4	3	5	18	3	4	6	4	5	5.4	4	18
4	7	3	3	4	14	5	3	7	4	5	5.5	4	14
5	6	4	2	4	13	5	4	8	4	5	6.2	4	13
6	5	3	2	4	10	6	4	7	4	6	7.3	4	10
7	4	3	4	5	9	8	7	9	11	10	5.7	7	11
8	7	5	7	10	11	14	9	12	18	12	7.7	10	18
9	5	7	7	8	13	12	9	19	15	10	7.5	8	19
10	4	6	6	9	10	9	10	12	12	11	6.2	8	12
11	5	6	6	6	10	10	8	12	9	11	6.4	7	12
12	5	6	5	6	8	7	8	9	10	8	8.5	7	10
13	4	5	3	7	6	10	10	8	8	8	8.8	8	14
14	6	8	5	9	6	6	9	10	8	14	6.4	8	14
15	6	8	6	7	7	6	9	10	10	35	6.6	10	35
16	7	9	5	8	8	8	11	10	10	10	11.0	10	11
17	8	16	10	8	16	12	13	12	16	13	15.7	12	16
18	7	15	11	10	15	13	10	16	14	14	12.1	14	16
19	6	10	4	12	12	10	8	17	10	12	7.1	12	17
20	5	7	6	10	9	9	5	13	10	7	8.7	7	13
21	7	6	7	9	9	8	6	13	8	6	6.6	6	13
22	8	5	7	9	16	6	8	12	8	8	7.3	8	16
23	8	6	7	7	26	14	9	10	8	10	8.3	7	26
24	8	8	6	8	26	8	8	18	9	6	9.0	7	26
MAXIMUM	8	16	11	12	26	14	13	19	18	35	15.7	14	35
DAYS WITH OBS.	28	31	28	30	22	30	31	29	27	31	30	8	

TABLE II-9

MAXIMUM 1-HOUR CARBON MONOXIDE CONCENTRATIONS (IN PPM)
AT ALBANY STREET STATION (BOSTON TRANSPORTATION PLANNING REVIEW)
JUNE 15, 1972-AUGUST 15, 1972

HOUR	JUNE	JULY	AUG.	MAX.
1	8.6	7.8	7.0	8.6
2	7.7	9.4	6.7	9.4
3	7.2	9.8	6.1	9.8
4	7.7	9.9	6.2	9.9
5	6.0	9.0	6.7	9.0
6	7.7	9.3	7.1	9.3
7	8.6	10.0	7.3	10.0
8	9.7	11.1	7.7	11.1
9	8.0	11.7	9.1	11.7
10	7.9	11.2	8.8	11.2
11	8.7	11.0	8.2	11.0
12	9.0	10.6	7.7	10.6
13	11.7	11.1	7.7	11.7
14	11.5	11.3	7.2	11.5
15	11.5	7.2	7.2	11.5
16	11.4	7.6	6.9	11.4
17	12.0	10.7	6.6	12.0
18	11.0	12.3	7.4	12.3
19	10.1	10.1	7.2	10.1
20	9.5	9.5	7.4	9.5
21	9.6	9.6	6.6	9.6
22	8.7	9.7	6.7	9.7
23	9.1	10.6	7.3	10.6
24	8.8	11.1	6.9	11.1
Max.	12.0	12.3	9.1	12.3
No. of Days with Obs.	15	27	15	

TABLE II-10

MAXIMUM 1-HOUR CARBON MONOXIDE CONCENTRATIONS (IN PPM)
AT D STREET STATION (BOSTON TRANSPORTATION PLANNING REVIEW)
JUNE 15, 1972-AUGUST 15, 1972

HOUR	JUNE	JULY	AUG.	MAX.
1	9.6	13.9	11.3	13.9
2	9.5	13.9	11.2	13.9
3	10.3	12.9	11.4	12.9
4	9.1	12.6	11.3	12.6
5	14.9	12.9	12.6	14.9
6	13.9	13.1	12.7	13.9
7	11.1	14.0	11.1	14.0
8	12.5	14.0	10.4	14.0
9	11.6	14.3	12.5	14.3
10	10.8	13.9	12.7	13.9
11	12.3	14.0	14.9	14.9
12	11.9	13.9	15.0	15.0
13	11.6	19.7	12.4	19.7
14	12.5	16.4	12.2	16.4
15	11.6	16.2	15.7	15.7
16	10.5	12.7	12.6	12.7
17	10.8	13.0	11.3	13.0
18	10.3	13.1	11.7	13.1
19	12.7	13.4	11.4	13.4
20	12.0	13.2	12.3	13.2
21	11.0	13.7	13.2	13.7
22	9.9	13.7	11.8	13.7
23	9.4	13.4	12.6	13.4
24	9.7	13.0	12.1	13.0
Max.	14.9	19.7	15.7	19.7
No. of Days with Obs.	14	30	15	

Figure II-1 Kenmore Square Maximum 1-Hour Carbon Monoxide Levels.

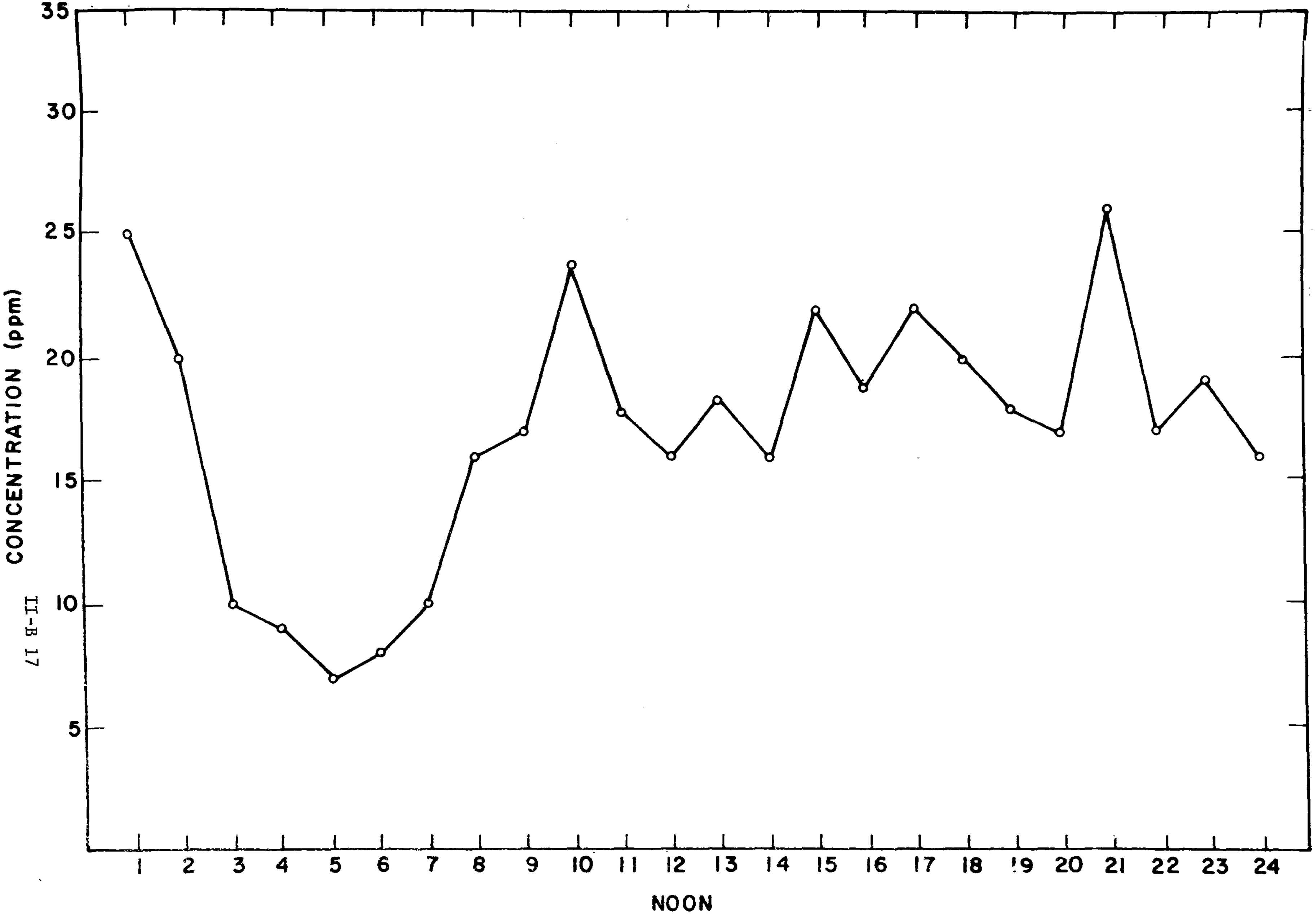


Figure II-2 Wellington Circle Maximum 1-Hour Carbon Monoxide Levels.

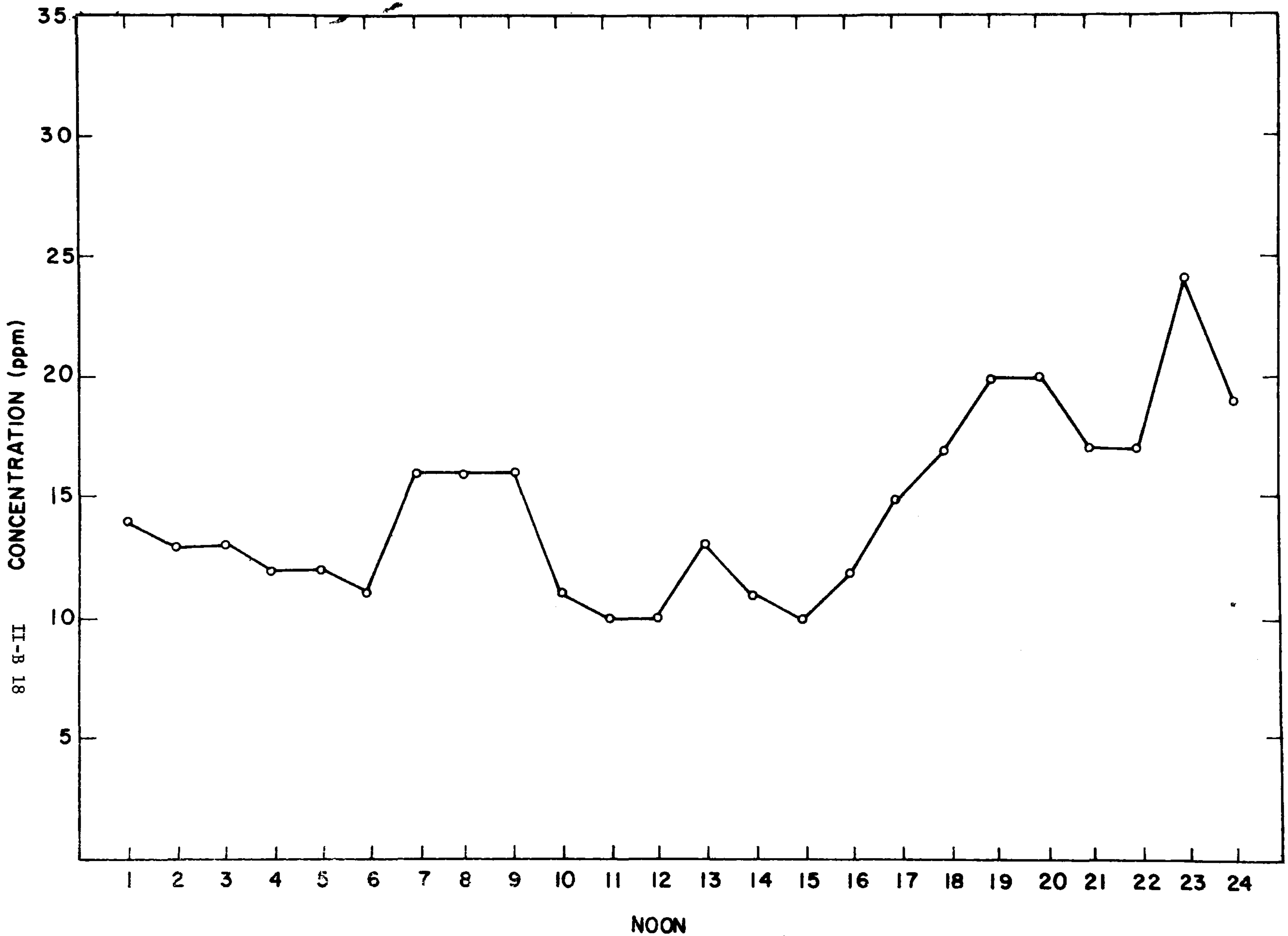
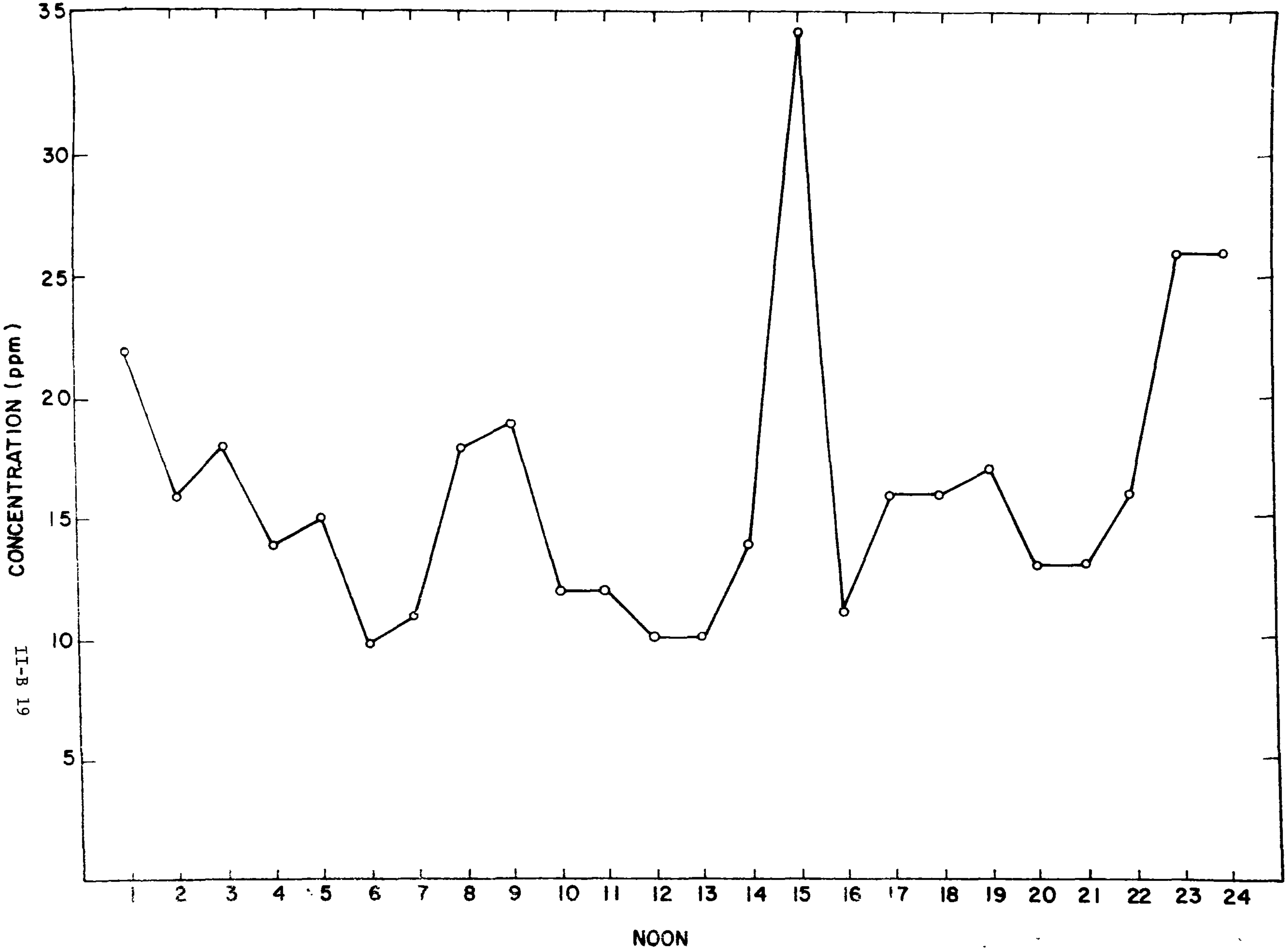


Figure II-3 Science Park Maximum 1-Hour Carbon Monoxide Levels.



sporting event, follows the typical diurnal pattern of two rush hours but has a relatively high late evening level, possibly a result of the local sports arena and other night spots in the area.

The summer months had relatively low levels and the fall and winter data appeared higher but the seasonal variations were not significant enough to evaluate based on the available data.

c. 8-hour Carbon Monoxide Levels

The data supplied by the Commonwealth of Massachusetts was summarized up to the period ending March 15, 1972. The summaries provided did not indicate levels if they did not exceed 8 ppm. The blank areas in Tables II-11, 12 are periods in which the levels never exceed 8 ppm. No summaries were available for Wellington Circle. The highest levels recorded were 16.9 at Kenmore Square and 18.9 at Science Park. These compare with the levels of 13.3 and 16.9 used in the implementation plan as maximum values. With the exception of the one peak period, the next highest levels unrelated to the 18.9 peak at Science Park was 14.3 ppm. This compares with the one hour data which, in general, showed Kenmore to be higher than Science Park.

d. Oxidant Levels

Hourly oxidants have only been monitored by the chemiluminescence method since April. The data reported previously has been monitored by the Mast KI method. The data is presented in Tables II-13 through II-18. The total oxidant levels recorded by the last Instrument

TABLE II-11

MAXIMUM 8-HOUR CONCENTRATION (IN PPM) OBSERVED AT KENMORE SQUARE (BOSTON)
DURING THE PERIOD OF 15 JUNE 1971 TO 15 MARCH 1972.
NO ENTRY INDICATES MAXIMUM LESS THAN 8 PPM. NUMBER OF ADDITIONAL
VALUES GREATER THAN STANDARD (9 PPM) ARE SHOWN IN PARENTHESIS. ENTRY
IS AT HOUR ENDING 8-HOUR PERIOD.

HOUR	JUNE 1971	JULY	AUG	SEPT	OCT	NOV	DEC	JAN 1972	FEB	MAR	MAX	NO. OVER STD.
1		13.6(2)	10.4	10.8(2)			10.4	16.0(3)			16.0	12
2		12.8(1)	9.6	9.9(1)			10.1	16.9(2)			16.9	9
3		11.6	8.4	9.0			9.6	15.8(2)			15.8	5
4		10.3		8.5			9.0	14.8(1)			14.8	3
5		8.8					8.1	12.4(1)			12.4	2
6								11.6(1)			11.6	2
7								11.9			11.9	1
8								11.8			11.8	1
9								10.8			10.8	1
10								10.8(1)			10.8	2
11				8.8			8.4	12.5(1)			12.5	2
12				10.0			9.9	13.8(1)			13.8	4
13				11.6			11.0	14.4			14.4	3
14		8.9		13.0			12.0(1)	14.8			14.8	4
15		10.0(2)	9.0	13.9			12.6(2)	15.0			15.0	8
16		11.0(1)	9.8	13.9			12.6(2)	15.0			15.0	8
17		11.6(2)	10.4(1)	13.6(2)			12.8(3)	15.6			15.6	13
18		12.6(2)	10.4(1)	13.6(3)		9.9	13.0(4)	15.6			15.6	16
19		13.0(3)	11.3(1)	13.9(3)		9.9	12.8(3)	14.8			14.8	16
20	8.1	13.0(2)	11.9(1)	14.0(2)		9.6	12.6(3)	14.0(1)			14.0	15
21	8.3	13.5(2)	12.1	13.5(3)		9.5	12.1(2)	13.8(2)		8.4	13.8	15
22	8.4	14.5(2)	12.6	13.5(2)		9.1	11.8(2)	13.9(2)			14.5	14
23	8.1	14.8(1)	12.4(1)	13.5(2)		8.6	11.5(1)	13.6(3)			14.8	13
24	8.4	14.6(2)	11.7(1)	13.5(1)		8.1	10.9	13.6(3)			14.6	12
MAXIMUM	8.4	14.8	12.6	14.0		9.9	13.0	16.9				
NO. TIMES EXCEED STD	0	36	17	36		5	39	48				
DAYS WITH OBS.	14	30	26	13	0	12	22	5	0	5		

TABLE II-12

MAXIMUM 8-HOUR CO CONCENTRATION (IN PPM) OBSERVED AT SCIENCE PARK DURING THE PERIOD 15 JUNE 1971 TO MARCH 15, 1972.

NO ENTRY INDICATES MAXIMUM LESS THAN 8 PPM. NUMBER OF ADDITIONAL VALUES GREATER THAN STANDARD (9 PPM) ARE SHOWN IN PARENTHESIS.

ENTRY IS AT HOUR ENDING 8-HOUR PERIOD

HOUR	1971 JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	1972 JAN	FEB	MAR	MAX.
1					15.0(1)			14.3	9.1		15.0
2					16.3(1)			13.0			16.3
3					17.5(1)			11.6			17.5
4					18.4(1)			10.9			18.4
5					18.9(1)			10.3			18.9
6					18.1(1)			9.6			18.1
7					16.0			9.3			16.0
8					14.1			8.8			14.1
9					13.0			9.3			13.0
10					12.3			10.0	8.6		12.3
11					11.3			10.8	9.4		11.3
12					10.5			10.9	10.0		10.9
13					9.4			10.8	10.3		10.8
14								10.9	10.5		10.9
15								10.8	9.6	10.0	10.8
16							8.1	10.3	8.8	10.8	10.8
17							8.8	9.1	9.0	11.5	11.5
18		8.3			8.3		9.0	9.0	9.4	12.1	12.1
19		8.6			8.9		8.1	9.3	9.9	12.0	12.0
20		8.8			9.7	8.3		9.3	10.4	11.8	11.8
21		9.1			9.4	8.8		(1)10.3	10.5	11.5	11.5
22		9.0			9.9	8.9		11.5	10.5	(1)10.4	11.5
23		8.9			10.8(1)	9.0		12.4	10.5	8.9	12.4
24		8.3			13.0(1)	8.8		12.9	10.4	8.5	13.9
MAXIMUM		9.1			18.9	9.0	9.0	14.3	10.5	12.1	18.9
O. TIMES XCEED STDS.	0	2	0	0	27	1	1	24	13	9	
DAYS WITH OBS.	12	31	24	30	19	30	28	27	26	15	

TABLE II-13

MAXIMUM 1-HOUR OXIDANT CONCENTRATION (IN PPM) OBSERVED AT KENMORE SQUARE

DURING THE PERIOD 1 JUNE 1971 TO 31 AUGUST 1972.

	MAST INSTRUMENT (KI)							BENDIX FRIEZ CHEMILUMINESCENCE							
HOUR	1971 JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	1972 JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG
1	.070	.070	.035	.065	.035	.055					.013	.056	.027	.018	.020
2	.070	.060	.035	.060	.030	.045					.017	.051	.034	.013	.022
3	.080	.050	.040	.055	.025	.040					.021	.051	.036	.025	.020
4	.090	.050	.050	.055	.020	.040					.032	.042	.037	.027	.016
5	.085	.055	.050	.050	.015	.030					.039	.041	.042	.032	.015
6	.075	.040	.045	.050	.015	.030					.029	.035	.038	.027	.008
7	.055	.035	.040	.040	.030	.045					.025	.041	.029	.024	.004
8	.055	.050	.045	.070	.045	.050					.035	.042	.020	.020	.004
9	.065	.045	.045	.060	.045	.035					.039	.048	.024	.021	.007
10	.090	.055	.045	.060	.030	.035					.038	.054	.029	.025	.006
11	.095(2)	.070	.050	.045	.030	.025					.039	.053	.042	.034	.012
12	.115(3)	.090(1)	.075	.050	.025	.045					.041	.067	.055	.048	025
13	.105(4)	.080	.110	.060	.030	.020					.043	.089	.079	.056	.023
14	.120(3)	.085	.120	.100	.035	.020					.058	.085	.082	055	.026
15	.120(5)	.080	.120	.080	.035	.015					.068	.092	.071	.058	.045
16	.125(4)	.090	.110	.070	.035	.025					.062	.094	.068	.062	.025
17	.115(3)	.090	.100	.070	.050	.030					.041	.095	.055	.062	.029
18	.110(2)	.080	.090	.075	.040	.040					.038	.095	.065	.075	020
19	.100(3)	.100(1)	.095(1)	.080	.035	.025					.047	.092	.058	.058	027
20	100(1)	.150(1)	.085	.090	.035	.025					.039	.079	.043	.045	.019
21	.130(2)	.110	105	.115	.035	.025					.048	.062	.045	.029	012
22	.145(2)	.080	.070	.080	.050	.035					.061	.034	.034	.022	.012
23	.110(1)	.060	.050	.080	.030	.030					.053	.030	.018	.014	.011
24	.085	.040	.040	.070	.035	060					.054	.031	.018	.019	.010
MAXIMUM	.145	.150	.120	.115	.050	.060					.068	.095	.082	.075	.048
NO. TIMES EXCEED STD.	52	10	9	3	0	0					0		1	0	0
DAYS WITH OBS.	28	29	26	[illegible]	24	15	0	0	[illegible]	[illegible]	15	31	30	31	22

TABLE II-14

MAXIMUM 1-HOUR OXIDANT CONCENTRATION (IN PPM) OBSERVED AT WELLINGTON CIRCLE DURING THE PERIOD APRIL 1, 1972 TO AUGUST 31, 1972

HOUR	1972 APRIL	MAY	JUNE	JULY	AUG	MAXIMUM
1	.030	.040	.025	.001	.030	.040
2	.032	.047	.027	.001	.032	.047
3	.035	.055	.035	.002	.035	.055
4	.040	.057	.045	.002	.032	.057
5	.040	.065	.055	.002	.037	.065
6	.037	.062	.055	.001	.028	.062
7	.037	.052	.055	.000	.017	.055
8	.040	.047	.035	.000	.014	.047
9	.045	.052	.035	.000	.023	.052
10	.047	.052	.035	.095	.030	.052
11	.050	.055	.040	.003	.046	.055
12	.050	.065	.040	.009	.081	.065
13	.050	.085	.055	.005	.101	.085
14	.055	.087	.075	.007	.102	.087
15	.055	.100(1)	.050	.006	.074	.100
16	.052	.110(1)	.055	.072	.070	.110
17	.050	.102(1)	.040	.005	.053	.102
18	.037	.075	.030	.003	.039	.075
19	.025	.062	.030	.002	.042	.062
20	.020	.052	.035	.004	.035	.052
21	.020	.040	.030	.001	.026	.040
22	.020	.042	.040	.000	.030	.042
23	.022	.045	.040	.001	.046	.046
24	.027	.042	.002	.001	.047	.047
MAXIMUM	.055	.110	.075	.095	.102	.110
NO. TIMES EXCEED STDS.	0	8	0	1	3	
DAYS WITH OBS.	24	29	26	9	20	

TABLE II-15

MAXIMUM 1 HOUR TOTAL OXIDANT CONCENTRATIONS (IN PPM) OBSERVED AT THE WALTHAM FIELD STATION DURING THE PERIOD OF JANUARY 1, 1971 - AUGUST 31, 1972 (MAST KI METHOD)

	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	JUNE	JULY	AUG	SEPT
1	.030	.028	.040	.042	.059	.055	.047	.040	.025	.018	.037	.039	.052	.019
2	.029	.033	.040	.049	.061	.045	.050	.037	.037	.019	.045	.037	.045	.015
3	.029	.034	.039	.053	.060	.041	.050	.045	.030	.017	.046	.043	.034	.017
4	.026	.034	.040	.055	.058	.039	.050	.035	.027	.017	.060	.042	.030	.015
5	.029	.019	.044	.048	.055	.032	.052	.040	.022	.022	.074	.035	.024	.017
6	.031	.024	.050	.044	.050	.035	.050	.042	.017	.017	.065	.039	.024	.017
7	.030	.025	.035	.050	.035	.038	.045	.030	.017	.016	.063	.032	.016	.022
8	.026	.024	.033	.045	.041	.044	.047	.032	.025	.015	.057	.032	.019	.028
9	.023	.026	.036	.049	.056	.054	.047	.037	.032	.019	.049	.038	.027	.027
10	.026	.029	.039	.055	.057	.068	.060	.045	.040	.023	.048	.057	.040	.035
11	.029	.026	.040	.065	.072	.086	.080	.085	.055	.027	.065	.064	.075	.055
12	.029	.027	.044	.067	.075	.083	.085	.110(1)	.055	.029	.075	.065	.095	.070
13	.030	.029	.044	.072	.081	.140(3)	.140(1)	.110(1)	.066	.039	.080	.080	.090	.085
14	.029	.031	.045	.065	.079	.140(2)	.100(1)	.107(1)	.080	.045	.069	.085	.087(1)	.077
15	.030	.033	.048	.063	.077	.140(2)	.097(2)	.112(1)	.087	.052	.065	.072	.084(1)	.077
16	.029	.033	.042	.061	.078	.110(2)	.100([illegible])	.122(1)	.085	.048	.055	.078	.090(1)	.082
17	.024	.029	.040	.055	.072	.102(3)	.092	.120(1)	.067	.039	.065	.070	.095	.080
18	.028	.017	.041	.054	.060	.100(2)	.105	.115(1)	.067	.028	.060	.088	.098	.064
19	.028	.020	.042	.060	.063	.112(1)	.137(1)	.112(1)	.050	.022	.055	.085(1)	.095	.058
20	.028	.013	.041	.056	.058	.137(1)	.127	.117	.075	.015	.050	.090(1)	.085	.037
21	.028	.016	.039	.055	.057	.142(2)	.097	.087	.030	.009	.049	.077	.066	.037
22	.029	.021	.037	.045	.056	.115(1)	.065	.060	.082	.012	.042	.055	.062	.031
23	.028	.031	.037	.048	.056	.090(1)	.055	.047	.067	.014	.038	.045	.060	.026
24	.028	.028	.049	.045	.057	.075	.047	.050	.060	.008	.041	.044	.056	.025
MAXIMUM	.030	.034	.048	.072	.081	.142	.140	.122	.087	.052	.080	.095	.098	.085
NO. TIMES EXCEED Stds	0	0	0	0	0	33	18	19	5	0	0	7	12	3
DAYS WITH OBS.	31	28	31	30	31	31	31	31	30	30	29	30	31	29

TABLE II-16

MAXIMUM 1HOUR OXIDANT CONCENTRATIONS (IN PPM) OBSERVED AT THE WALTHAM FIELD STATION DURING THE PERIOD JULY 19, 1971 TO AUGUST 31, 1971 (EPA Chemiluminescent Data)

(numbers in paranthesis indicate number of additional readings exceeding the standard)

	July	August
1	.049	.064
2	.049	.064
3	.059	.064
4	.059	.064
5	.054	.054
6	.054	.049
7	.049	.039
8	.059	.069
9	.094	.084
10	.109(1)	.099
11	.129(4)	.109(1)
12	.134(1)	.159(7)
13	.139(3)	.169(7)
14	.144(4)	.154(7)
15	.144(4)	.134(7)
16	.149(3)	.149(6)
17	.129(2)	.149(4)
18	.119(2)	.159(3)
19	.094(1)	.169(1)
20	.079	.179
21	.064	.144
22	.074	.104
23	.059	.064
24	.054	.074
MAXIMUM	.144	.179
NO. TIMES EXCEED STDS	39	57
DAYS WITH OBS.	13	31

TABLE II-17

MAXIMUM 1-HOUR OXIDANT CONCENTRATIONS AT ALBANY STREET (BTPR)
(numbers in parenthesis indicate number of additional readings exceeding the standard)
JUNE 15, 1972-AUGUST 15, 1972

HOUR	JUNE	JULY	AUG.	MAX.
1	.066	.108(1)	.054	.108
2	.072	.106(1)	.047	.106
3	.073	.114(1)	.043	.114
4	.121	.092	.048	.121
5	.123	.090	.057	.123
6	.091	.083	.061	.091
7	.071	.078	.058	.078
8	.058	.086(1)	.046	.086
9	.047	.089	.040	.089
10	.052	.088(2)	.063	.088
11	.066	.121(9)	.088	.121
12	.108(1)	.138(10)	.100	.138
13	.115(3)	.158(15)	.101(2)	.158
14	.125(3)	.172(14)	.102(3)	.172
15	.120(2)	.165(18)	.108(4)	.165
16	.109(1)	.177(18)	.120(2)	.177
17	.107(1)	.151(12)	.122(1)	.151
18	.090	.152(13)	.097(1)	.152
19	.087(1)	.186(11)	.084	.186
20	.072	.178(7)	.067	.178
21	.073	.138(6)	.065	.138
22	.086	.104(4)	.066	.104
23	.061	.140(4)	.055	.140
24	.056	.109	.050	.109
Max.	.125	.186	.122	.186
No. over Stds.	22	170	22	
No. of Days with Obs.	16	31	15	

TABLE II-18

MAXIMUM 1-HOUR OXIDANT CONCENTRATIONS AT D STREET STATION (BTPR)
(numbers in parenthesis indicate number of additional reading exceeding the standard)
JUNE 15, 1972-AUGUST 15, 1972

HOUR	JUNE	JULY	AUG.	MAX.
1	.070	.120	.046	.120
2	.064	.147(1)	.054	.147
3	.118(1)	.120(1)	.060	.120
4	.173(1)	.087(2)	.058	.173
5	.202(1)	.082	.058	.202
6	.218	.069	.055	.218
7	.219	.060	.057	.219
8	.181	.072	.052	.181
9	.147	.088	.050	.147
10	.127	.099(1)	.072	.127
11	.107(1)	.125(6)	.090(2)	.125
12	.117(3)	.138(9)	.125(3)	.138
13	.168(4)	.198(14)	.139(5)	.198
14	.151(2)	.175(14)	.146(4)	.175
15	.125(2)	.171(19)	.166(6)	.171
16	.156(3)	.167(6)	.167(6)	.167
17	.128(2)	.180(14)	.154(5)	.180
18	.132(2)	.161(9)	.143(2)	.161
19	.127(2)	.172(9)	.130(2)	.172
20	.106(1)	.165(9)	.107	.165
21	.127	.146(7)	.080	.146
22	.101(1)	.135(6)	.060	.135
23	.109	.121(2)	.055	.121
24	.099	.084	.045	.099
Max.	.219	.198	.167	.219
No. over Stds.	48	160	45	
No. of Days with Obs.	16	31	15	

in Waltham appear to be lower than those of ozone recorded by the chemiluminescence during the same time periods. The maximum levels recorded by the chemiluminescence method by the Massachusetts Bureau of Air Pollution Control were .110 ppm at Wellington Circle and .095 at Kenmore Square. The highest recorded by the Mast instrument was .150 ppm at Kenmore Square. The maximum reading recorded in Waltham as part of an EPA study in September 1971, was .179 ppm. The University of Massachusetts Mast KI instrument read .122 at the same hour. The Boston Transportation Planning Review recorded a level of .219 ppm at their D street station in South Boston using chemiluminescence, the EPA reference method. The implementation plan used the .179 ppm reported in Waltham as their basis.

Figures II-(4-7) show the maximum oxidant readings throughout the day. The Wellington Circle data and the Kenmore Square chemiluminescence follow typical patterns, but the Kenmore Square and Waltham data show some unexplained double peaks. These may be due to point sources in the area or other local factors which affect the normal traffic patterns.

4. Implementation Plan Assessment

a. Carbon Monoxide

The Commonwealth of Massachusetts followed the format described in 42 CFR, part 420, Appendix I. A proportional model based on two separate cases was presented. The first case used the highest eight-hour reading for the spring of 1971 at Kenmore Square which was

Figure II-4-Wellington Circle Maximum 1-Hour Oxidant levels.

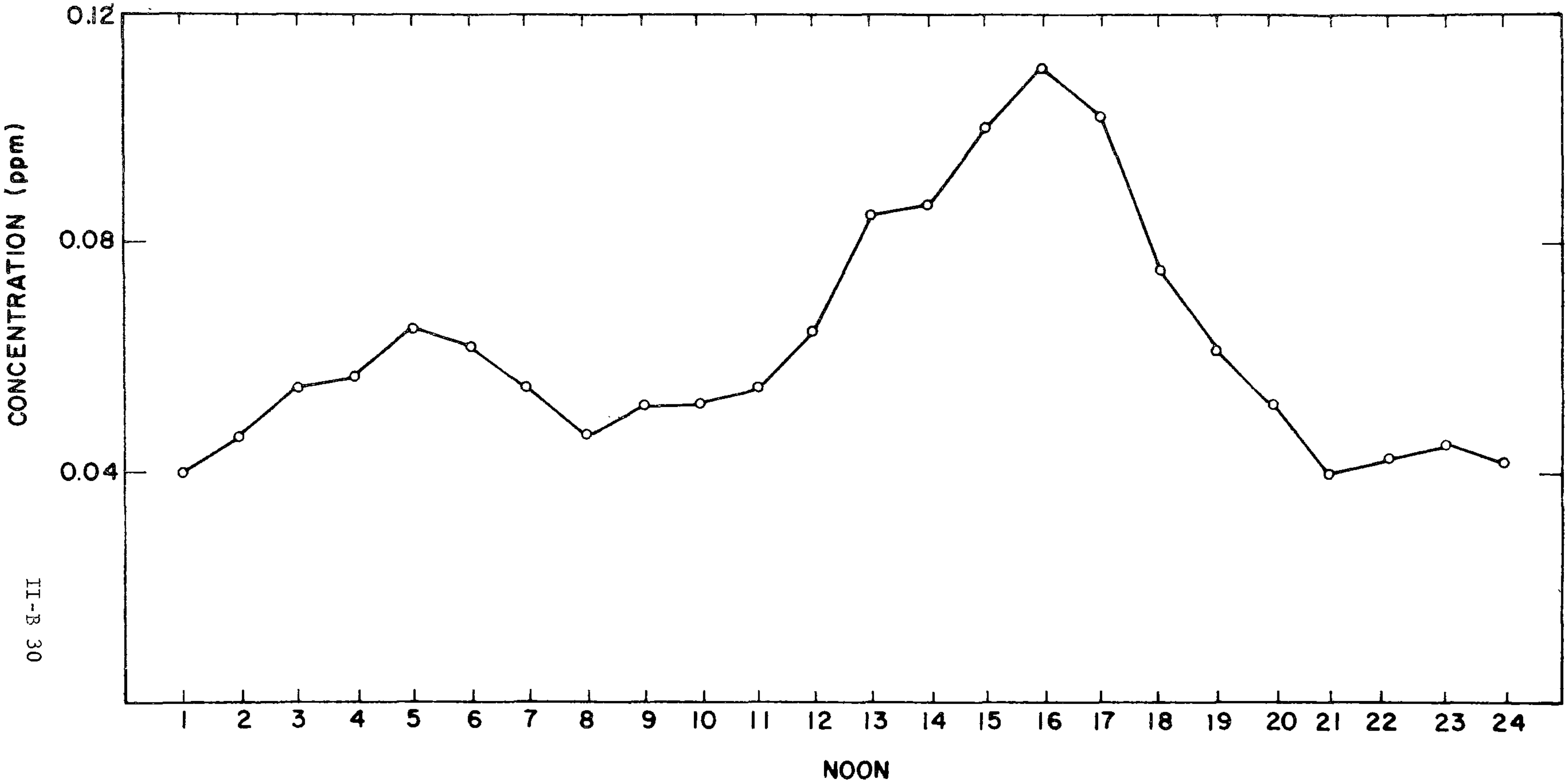


Figure II-5 Kenmore Square Mast Instrument Maximum 1-Hour Oxidant

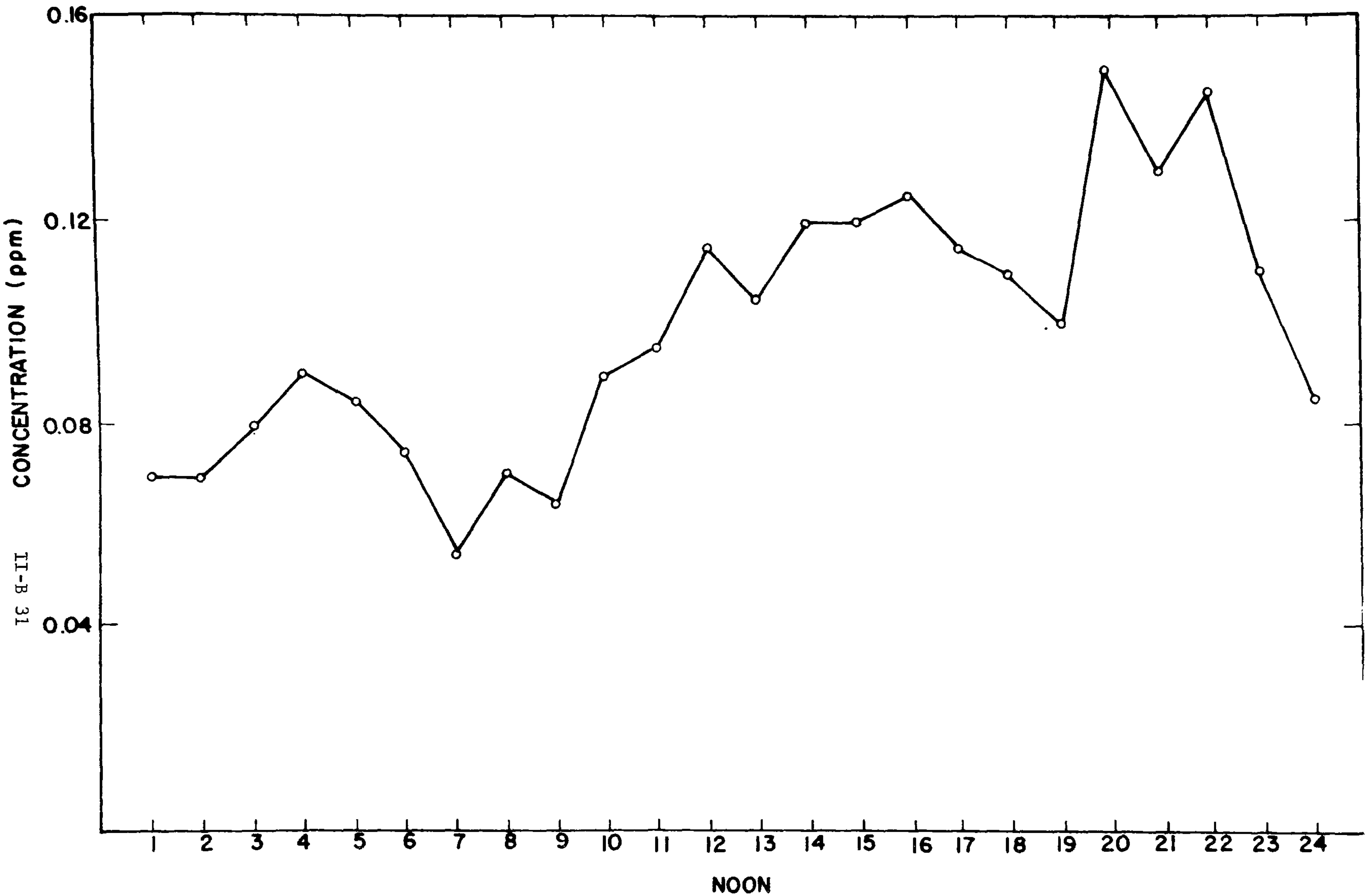


Figure II-6 Kenmore Square Chemiluminescence 1-Hour Maximum Oxidants

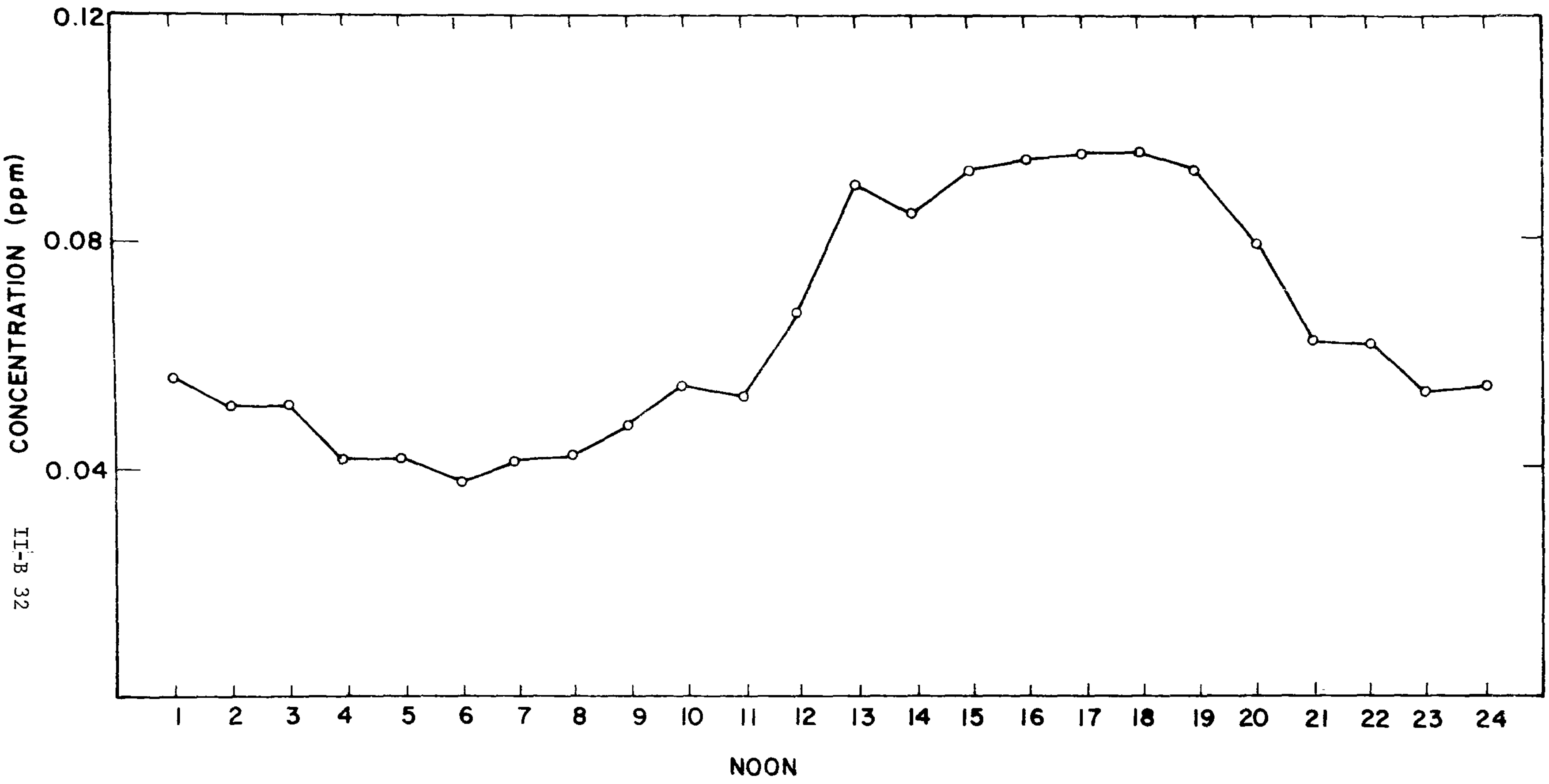
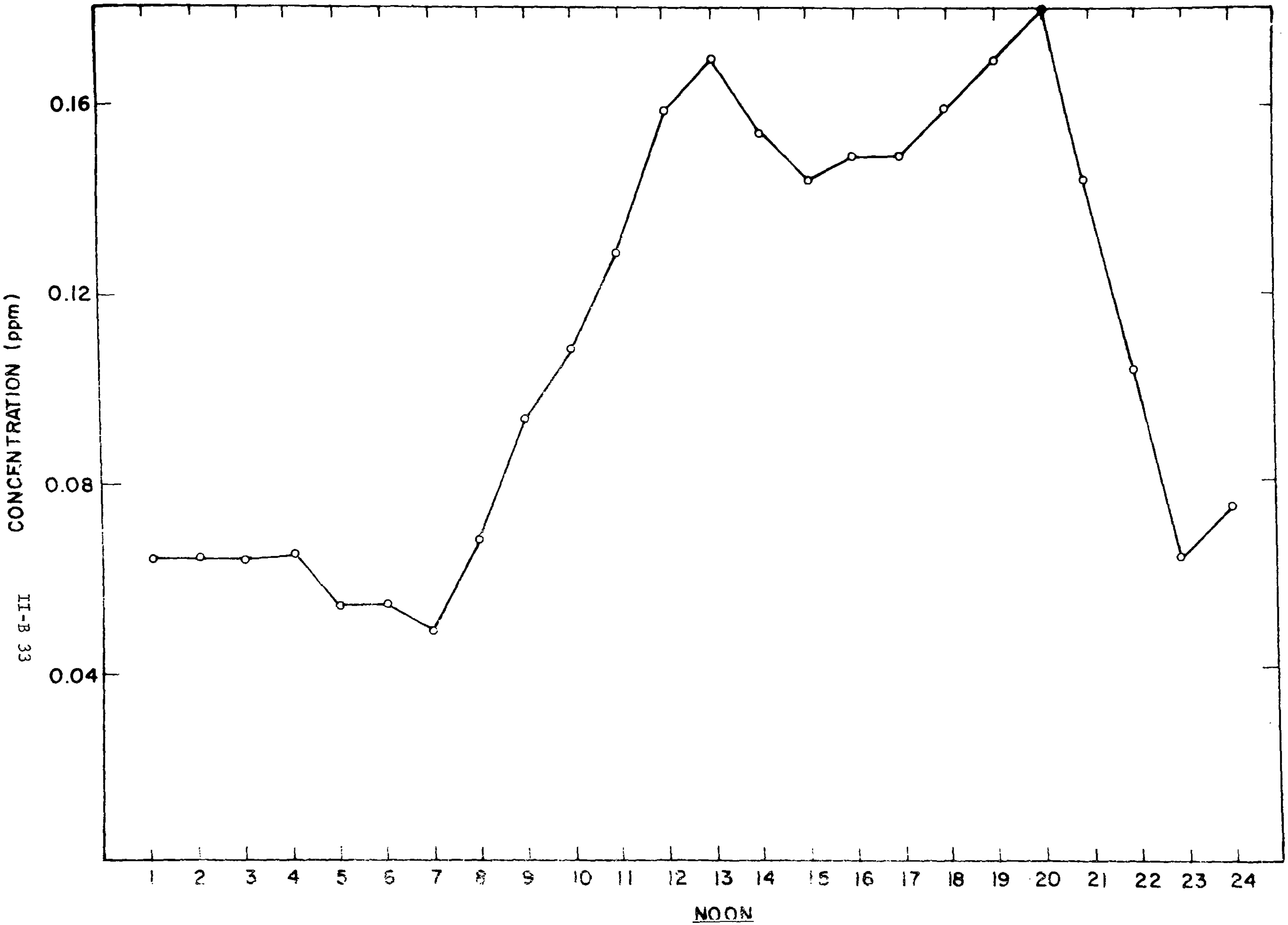


Figure II-7 Waltham 1-Hour Maximum Oxidants.



13.3 ppm. The second was based on the second highest eight-hour reading in 1970 of 16.9 ppm, also at Kenmore Square. The first case indicated a necessary reduction of 32% and the second case indicated a necessary reduction of 47%.

The estimate of carbon monoxide emission from motor vehicle and non-motor vehicle sources was based on the most recent inventory performed for the region. This inventory estimated total carbon monoxide emissions to be 707,625 tons in 1970 of which 698,424 tons were from motor vehicles. A growth factor of 20% by 1977 was estimated for the non-motor vehicle emissions. Referencing Appendix I of 42 CFR, part 420, the emission reduction from motor vehicles due to federal controls was estimated at 44% by 1977. The growth factor for motor vehicles implicit in the nationwide emission estimates in Appendix I of 42 CFR, part 420 were assumed.

These calculations indicated that if the more stringent case of 16.9 ppm were used as a baseline, then further reduction of 7% beyond that provided by the Federal regulations would be necessary. Although the plan stated that an additional 25% reduction in motor vehicle emissions beyond that to be expected by federal action was necessary, no further documentation was provided. Further communication with the appropriate agency corroborated the 7% estimate.

b. Oxidants

The Commonwealth of Massachusetts followed the format described in 42 CFR, part 420, Appendix J. The necessary reductions were based on an oxidant concentration of .18 ppm for 1 hour measured by EPA at the Waltham Field Station. Figure 2 in 42 CFR, part 420, Appendix J, indicates a reduction in hydrocarbon emission of 56% to be necessary to meet the oxidant standard.

The estimate of hydrocarbon emission from motor vehicle and non-motor vehicle sources was based on the most recent inventory performed for the region. This inventory estimated total hydrocarbon emissions to be 168,500 tons in 1970 of which 119,241 tons were from motor vehicles. A growth factor of 20% by 1977 was estimated for the non-motor vehicle emissions. Referencing Appendix J of 42 CFR, part 420, the emissions reduction from motor vehicles due to federal control was estimated at 50% by 1977. No other growth factor for motor vehicles other than that implicit in the nationwide emission estimates in Appendix J of 42 CFR, part 420, were assumed.

The calculations indicated that a further reduction of 60% beyond that provided by the federal regulations would be necessary (Table 19). The plan stated a 50% reduction. This difference was a result of use of the total transportation emissions rather than just the motor vehicle segment so outlined in Table 18.

TABLE II-19

CARBON MONOXIDE EMISSION CALCULATIONS FROM IMPLEMENTATION PLAN

Case 1

$\frac{13.3-9}{133}$ x 100 = 32.3 percent reduction

Total CO emissions 1970 = 707,625 tons

Total CO emission to meet standards = (707,677) x .677
= 479,062 tons

Total CO emissions from motor vehicles 1970 = 698,424 tons

Total CO emissions from motor vehicles 1977 = (698,424) x .56
= 391,117 tons

Total CO emissions from non-motor vehicle sources 1970 = 9,201 tons

Total CO emissions from non-motor vehicle source 1977 = (9,201) x 1.2
= 11,041

Total CO emissions 1977 = 402,158 tons

*No Controls Necessary

Case 2

$\frac{16.9-9}{16.9}$ x 100 = 46.7

Total CO emissions 1970 = 707,625 tons

Total CO emissions in order to meet standard = (707,625) x 53.3
= 377,164 tons

Total CO emissions expected 1977 = 402,158 tons (see above)

7% reduction necessary

TABLE II-20

HYDROCARBON EMISSION CALCULATIONS FROM IMPLEMENTATION PLAN

.18 ppm of Oxidants = 56% reduction

Total Hydrocarbon emissions 1970 = 168,650 tons

Total Hydrocarbon emission to meet standards = (168,650) x .44
= 74,200 tons

Total hydrocarbon emissions from motor vehicles 1970 = 119,241 tons

Total hydrocarbon emissions from Motor Vehicles 1977 = (119,241) x .50
= 59,621 tons

Total hydrocarbon emissions from non-motor vehicle sources 1970 = 49,409 tons

Total hydrocarbon emissions from non motor vehicle sources 1977 = (49,409) x 1.2

59,291 tons

Total hydrocarbon emission 1977 118,912 tons

60% reduction of 1977 emissions necessary

C. VEHICLE MILES OF TRAVEL

Basic transportation variables required in calculating emission factors and identifying emission reductions are: vehicle miles of travel (VMT) and speeds by facility type, vehicle age distributions, vehicle mix, vehicle travel by model year, and travel characteristics. Traffic and vehicle characteristic data were provided for the base year, 1971, and for the design year, 1977.

The ensuing discussion summarizes methodologies used in gathering and quantifying needed transportation data for 1971 and 1977. Assumptions made during the study to obtain the needed transportation data are stated and qualified.

1. Study Area

Transportation data was gathered for Boston and the environs included within the Route 128 circumferential. For purposes of obtaining emissions data as accurately as possible, the region was divided into three areas (Figures II-8 and II-9). These areas correspond to the inner city, the inner suburb, and the outer suburb. It was assumed that grids within each area contained a uniform density of activities. A grid was superimposed upon each of these three areas. The size of the grid used in each area was a function of urban densities and activity concentrations.

For the Boston inner city area, the grid configuration used corresponded to that developed by the Boston Transportation Planning

BOSTON AIR QUALITY STUDY
GRID CELL CONFIGURATION

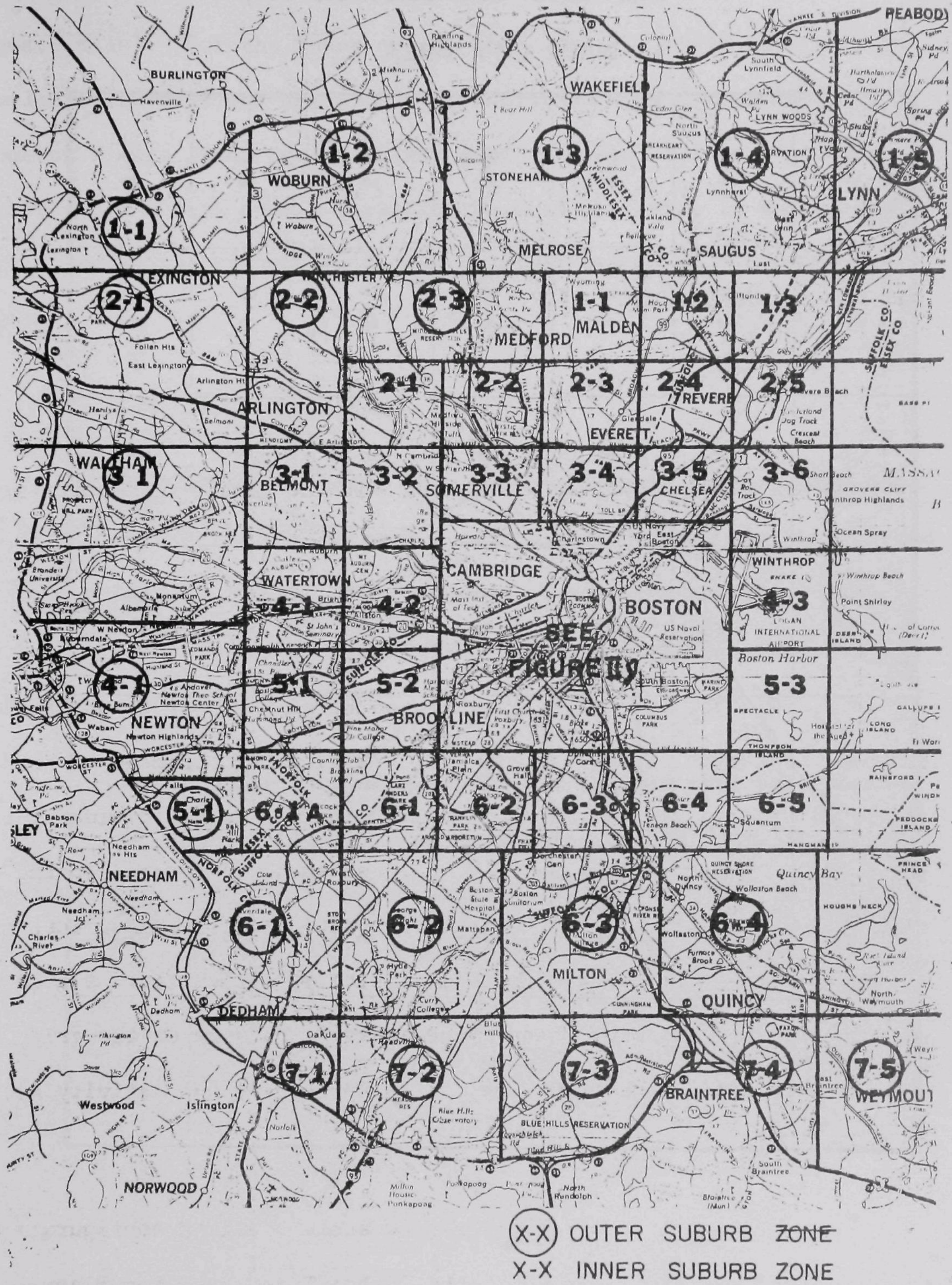


Figure II-8

BOSTON AIR QUALITY STUDY

GRID CELL CONFIGURATION

INNER CITY AREA

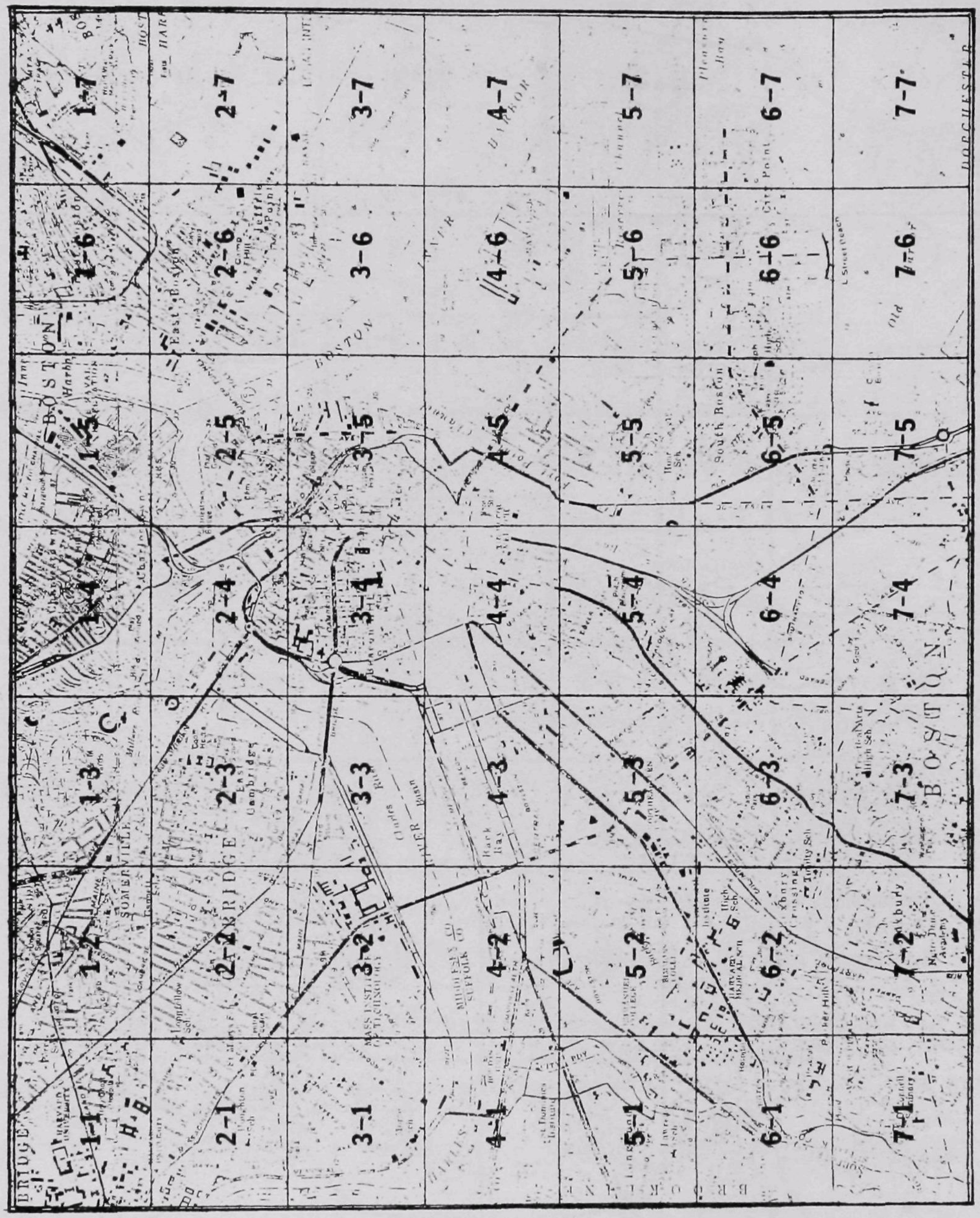


Figure II-9

Review (BTPR) in their analysis of transportation and air pollution impacts. Grid cells were 1.0 kilometer in length and 1.2 kilometers in width (0.47 square mile). For the inner suburb area, a 3 kilometer square (3.47 square miles) grid cell was used. Due to the study area configuration, a 5 kilometer square (9.65 square miles) grid cell was used as a guideline in the outer suburb area. Variation in grid cell size in the outer suburb area was needed to conform to the physical layout of the defined study area.

2. 1971 VMT Determination

Individual grid cells were used as a basis for inventorying VMT. To determine the effects of travel on air quality, VMT was categorized by type of facility and speed. The following classifications were used to categorize type of facility: expressway-freeway, arterial, collector, and local.

For the inner city area, total VMT by grid cell was obtained from the BTPR. To adapt the travel data into the required form, it was necessary to use the data which was classified by jurisdiction. A jurisdiction is a sub-area having its own characteristics with respect to vehicle miles of travel, vehicle hours of travel, and average speed by type of facility. By identifying in which jurisdiction each inner city grid cell was included, it was possible to factor total VMT according to type of facility and average speed. Appendix A tabulates the 1971 inner city VMT data by type of facility and speed.

For the inner suburb and outer suburb areas, it was necessary to inventory VMT by a different method. Expressway, arterial and collector facilities within each cell were identified and an estimate of Average Daily Traffic (ADT) was assigned. The Massachusetts Department of Public Works' automatic recorder counts were the primary source for estimates of ADT. In addition, counts obtained under TOPICS (Traffic Operations Program to Increase Capacity and Safety) studies were used to supplement the DPW automatic recorder counts.

With an estimate of ADT assigned to inventoried routes, the length of each route was calculated. The product of ADT times the length of the route resulted in an estimate of VMT. VMT for each grid cell was then tabulated according to expressway-freeway, arterial, and collector.

To account for VMT on network components not inventoried because of the unavailability of traffic counts (mainly local streets), a contingency factor of 30 percent was applied to existing grid cell totals. This factor was based on a comparison between VMT totals for routes inventoried in this study for selected communities and the VMT calculated from traffic volumes inventoried in the TOPICS studies, which includes major local streets. The City of Waltham was used as a representative case for the outer suburb area. Cambridge, Somerville, and Watertown were used as the representative case for the inner suburb area.

Appendix A-1 tables summarize inner suburb and outer suburb travel data in terms of total VMT by grid cell and VMT by type of facility.

Average operating speeds by facility type for the inner suburb and outer suburb zones were assigned using the Highway Capacity Manual[16] and average network speeds from network descriptions developed by the BTPR. Speeds in Table II-21 are identified for both uncongested (off-peak demand) and congested (peak demand) operations.

TABLE II-21

OPERATING SPEED BY FACILITY TYPE

Facility Type	Uncongested Speed	Congested Speed
Expressway - Freeway	50	25
Arterial	40	20
Collector	30	15
Local	20	10

To convert traffic data from a 24-hour basis to needed time frames, the following assumptions for the Boston area were made:

- Duration of AM congestion period = 1 hour
- Duration of PM congestion period = 1 hour
- Peak-hour volume = 10% of ADT
- Limits of 12-hour count period: 7:00 AM to 7:00PM
- 12-hour volume = 70% of ADT

truck use, research data compiled in A System Sensitive Approach for Forecasting Urbanized Area Travel Demands[4] was used. For a city the size of Boston, truck VMT is about 13.5 percent of auto vehicle miles. Adjustments in travel patterns were considered to account for truck prohibitions on designated Metropolitan District Commission facilities.

3. 1977 VMT Determination

In order to project VMT to 1977, the nature of the traffic network in 1977 was assumed. Currently, the BTPR is studying the feasibility of constructing several major elements to the regional transportation network. In light of the uncertainty of facility programming and construction, it was assumed that five years is an absolute minimum period needed before any major new highway facility could be operational. In all likelihood, a major new regional facility would not be operational before late 1978. If a third harbor crossing is built, it would not be open before 1980. The only major new facility programmed for opening in the 1977 time frame of this study is the I-93 link from Somerville to Boston.

No major land use changes were assumed. 1977 VMT estimates were prepared using these basic assumptions. Projected rates of increase in VMT to 1980 were obtained from the BTPR. Increases in 1977 VMT over 1971 were interpolated between 1971 VMT and the 1980 VMT obtained from BTPR as indicated in Table II-22. 1977 VMT was obtained by applying these rates of growth to 1971 VMT totals. Appendix A-2 tables summarize resulting 1977 VMT by grid cell.

TABLE II-22

PROJECTED INCREASES IN VMT

Area	1970-1980 Percent Increase	Interpolated 1970-1977 Percent Increase
Inner City	9	7
Inner Suburb	17	12
Outer Suburb	35	25

Distribution of 1977 VMT by type of facility for the inner city area was made by analyzing projected 1980 distributions obtained from the BTPR. For the inner suburb and outer suburb areas, it was assumed that the percentage of total VMT for each facility type in 1977 would be comparable to that calculated for 1971. This is a reasonable assumption inasmuch as no new major regional facilities were anticipated.

4. Vehicle Characteristics

Vehicles by age and passenger car-truck classification according to 1971 registrations were obtained from R. L. Polk & Company for the four counties comprising the study area as shown in Appendix B. Based on comparisons made between counties and analysis of past registration trends, a vehicle age mix and passenger car-truck classification representative of the overall study area as of December 31, 1971, was determined as shown in Appendix C.

To calculate the average percentage contribution of VMT by model year, percentages of vehicles by age classification were weighted by annual miles driven per year by each age vehicle as illustrated in Appendix D. This was done for both light and heavy duty vehicles.

Using R. L. Polk & Company data for the Boston truck registrations for the first six months of 1972, trucks over 6000 pounds gross vehicle weight (GVW) were further subdivided into diesel powered and gasoline powered classifications. Of trucks over 6000 pounds GVW, 10 percent were found to be diesel powered and 90 percent gas powered. Based on discussions with the Massachusetts Office of the American Trucking Association, it was assumed that a balance exists between in-state and out-of-state truck use in Boston.

To estimate the percentage contribution of diesel truck use and heavy duty gasoline truck use as a percent of total VMT, the previously obtained percentages were weighted by annual miles driven by each type of truck. Annual miles driven by classification was obtained from data compiled by the Massachusetts Department of Corporations and Taxation. Table II-23 summarizes the procedure used in weighting absolute percentages by miles driven.

Using these derived proportions with estimated truck VMT of 13.5 percent of passenger car VMT, the following constants (Table II-24) were calculated to identify truck VMT as a percent of total VMT.

TABLE II-23

PROPORTION OF TRUCK VMT BY FUEL TYPE

Truck Type	(1) Proportion of Total	(2) Annual Miles Driven	(1) x (2) (100)	Proportion of Truck VMT
Diesel	.10	60,000	60	60/168 = .36
Gas Powered	.90	12,000	108	108/168 = .64

TABLE II-24

PERCENTAGE TRUCK VMT OF TOTAL VMT
BY AREA AND TYPE OF FUEL

	Percent of Total VMT*	
Area	Gasoline Powered Trucks	Diesel Powered Trucks
Inner City	10.04	5.57
Inner Suburb	8.68	4.82
Outer Suburb	8.68	4.82

*Percentages for inner city vary because VMT data obtained from BTPR did not include truck VMT. Data compiled for the inner suburb and outer suburb areas accounted for truck use.

D. DERIVATION OF AIR QUALITY LEVELS

1. Baseline Air Quality Projections

a. Carbon Monoxide

The air quality data available for the Metropolitan Boston area indicated that the diurnal variation was not the significant factor in determining when the 8-hour carbon monoxide standard would be exceeded. Therefore, the projections were based on 24 hour daily traffic.

Discussion with EPA Region I and the Massachusetts Bureau of Air Pollution Control determined that estimates should be based on the highest level recorded in the implementation plan. Hence 22.4 ppm recorded on October 28, 1970 at Kenmore Square was used as the only baseline level for the whole region.

Review of the available stationary source data indicated that their contribution was minor. After discussion with the Bureau of Air Pollution a growth factor of 20% from 1970 to 1977 as used in the implementation plan was determined to be the best estimate available. The 9,201 tons/year were apportioned evenly across the region.

Since the air quality data is for 1970, the 1970 vehicle mix and an extrapolated 1970 vehicle mile tabulation are used. Rollback estimates were made throughout the region within Route 128, using an emission density-concentration ratio of $e/c = \frac{27,876}{22.4} = 1,240$ (Kg/day - mi^2 - ppm). Table II-25 presents the baseline estimates

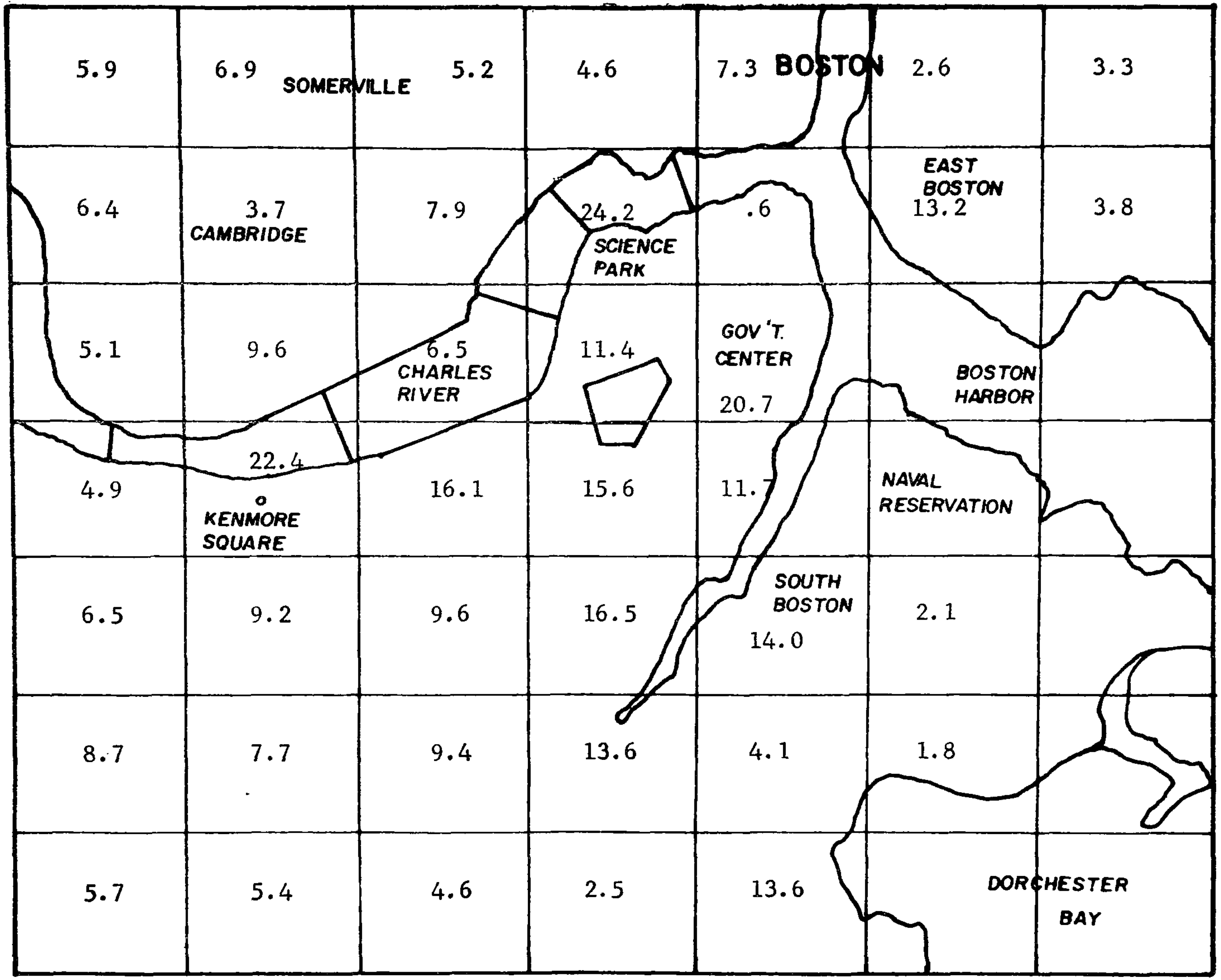


TABLE II-25 8-Hour Maximum Ambient Air Quality Estimates for Carbon Monoxide in 1970 (In PPM) for carbon monoxide in the region of interest. The levels outside that region do not exceed the standards.

b. Oxidants

Due to the nature of oxidants and the recorded high levels in the western suburbs, it was determined that air quality level should be projected regionwide within Route 128 consisting of 243 square miles. It was also determined in discussion with EPA Region I and Massachusetts Bureau of Air Pollution Control that 24 hour daily traffic should be used as the baseline.

After reviewing the air quality data with Region I EPA and Massachusetts Bureau of Air Pollution Control it was decided that the baseline estimate would be determined based on the highest daylight hour reading at any station. Accordingly, a baseline of .198 ppm, measured at BTPR 2, was used to determine the necessary rollback.

Projection of non-motor vehicular source emissions provided by the Massachusetts Bureau of Air Pollution Control proved to be significant. The basis for the figures is the most recent and revised emission inventory completed for the region. The most significant revision was the addition of bulk storage of gasoline which was estimated at 15,000 tons/year. Since this data was calculated for 1970 and the plan indicates 15% growth from 1970 to 1975, a 6% growth factor was used to estimate 1972 emissions. Non-vehicular emissions for 1972 were 68,274 tons/year or 170,000 kg/day. The data is summarized in Table II-26.

TABLE II-26

NON-VEHICULAR
HYDROCARBONS EMISSIONS INVENTORY FOR THE
REGION WITHIN ROUTE 128

	1970 Emissions (Tons/Year)	1972 Emissions (Tons/Year)
Aircraft	6,922	7,337
Other Transportation	246	261
Gasoline Marketing	6,530	6,922
Area Source Solvents	25,314	26,833
Point Source Solvents	4,818	5,107
Solid Waste Disposal	1,042	1,105
Fuel Combustion	4,537	4,809
Bulk Storage	15,000	15,900
	64,409	68,274

Motor vehicle emissions were estimated using the EPA emission factor for 1972 and vehicle miles for 1972. The 1972 vehicle miles were determined by interpolating between the 1971 and 1980 vehicle miles as discussed in Section II-C. The emission calculations for hydrocarbons were computed for each zone. However, after review of the air quality and discussion with EPA Region I and Massachusetts Bureau of Air Pollution Control, the entire region was taken in aggregate. The total motor vehicle hydrocarbon emission rate was 131,555 Kg/day.

The procedure outlined in 42 CFR, part 420 Appendix J was followed to estimate oxidant emission reductions necessary. The curve showing the relationship between the oxidant concentration and the required reduction in hydrocarbon emissions to achieve the standard is shown in Figure II-10. The necessary reduction of 65% was determined from the federal curve in the above guidelines and the calculations are summarized in Table II-27.

2. 1977 Air Quality Projections

a. Carbon Monoxide

Table II-28 presents the expected air quality for 1977 in the inner city region. The estimates are developed using the rollback technique described in 42 CFR, part 420. The emission estimates for 1977 use an adjusted vehicle age mix for 1977 and the 1977 traffic data. This data was developed by interpolating between 1971 and 1980 traffic data as described in Section II-C. The 1977 stationary emission

Figure II-10   Relationship of hydrocarbon reduction to oxidant concentration.

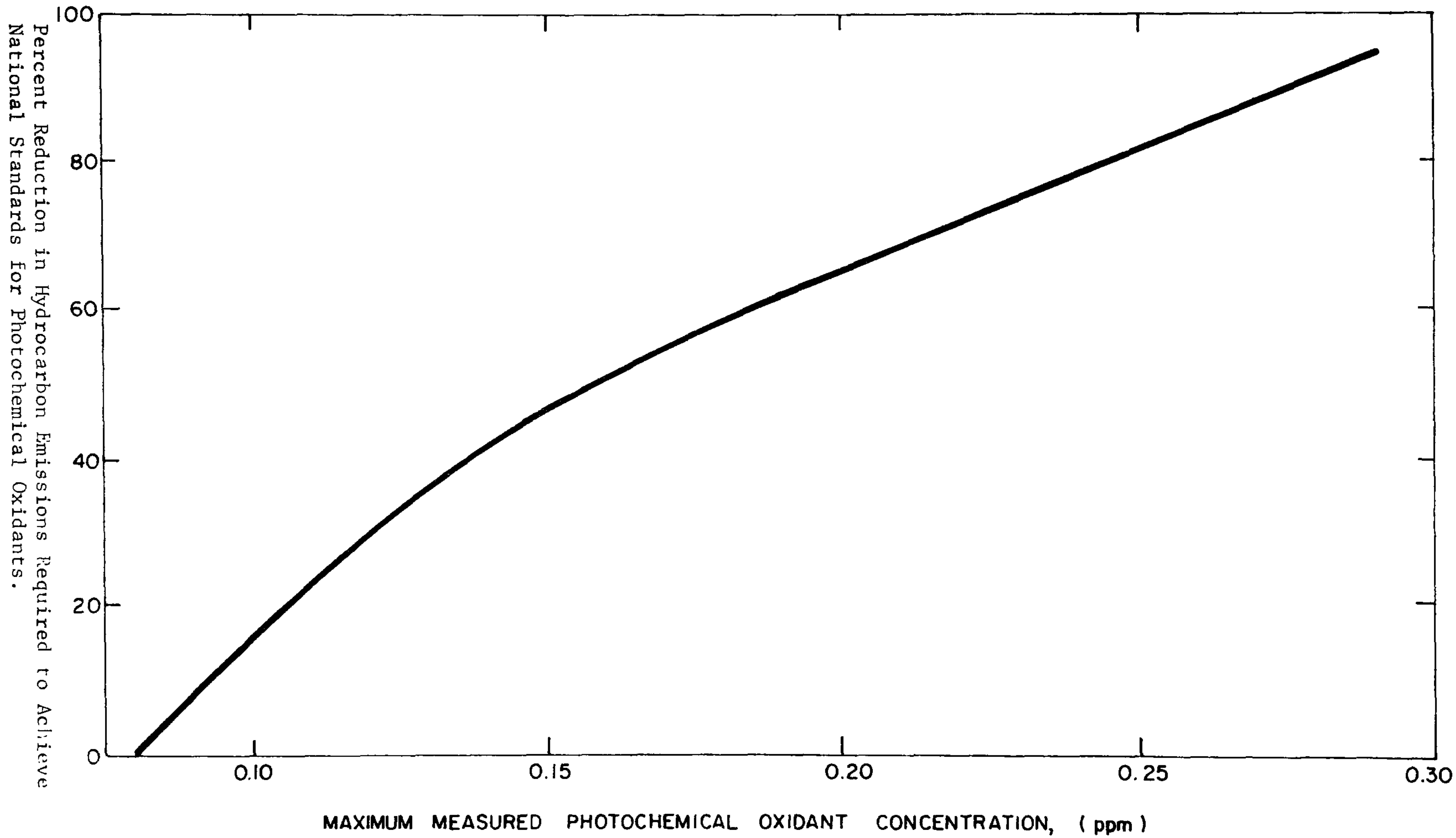


TABLE II-27

NECESSARY REDUCTIONS FOR HYDROCARBONS FROM 1972 EMISSIONS

Ambient Air Quality	=	.20 ppm
% Rollback	=	65%
Non-Vehicular Emissions	=	170,002 kg/day
Motor Vehicular Emission	=	131,555 kg/day
Total Emissions	=	301,557 kg/day
Emissions to Meet Std.	=	105,545 kg/day

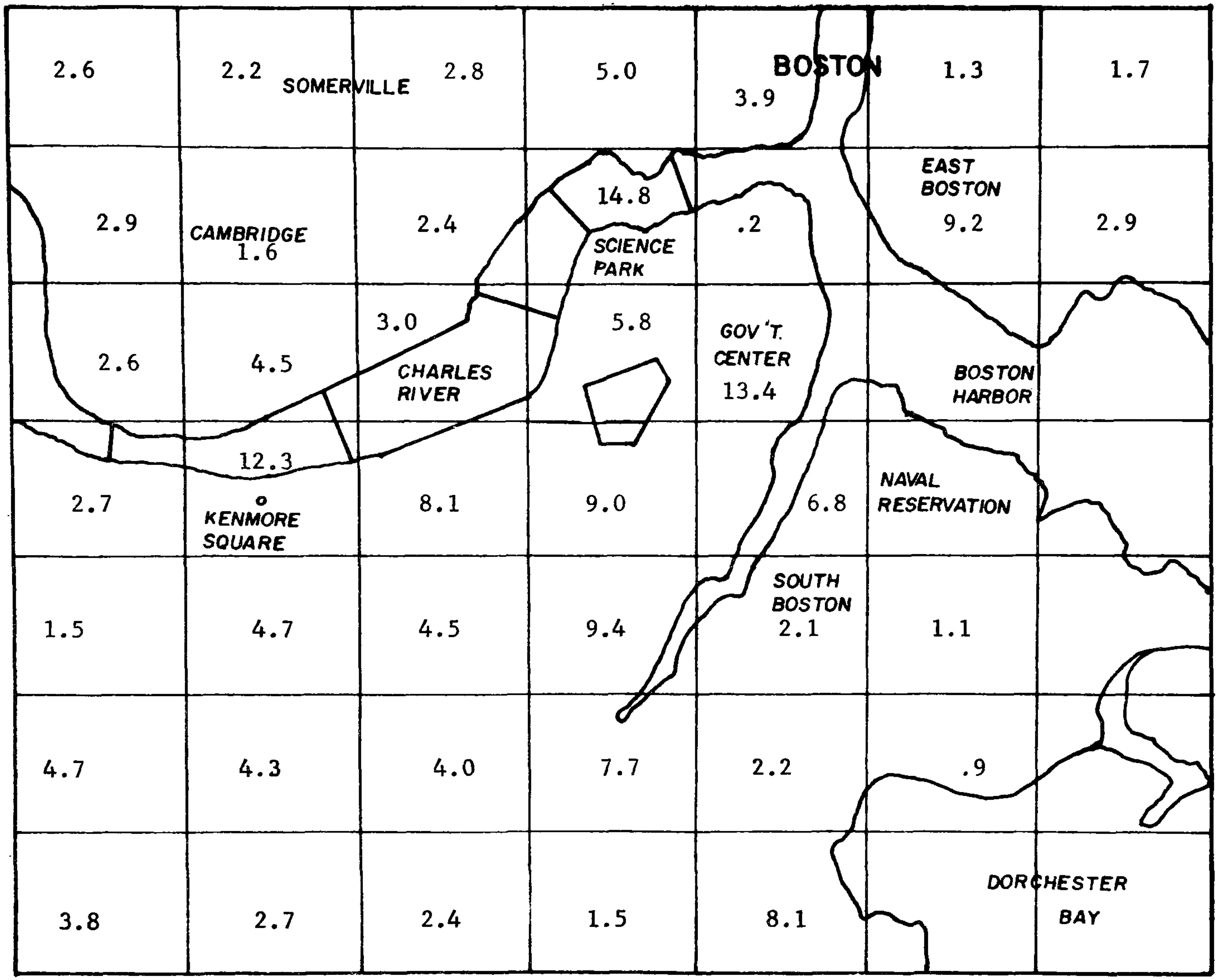


Table II-28. 8-Hour Maximum Ambient Air Quality Projections for Carbon Monoxide in 1977 (In PPM).

density of 114 Kg/mi^2-day was added. Then using the same e/c ratio, concentration projections were made. The three maximum zones, Science Park, Haymarket Square and Kenmore Square, exceed the standards by substantial margins and will require reductions in emissions of 39%, 33% and 27% respectively, from the expected 1977 levels. Two other zones, one in the Washington Street and Albany Street area, and the other in the East Boston area by the Callahan-Summer Tunnel, require much smaller reductions (4% and 2% respectively) within the region to meet the standards.

b. Oxidants

Due to the high level of stationary source emissions in the region it was necessary to develop an estimated reduction in non-motor vehicle emissions. Discussions with the Massachusetts Bureau of Air Pollution Control indicated that at maximum the emissions in 1972 of 170,002 Kg/day could be reduced to 51,000 Kg/day and indicated that this should be used to project 1977 estimates. Table II-29 indicates the reductions necessary. With the assumed emission reductions for stationary sources, transportation controls must further reduce motor vehicular generated hydrocarbons in the entire region by 25%.

TABLE II-29

HYDROCARBON EMISSIONS (Kg/24HR.) AND OXIDANT LEVELS (ppm)
WITHOUT SOURCE OR TRANSPORTATION STRATEGIES

	1972	1977 without Transportation Strategy	1977 with Necessary Oxidant Strategy Only
Vehicular Emissions	131,555	72,101	54,545
Non-Vehicular Emissions	170,002	51,000	51,000
Total Emissions	301,557	123,101	105,545
Oxidant Level (1-hr average)	.20 ppm	.10 ppm	.08 ppm

E. CARBON MONOXIDE AND OXIDANT IN 1978 AND 1979 WITHOUT CONTROL STRATEGIES

Following are air quality levels up to the year in which the standards are met by only the Federal Motor Vehicle Control Program.

1. Carbon Monoxide

Tables II-30 and II-31 show the expected air quality on emission density maps for 1978 and 1979. The problem is very greatly mitigated with the passage of time and all but one zone meet the carbon monoxide standards in 1979 without any controls. It is evident that this zone will also meet the standards with the passage of time. These tables were generated in the same manner the 1977 table was generated, using the adjusted vehicle age at mix the beginning of the year.

2. Oxidants

Predictions of hydrocarbon emissions from motor vehicles in 1978 and 1979 show, as Table II-32 indicates, that if the control expected for stationary sources are met and grow again yearly at a 3% rate and maintained in 1978 and 1979, then the air quality standards will also be met without any transportation controls in 1980. These predictions were made in the same manner previously described for 1977.

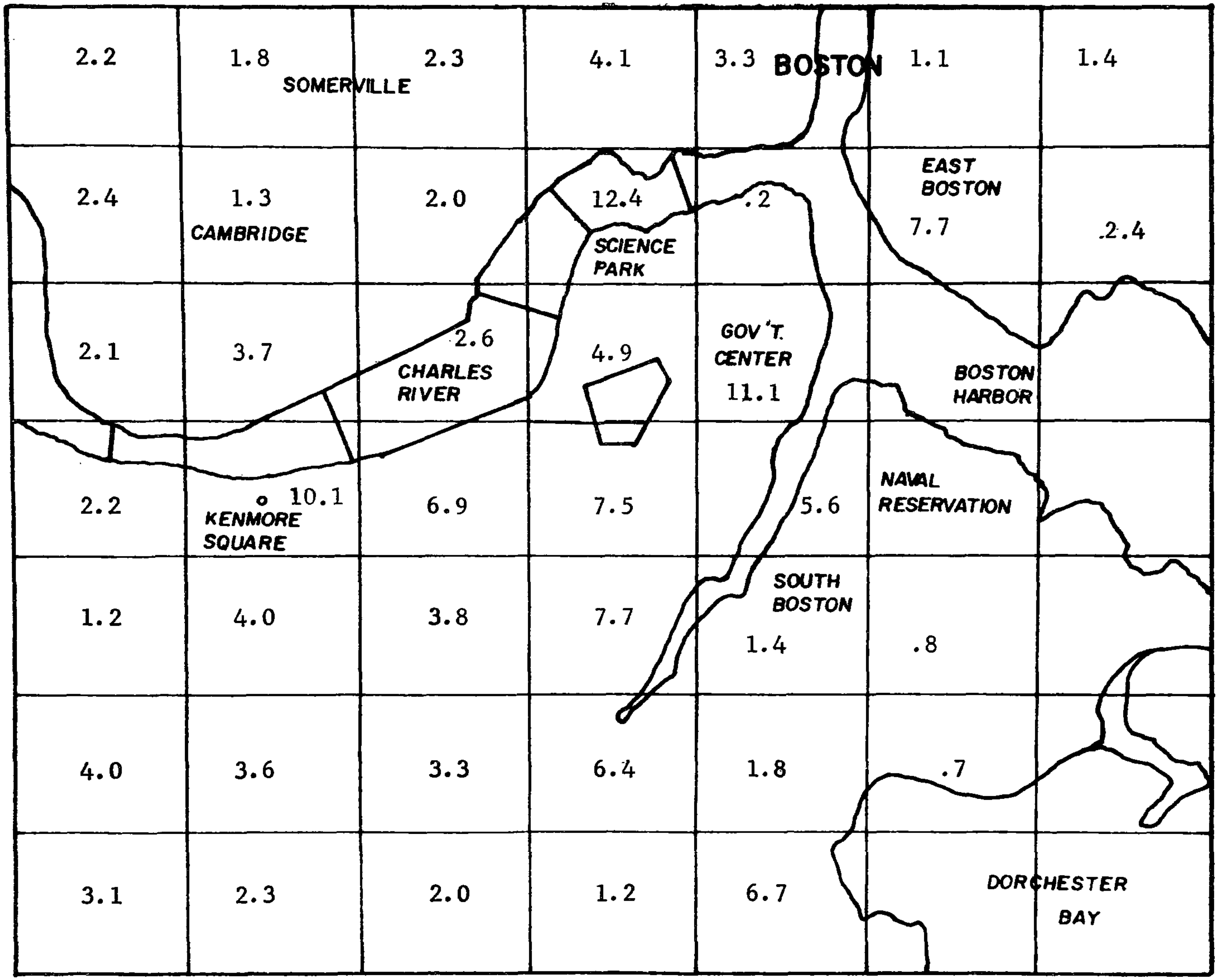


TABLE II-30 8-Hour Maximum Ambient Air Quality Projections for Carbon Monoxide in 1978 (In PPM)

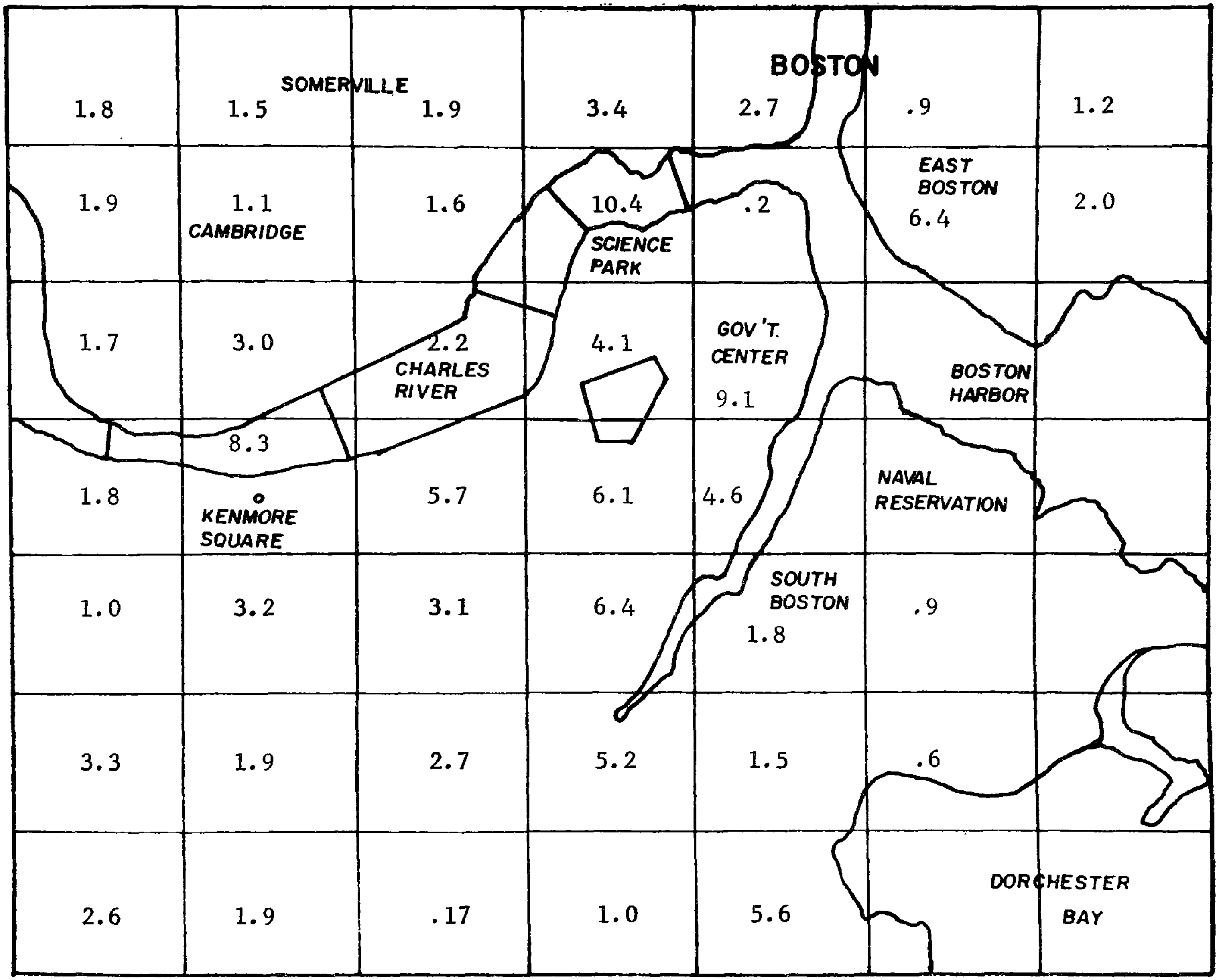


TABLE II-31 8-Hour Maximum Ambient Air Quality Projections for Carbon Monoxide in 1979

TABLE II-32

HYDROCARBON EMISSION RATES AND OXIDANT LEVELS (PPM) IN METROPOLITAN BOSTON WITHOUT SOURCE OR TRANSPORTATION STRATEGIES (Kg/Day)

	1977	1978	1979
Vehicular Emissions	72,101	61,000	52,500
Non-Vehicular Emissions	51,000	52,500	54,000
Total Emissions	123,101	113,500	106,500
Oxidant Level (1-hour average)	.10	.089	.081

III. EVALUATION OF CANDIDATE TRANSPORTATION CONTROLS

A. MAGNITUDE OF REDUCTION REQUIRED

It is necessary to cast the discussion of individual strategies or a program of strategies, within the framework of the air pollution problem definition so as to set a perspective on which controls would be most effective. To meet and maintain the mentioned ambient air standards for carbon monoxide in Boston by 1977, the percent emission reductions shown in Table III-1 are needed. Carbon monoxide is a localized problem, concentrated in the areas of the inner city shown in Table III-1. Controls aimed at reducing carbon monoxide emissions can therefore be directed to the particular problem area.

The oxidant problem in Boston, unlike carbon monoxide, is not a localized problem. To meet the national standards for oxidants, an approximate 25 percent reduction in hydrocarbon emissions is required for the area within Route 128. This will require enormous restrictions on urban mobility within the region.

TABLE III-1

CO REDUCTION REQUIRED - 1977

AREA	GRID DESIGNATION*	% REDUCTION FROM 1977
Science Park - North Station	2 - 4	39
East Boston by Sumner-Callahan Tunnel	2 - 6	2
Haymarket Square - Tunnel Entrance	3 - 5	33
Kenmore Square	4 - 2	27
Washington Street - Albany Street	5 - 4	4

* See Figure II-2

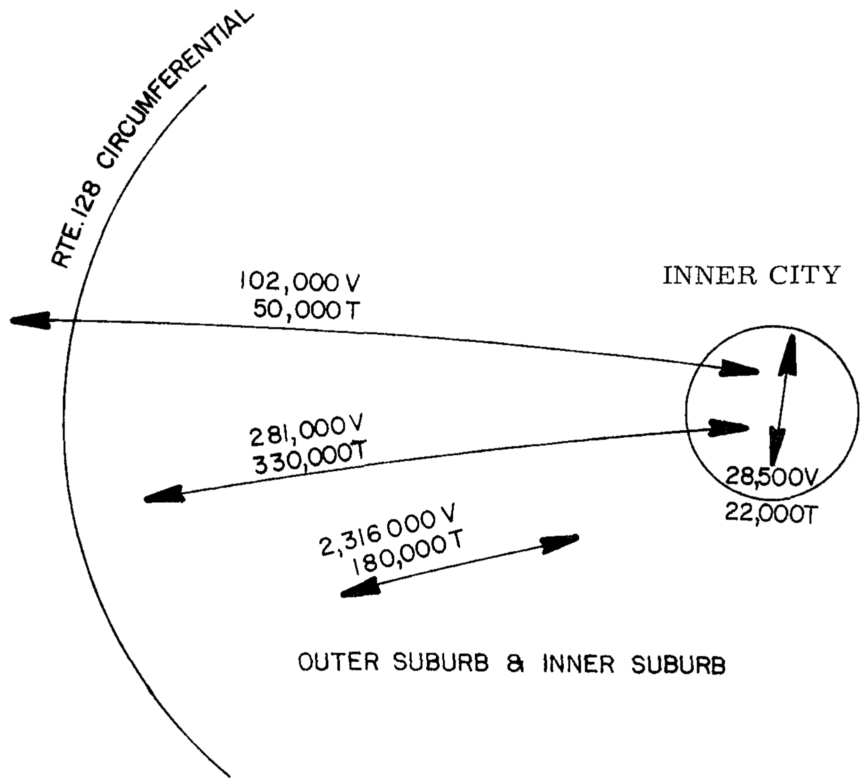
B. 1977 TRAVEL PATTERNS

Figure III-1 illustrates the nature of estimated trip movement into the Boston inner city area for 1977. Trips shown in Figure III-1 are those with destinations in the inner city, and do not include intra-zonal trips; trips with destinations external to the inner city; taxi, school or airport trips. The number of trips by vehicle and transit were obtained by interpolation from 1963 base year figures [23] and the BTPR 1980 trip generation estimates. Trips with origins or destinations in the inner city area represent an estimated 50 percent of total trip movement within Route 128. Working assumptions associated with the 1977 assignment include no further parking policies for the core area and a moderate investment improvement program in the transit system (these assumptions are outlined in the evaluation section for mass transit.)

The 1977 travel patterns are a base measurement of both total trips movement into the core and the mode used. With these figures and the needed VMT reduction, the number of trips affected were identified and the capabilities of mass transit to handle additional volumes were assessed.

Figure III-1

1977 TRIP MOVEMENT FOR BOSTON REGION



V = VEHICLE TRIP

T = TRANSIT TRIP

NOTE: FIGURES DO NOT INCLUDE THE FOLLOWING TYPE TRIPS; INTRAZONALS, TRIPS WITH DESTINATIONS EXTERNAL TO THE CORE, TAXIS, TRUCKS, SCHOOL TRIPS, AIRPORT TRIPS.

C. STRATEGY EVALUATION

Figure III-2 illustrates the process used in developing the recommended program strategy and timetable. Basic criteria used in evaluating each strategy included: technical feasibility, probable impact on air quality and implementation obstacles. Implementation obstacles, including institutional, legal, political, and economic impacts are described in Chapter V.

Table III-2 lists all the strategies considered in the framework of this study. Regional development strategies and transportation system planning strategies were not examined in the study, as they could not be implemented within the time frame for the selected strategies. Long term approaches should be considered in the continuing planning process.

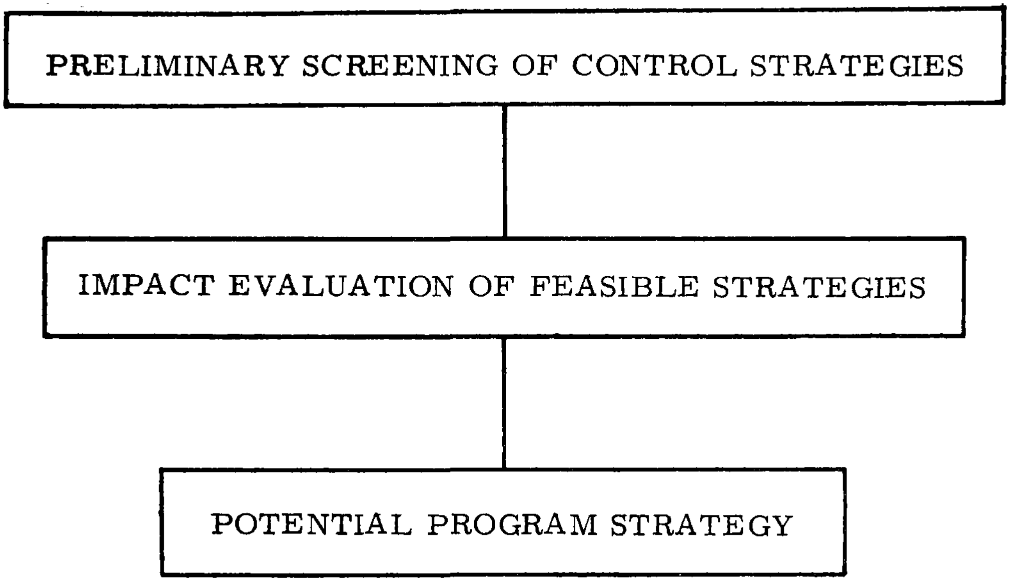


Figure III-2 Alternative Control Strategy Evaluation Process

Table III-2. CANDIDATE STRATEGIES

- Reduce Emission Rate
  - Source Control
    - Retrofit
    - Inspection/Maintenance
    - Gaseous Fuel Conversions
  - Traffic Flow Improvements
    - Surveillance and Control
    - Design and Operational Improvements
    - Truck Loading Zones
    - Driver Advisory Displays
- Reduce Vehicle Miles of Travel
  - Reduce Travel Demand
    - Four Day Work Week
    - Parking Management
    - Peripheral Parking Facilities
    - Road Pricing
    - Gasoline Rationing
    - Increased Fuel Tax
  - Increase Transit Use
    - Commuter Rail System
    - Rapid Rail and Bus Systems
  - Increase Car Occupancy
    - Car Pooling
  - Modify Travel Patterns
    - Work Staggering
    - Bypass Through Traffic
    - Vehicle Free Zones

D. PRELIMINARY CONTROL SCREENING

Initial review of candidate strategies consisted of identifying which strategies could be eliminated due to the necessary implementation time, the technical state of the art of the particular control measure, or the probable impact on air quality. Public agency contact played an integral role in this initial evaluation. Based on consideration of these criteria, the following strategies were not considered viable in the Boston area.

1. Driver Advisory Displays

The objective of this control is to inform motorists of the traffic conditions on a freeway, thereby encouraging the use of alternative routes when the expressway is congested. The effectiveness of this strategy is contingent upon the expressway being closely paralleled by one or more arterial streets which can serve as alternative routes.

The application of this strategy to the Boston region shows little potential in effecting improved traffic flow because of the latent demand on the expressway and arterial systems, and the absence of alternative routes paralleling major expressway facilities.

2. Gasoline Rationing

A gasoline rationing strategy would allot each vehicle a certain amount of gasoline per unit time. The vehicle owner would then be forced to regulate his vehicle travel to those trips that he would accomplish within his gasoline allotment.

Gasoline rationing was not considered to be a viable strategy for two reasons. First, it would be politically difficult to implement. Second, a statewide program of gasoline rationing would be ineffective because of nearby alternative supplies available in adjacent states.

3. Increased Fuel Taxes

One objective of increasing fuel taxes, other than for revenue purposes, could be to discourage auto trips. Gasoline taxes, however, are not a direct, out-of-pocket cost which is incurred with each trip, thereby reducing the motorist's sensitivity to the increased charge compared to a more direct pricing system.

As shown in the following discussion, the effect of increased fuel taxes on reducing VMT would not be significant unless a substantial rate increase was implemented. Again, the alternative of purchasing gasoline in adjacent states would be an obstacle to implementation.

The average auto trip length in Boston is approximately 7.5 miles. It is estimated that one gallon of gas can propel a car approximately 12 miles. This results in .625 gallons of gas being consumed per auto trip. If an additional fuel tax of 80 cents per gallon were instituted, then the additional auto user cost per trip would be 50 cents. An analysis of price demand relationships indicates that a 50 cent increase in auto user cost would decrease vehicle trip ends to the core area by 5.6 percent. Since local VMT generates approximately 33 percent of the total VMT in the core area, the resultant VMT decrease in the core area would be 1.9 percent.

Based on the necessary fuel tax increase needed to generate an approximate 2 percent reduction in VMT and the proximity of alternative fuel sources in neighboring states, it is concluded that increasing fuel taxes an amount that is politically and economically feasible would not effect a significant reduction in VMT.

4. Car Pooling

The average car occupancy for a home-to-work trip in the Boston region is 1.1 persons per vehicle. The concept behind car pooling is to accommodate the same number of persons in fewer autos, thus reducing the absolute number of vehicle work trips.

Past efforts to promote car pooling on a voluntary basis in other urban areas have been unsuccessful. To significantly increase car occupancy, a system of car pool incentives would have to be initiated. Such incentives could include graduated parking fees based on auto occupancy or a pricing policy with higher tolls for low-occupancy vehicles. Another approach is similar to that being implemented in the San Francisco Bay Area, wherein car-pool vehicles may share reserved bus lanes, and are not required to pay bridge tolls.

For the Boston area, car pooling is viewed as a complimentary control to be used in conjunction with a road pricing or parking management strategy. By itself, voluntary car pooling holds little promise.

5. Bypass Through Traffic

Bypassing through traffic would include designating a major facility such as Route 128, as part of the Interstate system. Currently, I-95 terminates at Route 128 south of Boston, with no connecting link to the continuation link north of Boston (under current conditions, it is unlikely that I-95 would be linked through the Boston inner city). The concept behind designating Route 128 as I-95 is to provide continuity between the two existing terminal points. In theory, this would divert trips from passing through the inner city area.

Because of the large number of "repetition" drivers in the Boston area, the effectiveness of this strategy is largely diminished. It is felt that commuter trips, the main group of auto trips which need to be reduced, will not be affected by efforts to bypass through traffic.

6. Vehicle-Free Zones and Moving Sidewalks

In the inner city area, one of the most critical problems is the lack of separation between pedestrian and vehicular traffic. Two schemes are presently in the planning phase by the Boston Redevelopment Authority (BRA). One is the establishment of vehicle-free zones, and the other is the moving sidewalk concept, with separation of vehicles and pedestrians.

The vehicle-free zone being considered lies along the Washington Street retail area. Final plans for the implementation of such a scheme are many years away, if in fact they will ever be implemented. Washington Street presently serves as the only south-to-north arterial street through the downtown area, forming one-half of a two-way couplet with Tremont Street. Providing an alternative facility will result in extensive land takings and does not presently appear to be a feasible solution. Application of vehicle free zones does not appear applicable to other parts of the city, also due to the dense urban activity and lack of alternative facilities.

The moving sidewalk concept is a means of separating vehicular and pedestrian traffic flow, with a resulting increase in safety and improvements in flow quality. This concept is in the design stage (post 1977) and should eventually offer a means of reducing congestion in the downtown core area, assuming the increased capacity derived from separation of vehicular and pedestrian flows does not induce further vehicular traffic into the area.

E. IMPACT EVALUATION OF FEASIBLE STRATEGIES

In this review stage, priority was given to those strategies capable of being introduced by 1977, and which would reduce carbon monoxide and hydrocarbon levels in the Boston region. Individual strategies were evaluated in the context of technical effectiveness, economic impacts, social impacts, and political feasibility. The product of this analysis was the determination of definitive strategies to be incorporated into the recommended program strategy.

1. Source Control Strategies

A transportation strategy based on inspection and maintenance, vehicle retrofit, or gaseous fuel conversion is a hardware-type control which attacks the emission problem at the source, the automobile. In considering retrofit, vehciles are discussed in the context of pre-controlled vehicles--light duty vehicles sold nationally prior to 1968-- and controlled vehicles--vehicles sold nationally in 1968 and subsequent years.

To achieve the maximum reduction from a retrofit program, an accompanying inspection/maintenance program would be necessary. Periodic testing of vehicles will ensure that control devices are operable and comply with inspection standards.

The Environmental Protection Agency has identified guidelines of possible emission reductions through retrofit of precontrolled vehicles, and retrofit of controlled vehicles. It is emphasized that if the reductions attributed to a retrofit program are used towards achieving air quality standards, then an inspection/maintenance program, requiring at least an annual inspection to ensure that implied reductions are actually being realized, is needed. An inspection/maintenance program would also ensure that fully controlled vehicles, 1975 model years and later, are continuing to meet EPA standards prescribed for 50,000 miles.

In the ensuing sections, the potential effect of retrofitting precontrolled and controlled vehicles is evaluated. The second section describes the potential of a state operated inspection/maintenance program, evaluated from a framework of technical feasibility and related costs. It should be noted at this point that although a retrofit program would need to be accompainied with an inspection and maintenance program, an inspection and maintenance program is not contingent on a retrofit program. The final section briefly explains the possible uses and results obtainable through gaseous fuel conversion.

a. Vehicle Retrofit

Emission reduction potential of a retrofit program for precontrolled and controlled vehicles for Boston depends upon the proportion of vehicle miles of travel generated by precontrolled and controlled vehicles and on the device used.

It is assumed that the 1977 age mix will be similar to the 1971 age mix of light duty vehicles. In 1977, precontrolled vehicles (pre-1968) will contribute 5.1 percent of the light duty vehicle VMT generated. Controlled vehicles between 1968 and 1974 will generate 66.5 percent of the total light duty vehicle VMT and controlled vehicles between 1968 and 1972 will generate 40.3 percent of the total light duty vehicle VMT.

Table III-3 shows the expected 1977 emission reductions that would occur if precontrolled or controlled vehicles are retrofitted with particular devices. Since these reduction devices are used on all gas-powered light duty vehicles, except for motorcycles, the reductions should be factored by the appropriate VMT factor. For example, if the most effective retrofit devices are used on precontrolled and controlled vehicles then the emissions from light duty vehicles would decrease by 38.4 percent for hydrocarbons, and 50.3 percent for carbon monoxide. Since light duty gas vehicles generate 86.5 percent of the VMT in the area and emissions per VMT are slightly more for heavy duty vehicles, the area emission reductions would be slightly less than 33.3 percent for hydrocarbons, and 43.5 percent for carbon monoxide. These reductions will depend on the successful enforcement of the retrofit laws.

TABLE III-3

POTENTIAL BENEFITS FROM RETROFIT

GASOLINE POWERED LIGHT DUTY VEHICLES

Average Percent Emission Reduction For The Area

PRE-CONTROLLED VEHICLES	1977 HC	1977 CO
Lean Idle Air/Fuel Ratio Adjustment and Vacuum Spark Advance Disconnect	2.9	1.1
Oxidizing Catalytic Converter and Vacuum Spark Advance Disconnect	7.9	7.8
Air Bleed to Intake Manifold	2.4	7.2
Exhaust Gas Recirculation and Vacuum Spark Advance Disconnect	1.4	3.8

CONTROLLED VEHICLES	1977 HC	1977 CO
Oxidizing Catalytic Converter and Vacuum Spark Advance Disconnect	30.5	42.5
Exhaust Gas Recirculation and Vacuum Spark Advance Disconnect	0	0

	1981 HC	1981 CO	1984 HC	1984 CO
Oxidizing Catalytic Converter and Vacuum Spark Advance Disconnect	20.8	37.5	8.9	15.2

b. Inspection and Maintenance

A comprehensive study by the Northrop Corporation for the State of California(22) has revealed that the key-mode inspection program is the most cost effective of those reviewed. Although the program would be costly for the State of Massachusetts, it would accomplish the greatest reduction in emissions per dollar cost. The Registry of Motor Vehicles has, for the time being, rejected the idea of an inspection program for Massachusetts; but those who have investigated the possibility agree that the key-mode procedure would be the best choice.

Due to the very large capital investments required for testing facilities, the program would be most efficient if state-owned and operated. A strict enforcement program to ensure that vehicle owners would not tamper with emission-critical components after testing would be required.

The implementation of an inspection and maintenance program using a loaded emissions test has been estimated to reduce initial emissions 25 percent for hydrocarbons, 19 percent for carbon monoxide, and 0 percent for nitrogen oxide. Assuming twelve month periods between checks and a linear deterioration rate this would result in an average reduction of 12 percent in the rate of emission for hydrocarbons and a 10 percent and a 0 percent reduction for carbon monoxide and nitrogen oxides, respectively. These average reductions in the rate of emission for each pollutant are applicable to gas powered light duty motor vehicles, and since these vehicles generate approximately 86.5 percent of all vehicle travel in the region, and emissions per VMT are slightly more for heavy duty emission reductions would be slightly less than 10.4 percent for hydrocarbons and 8.7 percent for carbon monoxide.

c. Gaseous Fuel Systems

Large-scale conversions to gaseous fuel systems in the Boston area would be impractical and unwarranted in view of efforts currently underway to meet emissions standards through modification of conventional gasoline engines. Basic limitations on a massive conversion to gaseous fuel systems include the following:

1. limitations on fuel supplies in the Boston area.
2. lack of refueling facilities
3. capital costs of conversions
4. current legislation-prohibited use of gaseous fuel systems on the Massachusetts Turnpike extensions and in harbor tunnels.

The concept of gaseous fuel conversion is most applicable to fleet vehicle operations such as taxicabs, or large industrial fleets. The costs of converting to a gaseous fuel system ($300-$500), and the provisions of a refueling station are a sizeable investment that can only be amortized when applied to a large number of vehicles with a higher than average mileage. The major incentive for converting to a gaseous fuel system such as compressed natural gas, liquified natural gas, or liquid petroleum gas, is the lower maintenance costs that would be incurred.

Fleet vehicles of 10 or more represent 3 percent of the vehicle population in Boston. These fleet vehicles account for approximately

7 percent of the VMT in Boston.[5] If one-fifth of these vehicles were converted, then 1.4 percent of the VMT in Boston would be affected. It has been estimated that an 85.3 percent initial reduction in carbon monoxide can be obtained for certain fleet vehicles.[17] Using this approximate reduction and applying it to the 1.4 percent, VMT affected would result in a 1.2 percent carbon monoxide emission reduction. In specific grid cells such as those in the Boston inner city, the VMT generated by fleet vehicles could be substantial. For example, if 5 percent of all VMT in a particular grid were generated by taxis, and if these taxis were converted, an approximate 4.3 percent reduction in carbon monoxide emission would occur.

As can be observed, gaseous fuel conversion can reduce emissions in a particular grid cell, if the conditions are favorable. Before a gaseous fuel conversion strategy could be implemented, safety standards and regulations to cover use of gaseous fueled vehicles would have to be developed.

2. Traffic Flow Improvements

The transportation system in the Boston area, as in other large urban areas, has many inefficiencies built into it. First, major portions of the existing transportation system are underutilized while other segments of the system are excessively overtaxed. Coordination between various municipalities and between operating agencies to achieve maximum system capabilities is inadequate.

Secondly, there is no policy within the region which effectively distinguishes between the movement of people and goods. Within the Boston metropolitan area, over 90 percent of all goods are distributed by trucks, which must compete with the automobile for use of the available resources. Trucks contribute significantly to urban congestion within the Boston metropolitan area, both by their presence within the traffic stream and by obstructions caused while loading and unloading goods.

With this as a framework, it is apparent that a top priority goal of a transportation program for Boston should be the enactment of management policies to better utilize available resources.

a. Surveillance and Control - Surveillance and highway monitoring controls are used to optimize traffic flow on freeways by maintaining a smooth, efficient, and economical level of traffic flow through the use of electronic traffic monitoring and control equipment. Studies toward implementing such a strategy for the expressway system throughout Boston are presently being made.

In concept, the technique consists of metering freeway traffic volumes entering an expressway system by some form of traffic control device, so as to maintain an acceptable level of service on the freeway. Traffic flow theories indicate that if flow conditions are kept below a certain level, stable flow will result; beyond this designated point forced flow (with its associated stopping and starting) will prevail. Several installations of ramp metering are being tested in other cities. Although these controls reduce delays along the expressway, they may tend to increase delays at entering ramps. Television surveillance is used in association with control methods to spot accidents and other bottlenecks in the system.

The effectiveness of this control for the Boston metropolitan area is questionable. To effectively limit traffic volumes from entering the expressway, an alternative facility is needed to enable vehicles to bypass a congested area. In the Boston core, such alternative facilities are not readily available. In addition, such a concept favors vehicles already on the system (through vehicles) and hinders those wanting to enter the system in congested areas (core city).

In general, less congestion on expressways will result in lower emissions of carbon monoxide and hydrocarbons; however, unless methods for handling detoured vehicles are available, higher emissions would result within the congested areas near the expressway. This concept would also tend to encourage longer trips as vehicles already on the system receive an advantage and may limit the number of vehicles closer to the core which can enter the system, forcing these vehicles to utilize the local street system.

Television monitoring in conjunction with "changeable message signs" advises motorists of traffic conditions on a freeway so they may take remedial action to either avoid the bottleneck by exiting from a roadway, or slow down to avoid adding to the bottleneck situation. The potential of this control is limited, due mainly to the fact that an insufficient number of vehicles will exit onto an alternate route and that the alternate route generally will not have the capacity to handle the diverted traffic.

In summary, it would appear surveillance and control, as currently practiced, would not be effective within the Boston inner city.

b. Design and Operational Improvements

(1) Expressway Design - In urban areas, there are locations which are most conducive to congestion. Boston is no exception. Locations where major expressway facilities enter the Boston inner city are obvious bottlenecks. Elimination of these bottlenecks is technically feasible, but these improvements would not provide the solution to the overall transportation problem within the Boston metropolitan area.

Many locations along the expressway system do warrant improvements based upon safety and capacity problems. These locations can be improved and congestion eliminated but only to the extent of available capacity on adjacent elements of the system.

In summary, design improvements of the existing expressway network can result in some pollution reductions. Two factors are needed to qualify this statement. First, is the assumption that the improvement does not result in an increase of traffic (through induced and diverted volumes) that would result in a pre-design situation. Management of the system is needed to overcome this occurrence. Second, the overall spot design improvement is not the basis for determining air quality or traffic improvement. The defining factor is the net improvement which can bring the bottleneck location up to the capacity of the adjacent roadway network. Improvements that result in a capacity greater than adjacent roadway network capabilities simply shift the traffic problem (air quality problem) to a different area (the new bottleneck area). Continual improvement will eventually result in the problem being shifted to the prime destination area (the core city).

(2) Expressway Operation - Improved operational design includes the utilization of reversible lanes, the possible closing of ramps during specified hours, and the use of special purpose lanes.

The utilization of reversible lanes and closing of ramps during specified hours are methods which may be applied to reduce congestion, especially during peak hours. Outside of design difficulties in implementing such a policy, this procedure encourages more vehicles to use the system, thus taxing the terminal facilities. Such a procedure is an effective way to eliminate a bottleneck with no major construction, but is again limited in its benefits by the overall capacity of the entire system.

The special use of expressway lanes can be an effective way of reducing the number of single-vehicle, single-person trips by the establishment of priority for buses or car pool vehicles. Successful applications of this technique are in operation in the Shirley Highway, outside Washington, D.C. and on the Lincoln Tunnel approach to New York City. The use of an exclusive lane for buses on the Southeast Expressway has not had significant impact on vehicle travel on the facility. The technical problems associated with this lane have meant that it could be operational only during summer months.

(3) Arterial Flow Improvements - Arterial and local street operation in Boston are characterized by frequent at-grade intersections, unrestricted midblock access, and traffic signal delays. Traffic on arterials and local streets is also susceptible to interruptions by pedestrians, truck deliveries, parking maneuvers, and transit buses. All of these factors result in both side and internal friction that cause lower vehicle speeds and more stops and starts. Furthermore, the potential for pollution control from smoothing traffic flow in downtown areas is limited in many instances (e.g., widening intersection approaches) by the already densely developed nature of the central business district (CBD). It is on or near these downtown facilities where the highest traffic and population densities are found, and where emission reductions would be most required.

Examining the metropolitan area as an entire region, traffic operational improvements to arterial streets can have an effect on improving air quality. Elimination of bottleneck areas in and around the region will eliminate some congested flow and its accompanying pollutant characteristics, but such improvements will be marginal.

In the inner city of Boston, traffic flow improvements over the next five years could increase vehicular speed by 10 percent for the peak 12 hour period. Since these programs affect only a portion of the total travel in the inner city, the overall effect would be less than 10 percent. It is estimated that 20 percent of the travel in the inner city would be affected by these traffic flow improvements. The result would be an average speed increase of 2 percent. Figure III-3 shows the approximate percent emission reduction for carbon monoxide and hydrocarbons as a function of the percent increase in speed. From Figure III-3 a 1.5 percent decrease in carbon monoxide and hydrocarbons emissions would result when the average speed is increased by 2 percent.

In a metropolitan area such as Boston, the additional capacity afforded by traffic flow improvements will quickly by used due to diverted and induced volumes the additional capacity attracts. Because of the imbalance in the supply-demand relationship, increased capacity can rarely keep pace with increased traffic flow. This highlights the need for coordination of traffic flow improvements with companion controls, such as auto disincentives. For a localized problem such as carbon monoxide, operational type improvements do show potential in a complementary role to the primary control strategies. Their application is particularly warranted in those grid cells where substantial carbon monoxide reductions are needed.

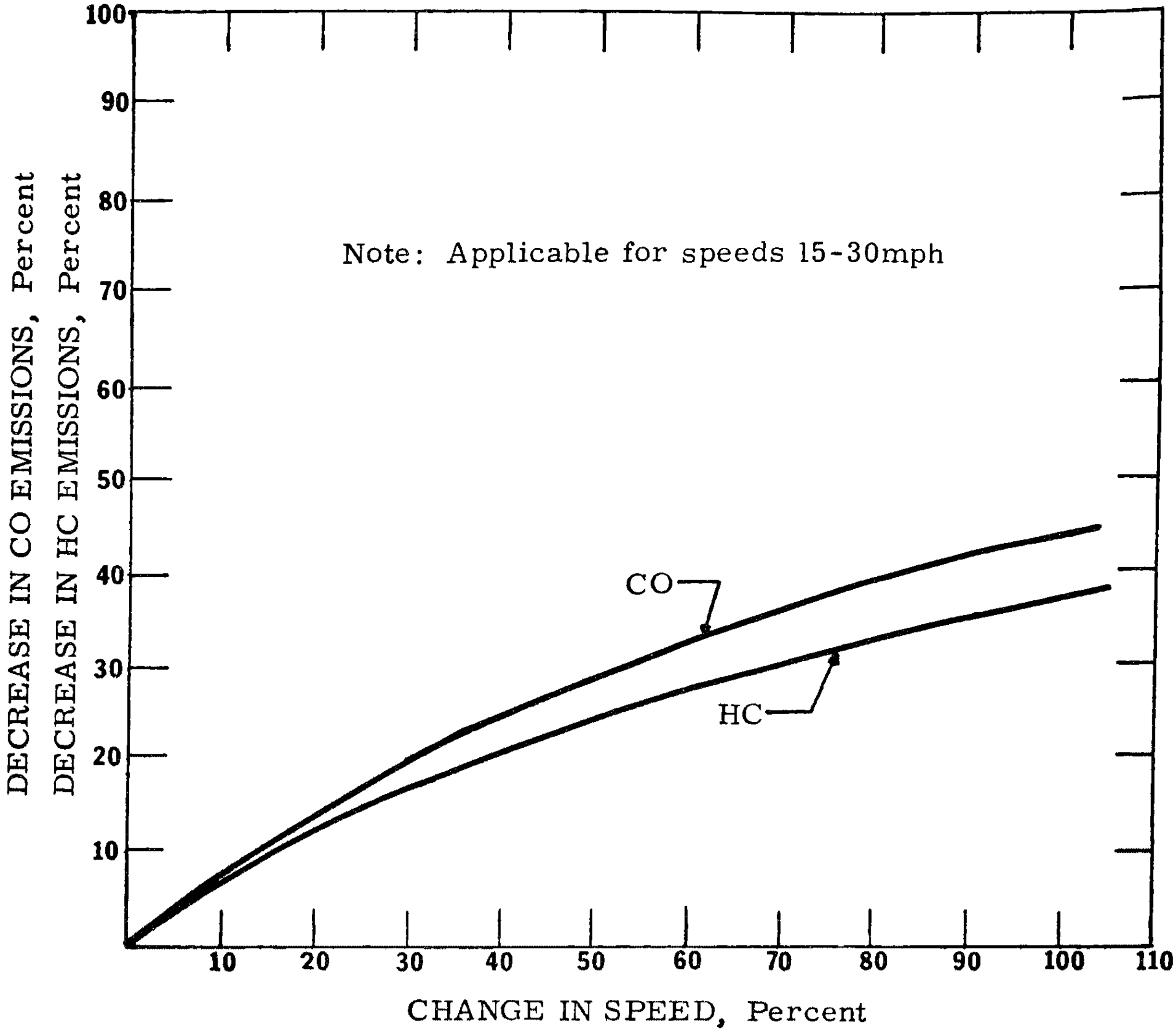


Figure III - 3 Emissions Reduction Vs. Speed Increase

(4) Truck Loading Zones - In the Boston inner city area, on-street loading and unloading of trucks and commercial vehicles seriously detracts from the operational capabilities of major streets. With the exception of some of the newer buildings, off-street loading facilities are relatively scarce in the downtown Boston area.

Alternatives are available to lessen the effect of truck loading operations on traffic movements. Hours of operation could be staggered so as not to coincide with work travel hours. As the largest demand for loading space is from 10:00 A.M. to 4:00 P.M., peak hour restrictions are a reasonable measure. However, such programs would be generally opposed by truck operators due to scheduling and work shift problems.

Off-street loading facilities could be required for all new buildings. In addition, when space becomes available through urban renewal or redevelopment of the more dense urban activity concentrations, a truck loading zone might be made available to provide an off-street loading and distribution facility for contiguous areas.

3. Reduce Travel Demand

a. Four-Day Work Week - The journey-to-work constitutes approximately 60 percent of peak hour traffic in Boston. In considering work schedule changes for the Boston area, we are dealing with the single most important travel pattern inherent to peak hour operation. In theory, a reduction and/or temporal redistribution of trips which ameliorate work peak travel demand has considerable potential. Of the two potential work schedule changes, the four-day work week has greater promise for reducing overall emissions than a program of staggered work hours. Because of the evolutionary nature of society, any widespread implementation of the 4/40 (forty hours of work in a four-day period) concept is some years away. Conversion to the four-day work week implies a profound alteration of societal patterns such as productivity, work habits, recreational patterns, and leisure time use. Implications of a large shift to a four-day week would seem to preclude its introduction before 1977; however, firms and government agencies could begin planning over that period for possible implementation.

An optimum reduction in work trips attributable to a four-day work week is 20 percent, based on spreading the eight trips equally over five days. An associated benefit to the 20 percent trip reduction would be an increase in average speed. It is estimated that decreasing work trips by 20 percent during the peak period (assuming auto occupancy and modal split remain constant), would increase average speed by approximately 20 percent on facilities which previously were at or near capacity. This would reduce carbon monoxide and hydrocarbon rates of emissions by approximately 12 to 15 percent. Based on the modal split model, work trips comprise approximately 40 percent of all trips in the Boston region and at least 40 percent of the vehicle miles of travel. Assuming an optimum trip reduction of 20 percent, the net reduction in vehicle miles of travel would be approximately 8 percent. With approximately 20 percent of trips occurring during the peak periods, the emission reduction due to increased speeds would contribute an additional .12 x .20

= 2.4 percent. In total, a 20 percent reduction in work trips per day would realize a 10.4 percent reduction in emissions.

Assuming that by 1977 approximately 15 percent of the total work force (a figure approximating existing employment in the government sector for Boston) could be on a four-day work week, a 1.5 to 2.0 percent decrease in emissions could be achieved.

b. Parking Management - Parking management can be effective in controlling vehicle trips to and from congested areas of a city. The supply of parking spaces, the use of those spaces, and the price of parking are all variables used to influence travel patterns.

Limiting the number of parking spaces in one area puts an absolute limit on the number of vehicles that can drive there and park. The supply of on-street parking can be limited through municipal parking regulations and their enforcement. Off-street parking available for public use is more difficult to monitor, but can be regulated by granting or denying land use permits to those proposing to build new garages or to create new lots. Another possibility would be to close certain key garages before 9:30 a.m. In addition, fringe parking can be provided along transit lines, major arterial facilities and commuter railroad lines, thus encouraging transit usage and replacing parking spaces lost from the central business district.

Manipulation of price levels and the price structure for parking can also divert many trips to alternate modes. Prices can be monitored either directly, through price controls, or indirectly, through taxes. Street parking can be made more expensive by reducing the number of unmetered spaces, raising meter rates and increasing fines for parking violations. Price control for off-street parking would specify rates which might give discounts to car pools, short-term parkers and others as well as raising the cost of all-day parking.

Taxation of all parking results in an increase in parking prices and, at the same time, provides revenue to the governing authority. This additional revenue may be used to improve transit and fringe parking facilities, thus providing an alternative mode of travel. Parking taxes may be levied as a transaction tax or as a tax on gross receipts or as a sales tax on parking fees. Any of these taxes could be limited to certain hours. By applying this tax for example, to gross receipts on parkers entering before 9:30 A.M., the tax would fall primarily on long-term parkers. Taxation could be imposed on spaces in a city's central business district, throughout the city or even on a regional basis. Taxation on a regional basis would tend to lessen the imbalance created by imposing parking taxes in the core only.

The use of off-street parking spaces can be controlled to some extent without managing parking supply or parking rates. For example, groups of spaces may be reserved for specific users, such as car pools, neighborhood residents or short-term parkers.

All of these methods provide means of encouraging at least some of the persons who drive their vehicles to the center of the city each day, to seek out alternatives to driving. Some will join car pools, others will use transit, and still others will continue to drive their vehicles. The overall effect, however, will be a reduction in total vehicle-miles of travel in the city.

The Boston Transportation Planning Review, after extensive analyses of the transportation system, travel patterns, and growth characteristics of the Boston area, has determined the approximate number of person trips between the core and suburbs which would be diverted from vehicular travel to transit by increasing parking costs. These trip reductions are shown below as a percentage of 1977 total person trips between suburb and core.

TABLE III-4

AUTO PERSON TRIPS DIVERSIONS

	Diverted Trips (Percent)		
	Work	Other	Total
$1.00 Increase in Daily Parking Fee	13.0	0	5.6
$2.50 Increase in Daily Parking Fee	26.0	0	11.0

In order to convert these vehicle trip reductions to reduction in total vehicle miles of travel, several assumptions were made. Trips from the area very near the core are far more elastic than trips from farther away, due to the greater availability of transit and shorter distances. Based on trip distribution analysis, 25 percent of all trips destined for the core area were estimated to originate outside Route 128. Another 25 percent were estimated to originate in the outer suburbs while 50 percent were estimated to originate in the inner suburbs.

The resulting values for vehicle-miles of travel reduced by each of the strategies are shown in Table III-5.

These figures show a maximum reduction in VMT of about four percent using any one of these strategies. These analyses, however, are conservative, since they are based for the most part on past trends and assume only minimal transit improvements.

TABLE III-5

REDUCTIONS IN DAILY VEHICLE-MILES OF TRAVEL

	$1.00 Increase In Daily Parking Charge	$2.50 Increase In Daily Parking Charge
Core		
Percent Reduction of Total VMT	1.87	3.74
Inner Suburbs		
Percent Reduction of Total VMT	1.06	2.12
Outer Suburbs		
Percent Reduction of Total VMT	.48	.96

Many of the measures discussed above can be implemented and would be effective to some extent in reducing vehicle trips into Boston. A parking tax levy would increase the cost of parking and provide revenue for transit at the same time. It is important that this revenue be earmarked for transit improvements. The tax would then benefit those who do not drive and penalize those who do, while maintaining mobility for each.

It is also essential that the cost of parking for the long-term parker and not the short-term parker be increased since the long-term parker is also the peak-hour driver--the source of peak-hour congestion and excessive concentrations of pollutants. The short-term parker presently pays a much higher rate than the all-day parker ($1.20/hour for 30 minutes, $0.31/hour for all day) and he would probably pay the same proportion of any imposed tax, if individual garage operators made the determination. The result should be a rate inversion, giving the all day parkers the disadvantages. This would also tend not to discriminate against downtown merchants and businesses. Rate changes might include long-term penalties or peak-hour penalties, and perhaps car pool discounts.

Some effort should also be made to control the supply of parking perhaps by refusing land use permits where added parking space would generate unwanted traffic. The use of existing spaces should also be controlled by closing certain key garages during the morning peak and perhaps reserving other spaces for car pools.

c. Peripheral Parking Facilities - Provision of park-and-ride and kiss-and-ride facilities in conjunction with improvements to the mass transit and commuter rail systems can have a positive effect on home-to-work trip movement in Boston in terms of air quality considerations. In addition to diverting auto trips to alternative modes of transport, fringe parking facilities are necessary to alleviate some of the negative impacts of enacting a CBD parking management plan.

The Massachusetts Department of Public Works is currently studying potential sites for fringe parking areas around the City of Boston, utilizing state-owned properties near major arterials and transit lines where they cross Route 128. The study will also explore sites along I-93 between Somerville and Route 128. It is hoped that a parking facility there might ease the problem at the Central Artery interchange. Special attention will also be given to the MBTA Riverside Terminal, where Route 128 and the Massachusetts Turnpike intersect.

The Boston Transportation Planning Review has made some recommendations, based for the most part on the need for fringe parking, at those locations. The feasibility of establishing parking facilities at the sites remains to be examined. BTPR's recommendations include parking at the Orange Line and the Blue Line of the MBTA Rapid Transit System and at 17 different sites adjoining commuter railroad lines.

If fringe charges are minimal, auto users could possibly save $1.50 per day by parking in fringe parking areas instead of parking in the inner city. According to the Boston modal split model, a savings of $1.50 per day could divert 7.3 percent of all vehicle trips destined to the inner city to terminate in fringe parking lots instead of in inner city garages. This would result in a 2.43 percent decrease in VMT in the inner city of Boston. By appropriately locating these fringe parking lots in particular transportation corridors, insignificant VMT increases would occur in the grid cells which contain these fringe parking areas. The object is to provide sufficient fringe parking near each transportation corridor so that auto users who used to park in the inner city would now park in the fringe areas without significant inconvenience.

d. Road Pricing - The implementation of a road pricing strategy can have a potential in effecting a reduction in VMT. Road pricing would help to decrease VMT by imposing operating penalties, or disincentives, in the form of special charges on traffic crossing into the central Boston cordon area.

To accurately evaluate a road pricing strategy requires sophisticated analysis of supply-demand relationships inherent to the Boston area that are beyond the scope of this analysis. In evaluating the potential of a road user charge on travel through the Boston core area, it is a safe assumption that the effect would be a considerable reduction in traffic volumes with an accompanying change in modal mix.

Based on results obtained from sensitivity analysis using the Boston modal split model, applying a 25-cent road user cost to all vehicle trips entering or leaving the core area would increase the modal split 1.4 percent. Since the approximate modal split ror the core area is projected to be 50 percent in 1977, the 25-cent road user cost would reduce local VMT by 2.8 percent in the core area. Also, since local trips generate 33 percent of the total VMT in the core area, a 25-cent road user cost would reduce total VMT by .9% in 1977. A 50-cent road user cost would correspondingly reduce local VMT by 5.6 percent and total users would also be penalized. In fact, by definition, a through trip would enter and leave the core area twice a day per trip and therefore would pay twice as much per trip as the local user. Therefore, a 25-cent road user charge would add up to a 50-cent charge per trip. This additional cost would divert a portion of the through trips around the CBD core, would increase car pooling or would increase transit usage.

Implementation of a road user tax could take the form of a toll charge on major facilities, a daily pass displayed within the vehicle, or some kind of metering internal to the vehicle.

Ancilliary affects of a road pricing scheme in terms of economic, social, and administrative implications need to be accurately quantified before the actual implementation of the strategy. Road-pricing policies can adversely affect the economic growth and viability of a region.

Techniques are available for imposing road pricing. The major problem associated with a pricing scheme is that of gaining widespread public acceptance to limiting "freedom of the road", even in areas of high pollution.

4. <u>Increased Transit Use</u>

In light of the needed reductions in VMT, alternative means of transporting people must be provided. The probability of providing these alternative modes of travel by 1977 in Boston is dependent on mass transit and commuter rail systems.

a. Mass Transit - Mass transit, as defined in the context of this analysis, includes both rapid rail and bus systems. To obtain a maximum diversion from auto travel to rail or bus systems, a mass transit strategy must be accompanied by motor vehicle use restraints. Assuming a modal split of the needed proportions necessitates a public policy commitment to institute a program for managing and planning for the expansion and improvement of the regional transit system.

An improved mass transit system is a vital component in providing efficient accessibility to downtown Boston and assuring the continued growth and viability of the inner city area. Underlying goals of a transit improvement strategy can be simply stated:

> Improve equality of mobility and provide the best possible level of service to those now using transit.
>
> Make the service as attractive as possible to increase ridership and reduce auto usage while still providing a high level of total mobility and accessibility to all parts of the region.

A transit improvement package capable of being implemented by 1977 can be termed a moderate investment program. In the case of the Boston mass transit system, a moderate investment program would include only minor extensions of existing lines such as the following:

- Needham extension of Orange line to Route 128
- Harvard line to Alewife Brook Parkway
- Green line to Franklin Park

Modal splits by zone shown in Figure III-1, entitled, "1977 Trip Movement for the Boston Region," were projected, assuming a moderate investment program and the implementation of needed service improvements such as improved physical plants, expanded schedules, and more efficient operating patterns. Based on the transit usage analysis performed by BTPR and assuming the institution of a moderate investment transit program, a .78 percent VMT reduction would occur in the inner city.

A maximum investment plan could be considered for greater diversion; however, there is little probability that this plan could be implemented by 1977. This plan would include an inner city circumferential system utilizing either a "people mover" system or a bus loop. Further extensions to the moderate system would be:

- Green line to Mattapan
- Orange line from Forest Hills to Canton
- Red line from Alewife to Lexington at Route 128

If the maximum transit investment program were instituted, a 1.45 percent VMT reduction would occur in the core area.

b. Commuter Rail - The commuter rail system in Boston is relatively extensive compared to those now operating in other comparable urban areas. Currently, thirteen lines radiate from Boston, with the Penn Central Railroad operating five to the south and west, and the Boston and Maine Railroad operating eight to the north and northwest. Because of the extensive geographical coverage of the system, there is no intensive ridership in any one corridor, thus the impact is diffused throughout the system.

Massachusetts is actively pursuing the development of the commuter rail system to its fullest potential. The Commuter Rail Improvement Program (CRIP) evolved out of the Boston Transportation Planning Review (BTPR) as a separate, subsidiary, correlated and coordinated effort in early 1971. It was co-sponsored by the Executive Office of Transportation and Construction (EOTC) and the Massachusetts Bay Transportation Authority (MBTA). CRIP's main purpose was to propose a program for placing the commuter rail on a permanent and expanding basis as an integral part of a balanced transportation system for the Boston metropolitan area. Table III-6 illustrates expected ridership on the commuter rail system.

The estimated system ridership for 1977 of 20,303 can be assumed to be on the conservative side. An outside estimate of ridership would approach 30,000. To set this estimated ridership in a perspective of "absolute system capacity," the post World War II one-way ridership ranged from 90,000 to 100,000. The tracks and right of ways used to achieve this ridership are still in place. The major capacity constraint is the lack of rolling stock.

TABLE III-6

PROJECTED COMMUTER RAIL RIDERSHIP

Year	Projected One Way Ridership/Day
1972	16,063
1973	16,911
1974	17,759
1975	18,607
1976	19,455
1977	20,303
1978	21,151
1979	21,999
1980	22,848

* Commuter Rail Improvement Program.

Society's desire for increased mobility is resulting in increased car ownership and an increased dependence on the motor vehicle. These socio-economic factors reduce the possibility of achieving any massive diversion to commuter rail on the part of riders in the post-war period.

Based on the 1964 Mass Transportation Commission Study entitled "Mass Transportation in Massachusetts," and the 1963 origin and destination survey, it is known that commuter rail is used proportionately more for work trips to downtown Boston than any other mode. Of all rail trips, 72.9 percent are work oriented. Due to this high percentage of work trips, commuter rail use is highly peaked with 72.0 percent of all inbound trips arriving between 7:30 and 9:00 A.M.

In light of the previous discussion of system capacity and associated benefits, the commuter rail system provides a valuable and apparently viable alternative mode of transport to the automobile. Through a well planned service and capital improvements program, coupled with a program of pricing and regulation to discourage auto use, commuter rail ridership could probably exceed the 30,000 upper limit expected for 1977 and possibly approach the ridership attained in the post World War II period. Based on sensitivity analyses performed on the Boston modal split model, the institution of an extensive transit network increased modal split by less than 1 percent and decreased VMT by less than 1 percent. As can be observed, an improved transit network is not expected to reduce auto travel significantly. The substantial commuter rail impact will come when VMT is reduced by imposing additional auto user costs.

5. Modify Travel Patterns

a. Staggered Work Hours - The effectiveness of a work staggering program is highly dependent upon the number of controllable employees who are:

(1) within the Boston inner city area;

(2) travel during the peak period, and

(3) work for an identifiable number of major employers.

In addition to the spatial and temporal characteristics of the work force, it is important to identify the major employment sectors in the Boston economy. Certain employment sectors (i.e. - Government jobs) are more adaptable to work staggering than others.

Over the past 20 years, jobs in the Boston area have shifted dramatically from a manufacturing base to a predominance of service sector jobs. The actual number of manufacturing jobs has been reduced, and the proportion of total employement in manufacturing has fallen from a third to a fifth.

Table III-7 illustrates the employment changes which have taken place in Boston over the past two decades. The growing sectors of the economy are those oriented to the production of services, specifically:

- wholesale trade
- retail trade
- finance, insurance and real estate
- services
- government

Within the City of Boston, work staggering is presently going on in certain employment sectors to a limited degree. Industry is generally staggered on a shift basis. Major retail operations start later in the morning and quit around 6:00 P.M. Some insurance companies have staggered their working hours to avoid peak hour congestion. The total percentage now utilizing the work staggering concept, however, is relatively small compared to total employment figures for Boston.

If the one-hour carbon monoxide standard is exceeded in the future in Boston, then application of a work staggering strategy could significantly reduce emissions during the peak hour. Work staggering

TABLE III- 7

EMPLOYMENT CHANGE 1947-1970 [7]
BOSTON SMSA AND BOSTON

(in thousands)

Metropolitan Area	1947	%	1970	%
Agriculture-Mining	3.7	.4	3.4	.3
Construction	39.5	4.3	51.0	4.1
Manufacturing	291.0	31.6	277.0	22.5
Transportation, Communication, Utilities	90.0	9.0	76.9	6.2
Wholesale	58.2	6.3	81.5	6.6
Retail	163.1	17.7	212.8	17.2
Finance, Insurance, Real Estate	49.9	5.4	92.9	7.5
Services	138.5	15.1	301.9	24.4
Government	86.1	9.4	137.2	11.2
Total	919.9	100.0	1,235.1	100.0

Boston				
Agriculture-Mining	2.5	.5	.6	.1
Construction	19.3	3.7	17.8	3.5
Manufacturing	112.6	21.7	65.2	12.8
Transportation, Communications, Utilities	73.3	14.1	42.0	8.2
Wholesale	44.3	8.5	41.0	8.1
Retail	93.1	17.9	77 7	15.3
Finance, Insurance, Real Estate	40.5	7.8	71.5	14.0
Services	71.8	13.8	114.3	22.5
Government	62.2	12.0	79.0	15.5
Total	519.4	100.0	509.1	100.0

can result in a decrease in vehicle miles of travel during the peak hour and an increase in average speeds. Assuming a 20 percent decrease in vehicle miles of travel during the peak and an average speed increase of 20 percent, an approximate 12 to 15 percent reduction in emissions could result.

In the case of Boston, the eight hour carbon monoxide standard is being exceeded, necessitating a reduction in emissions during the peak twelve-hour travel period. Work staggering would not significantly reduce vehicle miles of travel for the twelve-hour period. On a twelve-hour basis, the derived benefits of a work staggering program would result mainly from the associated speed increases which would reduce carbon monoxide and hydrocarbons emissions approximately 2 to 3 percent.

The Boston Chamber of Commerce looked at work staggering in the 1960's as a solution to some of Boston's congestion problems. Results of the study showed that work staggering on a scale large enough to have a major impact on congestion was not feasible.

With the growth of the service sector in Boston, even more definite limits are placed on the potential of work staggering in controlling peak period vehicle use. The service sector, geared to servicing the public, needs a compatibility of hours with the major influxes of people more than do the other sectors such as manufacturing. Retail activity can only shift hours of operation if customers reorient their buying habits. Retail and wholesale firms also adapt their working hours to industry requirements and to outside factors such as the flow of materials from external areas.

A secondary, but equally important, consideration is the relationship of hours of operation to national firms. Coordination of activity is particularly important to financial, insurance, and real estate sectors.

Summarizing, the factors limiting the potential of the work staggering concept include the following:

- existing laws regulating hours of operation--i.e., banks
- need for compatibility of service sector with public demand
- relatively long duration of peak travel demand periods
- the deleterious effects on alternative strategies such as car pooling and mass transit usage because of schedule limitations
- the fact that work staggering would not have a significant effect in achieving an eight-hour carbon monoxide standard.

F. POTENTIAL PROGRAM STRATEGY

Transportation control strategies designed to attain the necessary reduction in mobile source emissions by 1977 of carbon monoxide and hydrocarbon-formed oxides have been described above. Table III-8 summarizes the preliminary estimates that were placed on each in order to evaluate the candidate strategies. This Table was presented to the Environmental Protection Agency, Regional Review Committee during the course of the study.

The table shows the ranges of expected reductions and the probable feasibility of implementation. The total emission reduction of 58.0 percent for hydrocarbons and 67.4 percent for carbon monoxide overstates the potential somewhat, as the various elements are not necessarily additive. The second total, excluding source controls, is also non-additive. However, these indicate what level of reductions may be expected.

1. Strategy Ranking

The strategy evaluation matrix shown in Table III-9 was derived from analyses in the preliminary screening and impact evaluation phases. Individual strategies were rated on the following criteria:

- Technical Effectiveness -- the emission reduction potential of the specific strategy;
- Economic Impact -- a cost/effectiveness estimate, including capital cost for the public sector, private cost, and impact on regional economics;

TABLE III-8.

PRELIMINARY EVALUATION MATRIX

Actions	Technical Feasibility	Emission Reduction		VMT Reduction		Institutional Feasibility	Unresolved Issues
		Core	Region	Core	Region		
Reduce Emission Rate							
• Source Control							
1. Retrofit (pre '75 vehicles)	+		HC 53.2% CO 43.5%			?	Very high cost; $160-200 / vehicle, $110 million for region
2. Inspection & Maintenance	+		HC 10.4% CO 8.7%			+	Manpower training and testing equipment required.
3. Gaseous Fuel Conversions*	+	CO 4.3%	CO 0.8%				
• Traffic Flow Improvements							
4. Surveillance & Control	+					+	
5. Design & Operational Improvements	+	1.5%	0.3%		2.0%	+	Problem of induced VMT (+ 2%)
6. Truck Loading Zones	+					+	
7. Driver Advisory Displays*						+	
Reduce Vehicle Miles of Travel							
• Reduce Travel Demand							
8. 4-day Work Week	+	10.0%	2.0%		0.8%	?	Can it be effectively implemented by 1977?
9. CBD Parking Management	+	4.0%	0.8%	4.0%	0.8%	+	Can it be effectively implemented by 1977?
10. Peripheral Parking Facilities	+	2.4%	0.5%	2.4%	0.5%	+	
11. Road Pricing	+	2.0-10.0%	2.0%	2.0-10.0%	2.0%	?	Depends on price; institution needed.
12. Gasoline Rationing*	Not evaluated						
13. Increase Fuel Tax	-		2.0-10.0%		2.0-10.0%	?	Depends on price.
• Increase Transit Riding							
14. Commuter Rail, Rapid Rail and Bus Systems	+		2.0%		2.0%	+	Who will operate commuter rail?
• Increase Car Occupancy							
15. Car Pooling (voluntary)*	-	Not evaluated		Not evaluated			
• Modify Travel Patterns							
16. Work Staggering (hours)	+	2.5%	0.4%			?	
17. By-Pass Through Traffic*	-	2.5%	0.4%			?	
18. Vehicle Free Zones	?	Not evaluated		Not evaluated		?	

TOTAL - ALL STRATEGIES HC 58.0%; CO 67.4%

TOTAL - EXCLUDING SOURCE CONTROL HC 14.4%; CO 15.2%

---

* Eliminated from preliminary evaluation.

TABLE III-9. STRATEGY EVALUATION MATRIX

STRATEGY	Sub-Ratings				Final Rating
	Technical Effectiveness	Economic Impact	Political/ Social Implications	Institutional Feasibility	
Reduce Emission Rate					
Source Control					
Retrofit	5	2	2	2	3.2
Inspection/Maintenance	5	3	4	3	4.0
Gaseous Fuel Conversion	2	2	2	2	2.0
Traffic Flow Improvements					
Surveillance & Control	2	2	3	3	2.4
Design and Operational Improvements	2	3	3	4	2.8
Truck Loading Zones	1	1	2	1	1.2
Driver Advisory Signs	1	1	1	1	1.0
Reduce Vehicle Miles of Travel					
Reduce Travel Demand					
Four-Day Work Week	3	2	3	3	2.8
CBD Parking Management	3	3	3	3	3.0
Peripheral Parking Facilities	3	4	3	3	3.2
Road Pricing	4	1	2	2	2.6
Gasoline Rationing	1	1	1	1	1.0
Increased Fuel Taxes	1	2	2	2	1.6
Increase Transit Use					
Commuter Rail/Rapid Rail/Bus Systems	3	4	4	4	3.6
Increase Car Occupancy					
Car Pooling (Voluntary)	1	1	1	1	1.0
Modify Travel Patterns					
Stagger Work Hours	2	1	2	3	2.0
Bypass Through Traffic	1	2	2	2	1.6
Vehicle Free Zones	5	2	3	2	3.4

- Political/Social Implications -- impact on social problems and public acceptance;
- Institutional Feasibility -- relationship to existing institutional framework and/or need for new institutions to implement.

Of the four criteria, technical effectiveness was identified as being most important and was weighted double. The final rating, based on a one to five scale, was determined in the following manner:

$$\text{Final Rating} = \frac{2\,(\text{Technical Effectiveness}) + \text{Economic} + \text{Political/Social} + \text{Institutional}}{5}$$

Those strategies that received the higher rating were recommended and selected such that their impact on the air quality was sufficient to meet the standards. They are discussed in the next chapter.

IV. SELECTION OF TRANSPORTATION CONTROLS AND ESTIMATE OF AIR QUALITY IMPACT

A. RECOMMENDED PROGRAM STRATEGY

The recommended transportation control program for Boston is shown in Table IV-1. Due to the uncertainties associated with the feasibility and potential effectiveness of the primary strategies, a set of contingency strategies has also been included.

Source control strategies have the greatest potential for reducing regional emissions. Assuming retrofit of all pre-1975 light duty vehicles for the four counties (Essex, Middlesex, Norfolk and Suffolk) comprising the study area, a 33.2 percent for hydrocarbons and 43.5 percent for carbon monoxide emission rate reduction on a region-wide basis could be attained. An inspection and maintenance program is required if a retrofit program is implemented. Utilizing Environmental Protection Agency (EPA) guidelines, inspection and maintenance of light duty vehicles can bring about 10.4 percent emission rate reduction in hydrocarbons and a 8.7 percent reduction in carbon monoxide on a regional scale.

Transportation control strategies are more applicable to localized areas. In quantifying the effects of transportation planning strategies, the reduction in vehicle miles of travel and/or emission rate was calculated for the inner city zone. For the inner and outer suburb zones, it was found that the reduction in VMT or emissions would be approximately 20 percent of that assigned for the inner city area, using total VMT in each zone as a guide.

TABLE IV-1

RECOMMENDED TRANSPORTATION CONTROL PROGRAM

Control Strategy	Inner City Emission Reduction	Regional Emission Reduction	Source of Emission Reduction: Emission Rate Reduction	Source of Emission Reduction: Vehicle Miles of Travel Reduction	Estimated Capital Cost
Inspection and Maintenance	0% CO HC 25%; 8.7 10.4	0% CO HC 25%; 8.7 10.4	Expected to reduce average emission rates for HC and CO by 10.4% and 8.4%.	No reduction expected	$40-50 million
Retrofit	0% HC CO 50%; 33.2 43.5	0% 50%; 33.2 43.5	Expected to reduce HC and CO average emission rates by 33.2% and 43.5%.	No reduction expected	$110 million ($160-200 per vehicle)
Traffic Flow Improvements	0% 25%; 1.5	0% 25%; .3	Inner City - 1.5% Region - .3%	May increase VMT because of induced traffic	Non-capital intensive
Road Pricing*	0% 25%; 3.5	0% 25%; 1.3	No reduction expected	Inner City-Reduce VMT by 3.5% Region-Reduce VMT by 1.3%	Not evaluated
CBD Parking Management,* Peripheral Parking Moderate Transit Improvements	0% 25%; 7.6	0% 25%; 2.6	No reduction expected	Inner City-Reduce VMT by 7.6% Region-Reduce VMT by 2.6%	Parking costs not evaluated. Moderate investment transit improvements @ $425 million

* These two strategy groupings complement each other. Total reduction expected will approximate 11.1 percent for the inner city, and 3.9 percent for the region.

A combination of CBD parking management, peripheral parking facilities, and mass transit improvements could reduce emissions by 7.6 percent in the inner city area and by 2.6 percent in the region.

The effect of road pricing on travel characteristics is highly dependent on the price charged. Reductions in VMT from road pricing for the Boston area could vary from 2 to 10 percent while reductions for the region could vary from .68 to 3.4 percent. It was calculated that a 25-cent toll on facilities crossing the Boston cordon line would reduce local trip movement by 2 percent.

The effect of road pricing on external trips was not evaluated as sufficient data on external trip movement was not available. Assuming that external trip reduction approximates that of local trip reduction, a 3.5 percent total reduction can be attributed to road pricing. As road pricing, parking management, peripheral parking, and mass transit improvements complement and support each other, it is expected that a total emission reduction of 11.1 percent for the inner city and 3.9 percent for the region could be achieved through a combination of the four strategies.

Traffic flow improvements, in combination with motor vehicle restraints, would reduce emissions by 1.5 percent in the inner city and by less than .3 percent in the region.

Table IV-2 summarizes the potential emission reductions of the recommended program package. A 25 percent reduction of hydrocarbons on a regional scale is necessary to meet the oxidant standards in Boston.

TABLE IV-2

EMISSION REDUCTIONS WITH RECOMMENDED CONTROL STRATEGIES

Program Element	Program Strategy	Percent Emission Reduction: Inner City HC	Inner City CO	Region HC	Region CO
Source Control	Inspection and Maintenance	10.4	8.7	10.4	8.7
	Retrofit	33.2	43.5	33.2	43.5
Transportation Oriented	CBD Parking Management, Peripheral Parking Facilities, Mass Transit Improvements, Road Pricing	11.1	11.1	3.9	3.9
	Traffic Flow Improvements	1.5	1.5	.3	.3
	TOTAL	56.2	64.8	47.8	56.4

A program of inspection/maintenance, CBD parking management, peripheral parking facilities, and mass transit improvements would realize a 23.0 percent reduction in the inner city and 14.6 percent reduction in the region. It is left to a retrofit program to contribute the additional needed reductions across the region.

It is concluded that the required oxidant reduction can be achieved in Boston through a program of source control and transportation oriented strategies. Primary reliance is placed on the source control strategies.

The Federal Motor Vehicle Emission Control Program greatly mitigates the extent of the carbon monoxide problem by 1977, reducing emissions of carbon monoxide by 40%. Application of the recommended oxidant strategy should eliminate the carbon monoxide problem entirely by 1977 for it provides an additional 56% reduction on the 1977 baseline or a total reduction of 74% of the 1970 levels.

Special localized controls are possible in absence of a control plan for oxidants and are described below.

Five inner city grid cells exceeded the carbon monoxide standards in 1977. Two of these areas, the east Boston area by the Sumner-Callahan Tunnel and the Washington St. - Albany St. area will be able to attain carbon monoxide standards through a CBD parking management plan. The remaining areas, Science Park, Haymarket Square and Kenmore Square, need substantial emissions reductions to meet the standards.

Special treatment will be needed in these particular grid cells. For example, the problem in the Science Park area will necessitate further consideration of how many lanes on I-93 should be opened.

The Haymarket Square area is the one problem location where a partial vehicle free zone may be applicable and where the four-day work week concept could be instituted on a large scale because of the high percentage of government employees. Unlike the other two major problem areas, the Kenmore Square area does not seem readily adaptable to any special strategy consideration.

In the absence of localized treatments as mentioned above, carbon monoxide standards will not be met in the Science Park, Haymarket Square, and Kenmore Square grid cells unless a major retrofit program in implemented.

B. IMPACT OF RECOMMENDED SOURCE AND TRANSPORTATION CONTROLS ON AIR QUALITY

The effects of the recommended strategies were calculated for the inner city zones by estimating the emissions with the new 1977 VMT's and reducing the light duty vehicle emissions first for inspection-maintenance and then for retrofit. As done in Chapter II the stationary emission density was added, and then the rollback technique related the emission densities to air quality. The 1977 VMT's and the calculations for each zone are found in Appendix

1. <u>Carbon Monoxide</u>

Table IV-3 presents the expected air quality for 1977 in the inner city region. The three maximum zones, Science Park, Haymarket Square - Government Center, and Kenmore Square, which exceeded the standard by a substantial amount, meet the standards. To reduce the emissions at Science Park, where they are highest, all the pre-1975 light duty vehicles are required to be retrofitted even though it is more than enough for most zones.

Figure IV-1 shows how the implementation of the control strategies reduces the concentration of carbon monoxide at Kenmore Square. The effects of the transportation oriented strategies is noted during the years 1973 through 1975. Then inspection-maintenance and retrofit applied during 1975 and 1976 drastically reduced the concentration below the standard. The curve with the control strategy approaches the other around 1986 when retrofit, inspection-maintenance is no longer applied.

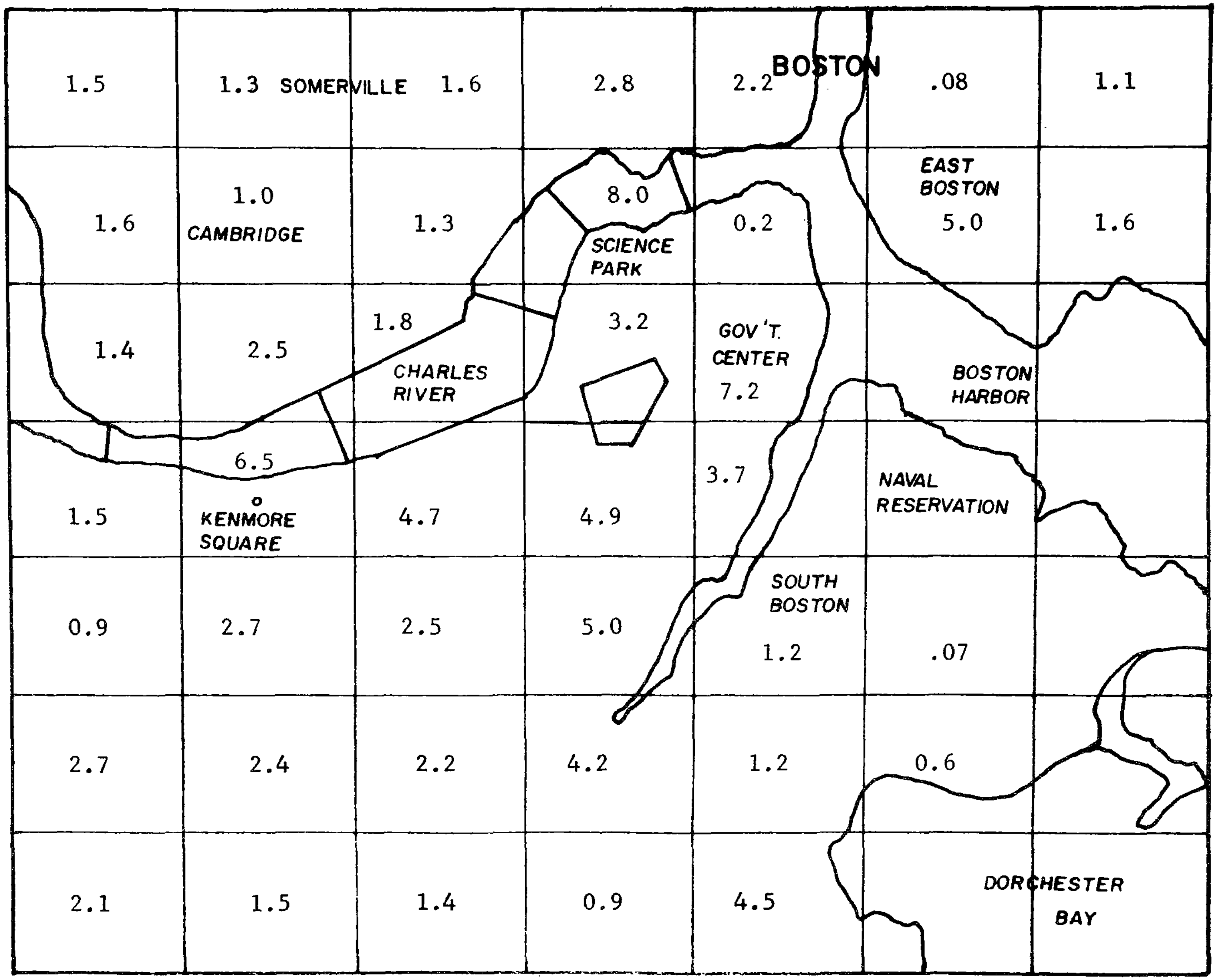
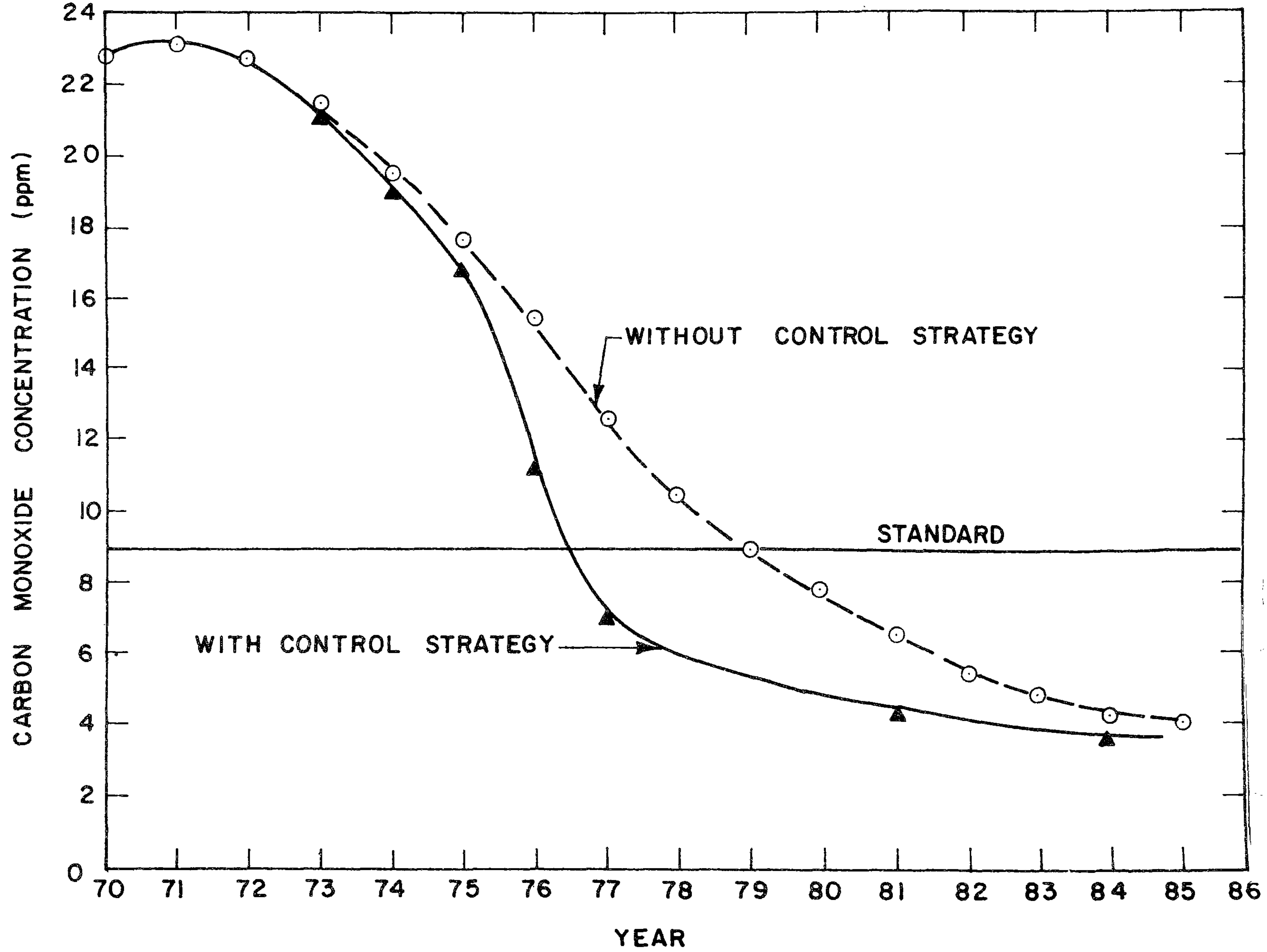


Table IV-3. 8-Hour Maximum Ambient Air Quality Estimates in PPM for Carbon Monoxide in 1977 with recommended transportation control program.



CARBON MONOXIDE CONCENTRATION (ppm)
24
22
20
18
16
14
12
10
8
6
4
2
0
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
YEAR
WITHOUT CONTROL STRATEGY
STANDARD
WITH CONTROL STRATEGY

2. <u>Oxidants</u>

The recommended strategies sufficiently reduce the hydrocarbon emissions to meet the oxidant standard of .08 ppm in the region within Route 128. The calculations on Table IV-4 show how the various strategies reduce the emission by 1977 to 98,830 Kg/day - 243 sq. miles, which corresponds to .074 ppm. Figure IV-2 demonstrates the impact of the control strategies measuring the percent reduction from the 1972 base year up to 1985. The corresponding concentrations are calculated using the curve in Figure II-8. This new figure is found in Chapter VI where the Surveillance Review Process is discussed.

TABLE IV-4

1977 HYDROCARBON EMISSIONS AND 1977 OXIDANT LEVELS WITHIN ROUTE 128 REGION REDUCED BY SOURCE AND TRANSPORTATION ORIENTED STRATEGIES

Area 243 sq. miles

	HYDROCARBON EMISSIONS (Kg/day)	OXIDANTS LEVELS (ppm)
WITHOUT STRATEGY		
Vehicular Emissions	72,101	
Non-Vehicular Emissions	+ 51,100	
Total Emissions	123,101	.100
WITH STRATEGIES		
Vehicular Emissions	68,780	
(less) Inspection & Maintenance (12% Reduction on LD Emissions) .12 (45,727)	- 5,500	
	63,280	
(less) Retrofit (38.4% Reduction on LD Emissions) .384 .88 (45,727)	- 15,450	
	47,830	
Non-Vehicular Emissions	+ 51,000	
Total Emissions	98,830	.074

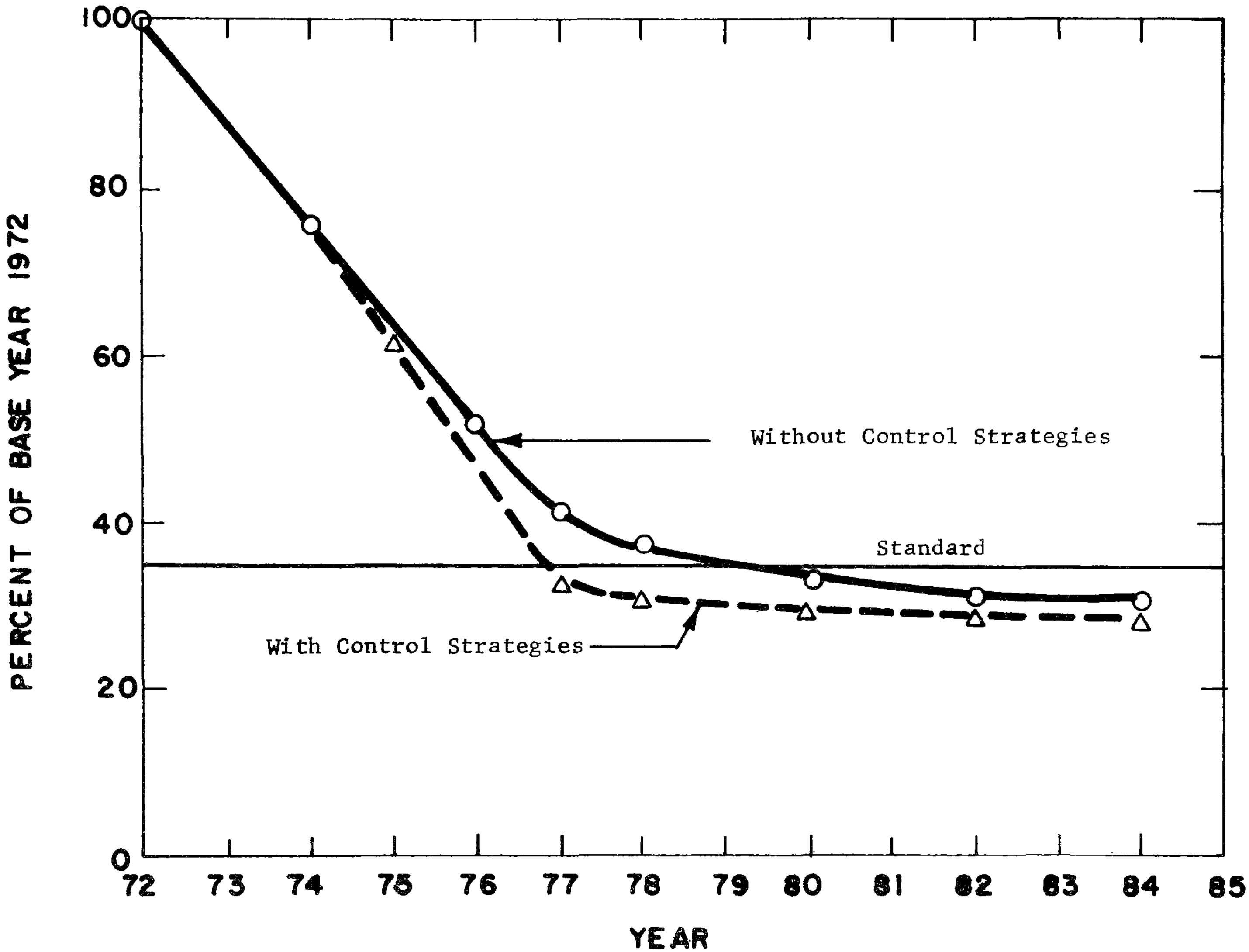


Figure IV-2 Reduction of Hydrocarbon Emissions with and without Control Strategies

V. IMPLEMENTATION OBSTACLES

The following agencies and civic groups participated in meetings and discussions concerning implementation obstacles:

Executive Office of Transportation and Construction

Boston Transportation Planning Review

Massachusetts Department of Public Works

Massachusetts Department of Public Health

Massachusetts Registry of Motor Vehicles

Massachusetts Bay Transportation Authority

Boston Redevelopment Authority

City of Boston Air Pollution Control Commission

Greater Boston Chamber of Commerce

Following are descriptions of obstacles that may be encountered in attempting to implement the various transportation control strategies outlined in the preceding sections. The discussion here covers only non-technical factors, since technical factors are described above. Conclusions regarding both technical and non-technical factors are presented in Chapter III.

The evaluation in this study is preliminary, but will provide a substantive basis for more thorough and detailed evaluation of control strategies in subsequent studies.

Non-technical obstacles considered herein are:

- Institutional Obstacles
- Legal Obstacles
- Political/Social Obstacles
- Economic Obstacles

Discussion of these obstacles, which follows, is presented according to control strategy.

A. INSPECTION, MAINTENANCE, RETROFIT

This strategy would require retrofit of precontrolled (pre-1968) and controlled vehicles (1968-1974) to achieve maximum emission reduction, periodic inspection, and maintenance of vehicles not meeting control criteria.

1. Institutional Obstacles

In Massachusetts, this program might fall within the jurisdiction of the Registry of Motor Vehicles which presently supervises a semi-annual safety inspection program. The existing Registry safety inspections are conducted at some 3,500 private service stations for a nominal fee.

One view is that emission inspection equipment cannot be effectively installed and supervised at private stations. Therefore, state owned and operated stations may be necessary. Alternatively, it may be cost-effective to establish both safety and air pollution inspection at the same sites. Since the proposed emission inspections would be required annually and the safety inspections are semi-annual, it may be possible to continue the same safety inspection program with perhaps a visual inspection of anti-pollution equipment at the midyear safety check. The question of interaction between the safety and pollution source inspection programs requires further analysis. Total removal of inspections from private operators would cause considerable opposition.

Police enforcement of the inspection programs would probably be no more difficult than enforcement of the safety inspection program if a sticker were placed on each approved vehicle.

The maintenance phase of the program, however, would raise serious problems if sufficient qualified mechanics are not available. Vehicles rejected during inspection would be required to have the necessary corrections made and returned for reinspection. If this work cannot be completed within a reasonable time limit, added enforcement problems would occur.

Another candidate for supervising this program may be the Department of Public Health which presently has authorization for inspection of vehicles suspected of air pollution violations.

2. Legal Obstacles

One requirement for such a program would be passage of state legislation which clearly identifies the agency chosen as a matter of public policy to supervise the inspection and maintenance program. The legislation for the program would apply to all vehicles, with pre-1968 and pre-1975 controlled vehicles required to install retrofit devices to comply with the law. It probably would not be regarded as class legislation, which is discriminatory and in violation of the Massachusetts Constitution. This could take considerable time which would increase the required lead time to initiate and establish an effective system of inspection stations. Furthermore, there must be state legislation appropriating funds for the program.

The legislation for a Registry supervised program may be added as part of the Chapter 90 (Massachusetts General Laws) inspection program presently under the jurisdiction of the Registry of Motor Vehicles. The law would include a statement of purpose, delegation of power to the Registry to set up and administer the air pollution program, and fines and other penalties necessary for enforcement. In addition, air pollution emission standards and rejection rates would have to be included in the legislation.

3. Political/Social Obstacles

There is no known opposition from political figures in the City of Boston or the Commonwealth of Massachusetts to this program. However, the retrofit program will be regressive on low income persons who tend to own older cars and can less afford to purchase the retrofit device. An alternative to private purchase would be to provide for state purchase from inspection fees, parking fees, etc. Few objections, however, may be expected to the inspection program in view of the already accepted semi-annual safety inspection program.

4. Economic Obstacles

The startup cost of a state operated inspection/amintenance program would be approximately $14 - 15 million with an annual operating cost of $5 - 6 million. The state revenue source would be the General Fund. No bonding would be required unless there is major construction. The cost of acquiring the retrofit device for each vehicle might be placed upon the individual car owner; however, state or federal direct or tax derived subsidies might be considered for partial aid to those low income persons who are auto dependent and unable to afford the required devices.

B. TRAFFIC FLOW IMPROVEMENTS

This transportation control strategy would involve improving traffic flow rates to alleviate the idle mode and to generally increase speed on arterials.

1. Institutional Obstacles

In general, institutional obstacles to improving traffic flow are few in the Boston area, if funds are made available for the improvements. Opposition to improvement measures is often expressed by commercial land owners whose access is affected; but, in general, traffic flow improvements are accepted by the public. In fact, minor transportation improvements such as those contemplated here are more readily accepted than new highway construction, and clearly within the framework of the regional transportation policy announced by Governor Sargent in his November 30 statement.

There is presently no metropolitan transportation district or other body to coordinate traffic flow improvements among street-highway agencies and with the transit management agency (the MBTA) in the Boston area. The present institutional structure of transportation agencies, as shown in Figure V-1, tends to obstruct achievement of an optimum system for coordination of traffic. Presently, the primary bases for coordination are: (a) the channeling of state and federal funds, and (b) planning as part of the Section 134, "3C" process of coordinated, continuing, comprehensive planning.

Streets and Highways	Mass Transit (Subway, Trolley, Bus)
Executive Office of Transportation and Construction Massachusetts Department of Public Works - Highways for Entire State Metropolitan District Commission - Parkways in the Boston Region Massachusetts Turnpike Authority - Massachusetts Turnpike and Summer and Callahan Tunnels Massachusetts Port Authority - Mystic River Bridge City of Boston - Traffic and Parking Commission - Promulgation of on-street parking and other traffic regulations with State DPW approval Boston Public Works Department - Local street improvements, etc.	Massachusetts Bay Transportation Authority - Boston Region

Figure V-1

EXISTING INSTITUTIONAL STRUCTURE
BOSTON AREA TRANSPORTATION AGENCIES

To achieve optimum traffic flow, it may be necessary for either the State or a new metropolitan entity to be given authority over the management, budgeting, and planning of transportation facilities in the Boston region. One possible means of doing this would be to give the necessary authority to the existing Executive Office of Transportation and Construction, a State cabinet-level office. These and other matters must be reviewed after information is received concerning the course of reorganization of all State agencies and authorities, taking place in Massachusetts.

2. Legal Obstacles

There are no significant legal obstacles to carrying out traffic flow improvements on streets and highways. The only major obstacle to overcome is the legislative one, necessary to establish the above-mentioned regional transportation entity. The legislation for this purpose would include a statement of purpose, delegation of power to the chosen entity, establishment of necessary powers and duties, possible transferral of powers from existing agencies, and appointment of a chief executive.

3. Political/Social Obstacles

Political opposition to agency reorganization may be expected. A social obstacle exists in that highway construction through existing neighborhoods will be opposed.

4. Economic Obstacles

Implementation is dependent on Federal and State funding. The Governor's recently announced transportation local aid proposal includes funding for local street improvements and will have to be reviewed in detail as it is processed through the legislature.

C. IMPROVEMENT IN PUBLIC TRANSIT

The objective of this strategy is to improve transit systems to attract new riders, and to achieve a corresponding reduction in auto miles traveled in the region.

1. Institutional Obstacles

The manner of funding the operating subsidy of the Massachusetts Bay Transportation Authority (MBTA) is by assessments levied on the property tax rates of the jurisdictions within the MBTA district. The assessment formula proportions the levy to each city and town based on the relationship that the number of cummuters in each city or town bears to the total number of cummuters in all of the cities and towns.

The assessment formula, applied to an already overburdened tax in Massachusetts, has generated two institutional obstacles to improving the transit system:

a. It has generated opposition to rapid transit extensions.

Based on the number of commuters boarding in each town, towns in the path of the extensions foresee being assessed for numerous commuters from nearby towns. They believe their assessment would rise while those towns contributing the added ridership would be relieved of the obligation.

b. It has generated a taxpayer's revolt against the MBTA and the assessment formula.

The inflationary spiral in the MBTA deficit has led to extraordinary increases in the assessments levied on the member communities. In 1972, the MBTA Advisory Board followed popular negative reaction to the assessment's growth by refusing to authorize a supplemental budget submitted by the MBTA to cover year-end cost of service increases. The ensuing crisis was avoided by the temporary suspension of the Advisory Board's power to veto the MBTA budget and by appointment of a special Executive Legislative Recess Commission to consider revised formulae for funding the deficit. Service increases will lead to deficit increases and further public opposition unless and until the legislature resolves the problem.

An additional problem to improving the transit system is the labor situation in the MBTA. Currently, MBTA disputes are subject to compulsory arbitration, which is binding on labor and management.

2. Legal Obstacles

There are apparently no significant legal obstacles to improving transit systems in the Boston area. Legislation is needed to create a more coordinated transportation management agency. In addition, legislation which would assure funding of the MBTA deficit beyond one year (e.g., five years), has been proposed.

3. Political/Social Obstacles

Political/Social obstacles stem largely from the institutional sources mentioned above. Political opposition to financing the MBTA deficit is strong, coming primarily from areas not served by the system, but also from member communities objecting to increased assessments.

4. Economic Obstacles

This is the principal obstacle to improving the MBTA system. The long-range (up to 20 years) transit program proposed by the Governor on November 30 is shown in Table V-1.

Implementation of this improvement program would require substantial state and federal funding assistance. Total funds in the Governor's proposed long-range transportation program are shown in Table V-2.

It is the Governor's view that the projects and programs described above are eligible for Federal assistance under the Urban Mass Transportation Administration's capital and technical studies grant programs. This must be further studied in light of the present scarcity of UMTA funding and possible changes in the program, such as increased overall levels of funding and changes in the amount of the Federal share, which is presently two-thirds of the total.

TABLE V-1

COST OF RECOMMENDED TRANSIT INVESTMENTS (Millions of Dollars)*[24]

PROJECT	Low Estimate	High Estimate	EXPLANATION OF RANGE
1. Modernization Projects Authorized Under 1971 Bond Issue.	243	243	---
2. Modernization Projects for Rapid Transit and Bus Service in Addition to Those Authorized Under the 1971 Bond Issue.	250	250	---
3. Commuter Rail Modernization.	70	70	---
4. Red Line Extension from Harvard Square to Alewife or Arlington Heights.	112	200	Remaining issues: should there be stations at Porter Square, Davis Square, and Arlington Heights? how much deep bore construction, as opposed to cut and cover?
5. Relocated Orange Line from South Cove via Forest Hills to both Needham and Canton.	172	240	Should the section from Ruggles Street to Forest Hills be on the existing Penn Central embankment or be depressed?
6. Replacement Service for the Washington Street El through the South End, Roxbury and Dorchester to Mattapan.	106	274	How much of the system should be underground?
7. Inner Circumferential Transit Line.	112	254	Which rapid transit technology should be used? how much of the system should be underground?
8. Blue Line Improvements in East Boston and Revere.	10	10	---
9. Red Line Extension from Quincy Center to South Quincy.	10	10	---
10. Green Line Extension from Lechmere to Somerville (under study).	26	26	---
TOTALS:	1,111	1,577	

* These figures do not include the cost of the bus/truck tunnel to Logan Airport ($200 million) or the cost of parking facilities and access roads at transit stations that will be constructed by the Department of Public Works (roughly, $100 million).

TABLE V-2

MAJOR CAPITAL PROJECTS [24]

HIGHWAY FUNDS*	Recommended	Under Study	TRANSIT FUNDS*	Recommended
NORTH SHORE				
Beverly-Salem-Peabody Connector	25		Blue Line Upgrading	10
Route 1 Upgrade	18			
Revere Beach Connector	20			
Wonderland Parking	5			
NORTHWEST				
Arterial Improvements to be determined pending completion of BTPR Northwest Study.			Red Line Extension from **Harvard to Alewife or Arlington Heights	112-200
			**Green Line Extension in Somerville(under study)	26
SOUTHWEST				
Arterial Street Improvements	20		Relocated Orange Line	
			Back Bay to Forest Hills	72-140
			Forest Hills to Needham	40
			Forest Hills to Canton	60
			Replacement Corridor to Mattapan	106-274
SOUTHEAST				
Access and Parking to Red Line	17		Red Line Extension to South Quincy	10
CORE/REGIONAL				
Bus Tunnel	200		Circumferential Transit	112-254
Central Artery Improvements	20	200	Commuter Rail Improvement Program	70
Fringe Parking Program	100		Plant and Equipment Modernization	493
TOTALS:	$425	$200		***$1,111-$1,577

* All costs in 1972 dollars.

** Preliminary figures subject to final Northwest Study results.

***Possible future additions to this program include:(1)extension of Red Line from Arlington Hts. to Rte. 128,(2)A rail connection between North and South Stations,(3)commuter rail right-of-way acquisitions.

D. PARKING POLICIES AND ROAD PRICING

This approach to controlling vehicular movements includes various methods of discouraging auto travel into and within the inner city. Among the methods are parking regulations, parking price increases (taxes), regulating road use (e.g., forced car pooling), and pricing road use.

1. Institutional Obstacles

The first two items above (regulating parking supply and pricing parking) appear to present fewer institutional obstacles than the others. In general, it may be noted that both state and local governing bodies have extensive powers relating to parking policy. If anything is lacking, it is coordination, which could be achieved through the Executive Office of Transportation and Construction or the agency given responsibility for overall transportation coordination. This would, however, require legislation.

Opposition of citizens to regulation and pricing of road use may be great in comparison to parking policy opposition. There may also be legal problems as indicated below.

2. Legal Obstacles

Following is a fairly detailed analysis of legal factors (obstacles and possibilities) that will affect the feasibility of parking and road user policies. This discussion is excerpted from work done under the Boston Transportation Planning Review.

a. Parking

Various state and local jurisdictions may have some legal authority and influence over the development of metropolitan parking policies. What follows is basically a summary listing of those jurisdictions and their capabilities with respect to the control of parking supply and pricing.

(1) On-Street Parking - Cities and towns generally have the authority to regulate "carriages and vehicles" used within the locality. This regulatory capability includes the power to prohibit parking at designated places along ways within the control of the municipality, and to establish penalties for violations of parking regulations not exceeding $20.00 for each violation. Also, municipalities may establish parking meters along ways and set meter fees at rate levels; however, the revenue cannot exceed expenses incurred by the locality for the acquisition, maintenance and operation of parking meters and the regulation of parking and other related traffic activities.

In the City of Cambridge, this basic, on-street parking regulatory power is vested in the City's Department of Traffic and Parking. In Boston, the City's Traffic and Parking Commission is given this general authority.

However, all such parking and traffic regulations are subject to the approval of the Massachusetts Department of Public Works, which also may revoke its approval once given. Further, the Department of Public Works has principal authority to regulate traffic and parking on all state highways and main ways leading from town to town, including limited access and express state highways. No municipality may regulate parking or traffic on state ways without the approval of the Department of Public Works.

(2) Off-Street Parking - Cities and towns generally, once having installed parking meters, may acquire off-street parking areas and facilities by eminent domain as well as by purchase, gift, etc. With respect to the rates charged at such municipally owned facilities, any city or town already having installed parking meters may install parking meters or other devices for control in minicipally owned parking lots, and may use the receipts for the purchase and/or construction of additional parking lots, maintenance, and traffic control or safety programs. It appears that the municipalities authorized to construct and own off-street parking lots have considerable flexibility in charging rates for those parking areas in accord with a high-rate policy as well as with the more traditional cost-based, low rate policy. However, it should be noted that the power of municipalities to institute a high-rate policy has not been determined by a Massachusetts court.

In the cities of Cambridge and Boston, special legislation has been enacted with respect to municipal off-street facilities. In Boston, the Real Property Board is vested with general responsibility for the establishment of off-street parking facilities. The role of the Commissioner of Traffic and Parking is that of approving site location and facility plans. The Real Property Board also is subject to the approval of the Mayor regarding municipal parking facility acquisition and construction. The Board has no authority to operate municipal parking facilities and thus has no direct control over rates charged at those facilities. It may lease the garages to private operators and may specify in the lease agreements schedules of maximum rates to be charged by the lessee, regulations as to use, etc.

In Cambridge, legislation was enacted in 1970 which created a City Parking Fund (drawn principally from parking meter revenues) from which the City intends to acquire and/or construct municipally-owned parking facilities. The City Manager has been vested with general responsibility for this new facility program and has the authority to set rates at new facilities acquired. However, facility construction would also be financed through bonds amortized over a period no longer than 20 years. Thus, rate constraints may be created as a result of bond trust agreements covering the construction of the new facilities. Also, legislation provides that fees charged at the new facilities must be just and equitable although not uniform throughout the system, and shall take into account the primary purpose of relieving traffic congestion and encouraging free circulation of traffic throughout the city. It is also provided that when adequate parking facilities for the accommodation of traffic have been provided and paid for, fees and charges for the use of any parking system or systems shall be adjusted to provide funds for maintenance and operation only. Long-range parking policy planning in Cambridge should thus take this present mandate into account. The City of Cambridge already owns several municipal parking lots which, under long standing administrative practice, have been under the control of the Department of Traffic and Parking; however, the Cambridge Parking Facilities Act provides that the City Manager shall have jurisdiction and control over the City's parking system. It would thus appear that the City Manager and his planning advisors in the Planning Department are important to the implementation of a coherent rates policy with respect to municipally owned parking areas and facilities. With respect to provate parking supply, the City of Cambridge presently has few privately owned and operated parking facilities.

In Boston, there are a large number of private open-air lots. They are subject to the narrow regulatory control of the Boston Traffic and Parking Commission which licenses such lots. At present, the Commission exercises no control over rates set at such lots and has not power to do so under its present mandate. The development of parking supply and the charging of prices for such supply by private owners is subject to control in Boston, if at all, only through the land use control processes on-going under the Boston Redevelopment Authority, including the zoning process.

At the state level, the Department of Public Works has authority to lease land over, under or adjacent to state highways for public parking facilities, subject to approval by the Governor. Presumably, the Department of Public Works may control rates policies at such facilities through its lease agreements. Also, the 1972 Accelerated Highway Act empowers the Department of Public Works to construct parking facilities and, by implication, to control rates at those facilities. This authorization becomes increasingly significant in light of amendments to the Federal-Air Highway Act allowing federal funding for parking facilities under the fringe and corridor parking facilities program and the urban highway public transportation program. This combination of federal and state authorization for parking facility construction provides a substantial basis for the implementation of a fringe parking program with suitable rates policies for the Route 128 metropolitan area.

The Massachusetts Bay Transportation Authority (MBTA) is also clearly authorized to construct and also to operate public parking facilities in conjunction with its public transportation stations and terminals. There are no locational constraints on such facilities as long as they are reasonably related to the MBTA's program. The significant issues involve means of financing actions undertaken by the Authority in general, as well as the specific concern of parking construction.

Similarly, the Massachusetts Port Authority presently has authorization to construct parking facilities in relation to port and airport projects over which it has jurisdiction under its present enabling legislation. The Massachusetts Turnpike Authority may also construct parking facilities utilizing air rights over the Turnpike or excess land. Both Authorities may, by implication, exercise controls over rates charged at such public facilities, subject to any constraints caused by trust agreements under bond financing arrangements.

Finally, the Massachusetts Parking Authority operates the Boston Common Garage and consists of three members: two appointed by the Governor of Massachusetts and one by the Mayor of Boston. Its general grant of powers includes the power to fix and revise from time to time, and charge and collect fees for parking at the Boston Common Garage. However, the garage is financed with revenue bonds pursuant to which the Authority has entered into a trust agreement which likely specifies in influences rates policies. The Authority is expressly exempted from taxation, although that term probably means only property tax exemption. Upon payment of all obligations incurred with respect to construction of the Boston Common Garage, it is to be turned over to the Boston Real Property Board.

Given the number of state and local jurisdictions which do or may influence parking policies, it is apparent that some type or coordination must occur, particularly in the absence of new legislation giving a single entity control over metropolitan parking policy (an unlikely and possibly undesirable event). One office which presently exists and may be a prime candidate for such coordination is the Executive Office of Transportation and Construction.

Also, as a method of influencing parking pricing, especially in the metropolitan core, the possible implementation of a Boston municipal parking excise tax has been suggested. Legal analysis performed to date indicates that the City of Boston, if it so desires, may enact such a tax for its jurisdiction but only via enabling legislation from the state legislature. There is only a marginal possibility that the courts would condone a unilateral effort to enact such an excise tax on a part of a locality under the Home Rule provisions of the 1966 Amendment to the Massachusetts Constitution. However, given the possibility of such an excise with special legislation from the General Court, the central issues do and should focus on the policy merits of such an excise in terms of its social and economic effects. The General Court apparently does have ample authority to authorize the City of Boston to levy an excise on parking.

(3) Regulating Road Use - Cities and towns may regulate such items as speed, parking, and types of vehicles permitted on public ways; however, this power is significantly limited with respect to certain highways.

The Department of Public Works is given primary authority to install, maintain and regulate signs, lights, signal systems, traffic devices, parking meters, pavement markings, etc., on state highways, on ways leading thereto, and on all main highways between cities and towns. Cities and towns retain authority to enact ordinances, regulations and bylaws concerning the above items but such regulations must be approved in writing by the Department of Public Works. In actual practice, such approval is normally given as a matter of course, provided the proposed regulation or device complies with the Department of Public Works manual on uniform traffic control devices; however, the Department is empowered to disapprove proposed and existing parking regulations if judged necessary.

One section of Massachusetts law tends to limit the power of local jurisdictions to regulate motor vehicles and and the use of public ways by motor vehicles, and provides that entities (cities, towns, Department of Public Works) may, on ways within their control, promulgate regulations on the use of those ways. Such regulations are valid only when they have been published and certified by the Department of Public Works as to consistency with the public interest. Moreover, no regulation shall be valid if it:

- excludes motor vehicles from any state highway;
- excludes motor vehicles of less than five tons from any main highway leading from one town to another;
- excludes motor vehicles of five tons or more from such main highways unless the regulation describes a reasonable alternate route.

With respect to the "reasonable alternate route" provision, the Department of Public Works normally requires that the alternate route be located entirely in the same city or town as the restricted route; however, where both municipalities agree, the Department has in the past approved an alternate route located in the second municipality. The General Court could, by special act, further expand or limit the powers of cities and towns to regulate motor vehicles and the use of motor vehicles.

The strategy of pricing road use may be most suitable for those routes which are heavily used by core commutation traffic. However, many such major arteries and expressways in the Boston area, e.g., Route 1 (U.S. 1), Brighton Avenue (U.S. 20) and Memorial Drive - Alewife Brook Parkway (U.S. 3), are federally assisted facilities.

The Federal Aid Highway Act (Section 301, Title 23, U.S.C.) provides:

> "....Except as provided in Section 129 of this title with respect to certain toll bridges and toll tunnels, all highways constructed under the provisions of this title shall be free from tolls of all kinds...."

There are a number of specific exceptions to and qualifications of this section; however, these exceptions apply in circumstances of improvements to existing toll facilities or construction of new toll facilities. There is no explicit mention of what will occur if a state, once having built a federally assisted facility, applies tolls or other pricing mechanism to the road. The question of application of tolls to existing non-toll, federally assisted facilities must be examined in detail.

3. Political/Social Obstacles

There have been no stated positions taken by political leaders in the Boston area on these strategies. It is likely that they will consider public reaction which may be expected to be weakly negative to parking policies and strongly negative to road use regulation.

4. Economic Obstacles

Increased parking costs may reduce total receipts, which in turn would create concern among holders of parking facility bonds. Further, restrictions on auto access may contribute to economic decline of the Boston central business district which must compete with suburban shopping centers and office parks offering free parking and easy access via expressways.

VI. SURVEILLANCE REVIEW PROCESS

This section describes a schedule for implementation and surveillance of the recommended transportation control strategy program.

A. IMPLEMENTATION SCHEDULE

An implementation schedule, based on the assumption that the proposed strategies described in Chapter III will have the calculated effect on the 1977 air quality problem, is shown in Figure VI-1. The material in this section was prepared prior to Governor Sargent's "Policy Statement on Transportation in the Boston Region" on November 30, 1972. This report did not incorporate relevant changes based on that statement.

Implementation of the program is staged to achieve the 25 percent reduction in hydrocarbon emissions in the region and to reduce carbon monoxide emissions in the three inner city hotspots so that standards will be met by 1977.

It should be noted that a "crash program" oriented toward maximum emission reductions within a minimum time period could result in a more condensed schedule. This would require in the immediate future, the nearly simultaneous undertaking of control measures at the outset of the initial improvement. However, it should also be recognized that this type of programming of emission reduction control measures would involve higher implementation costs, reduced cost/effectiveness and public acceptance problems not accounted for in the rating of strategies that accompanied the analysis in this report.

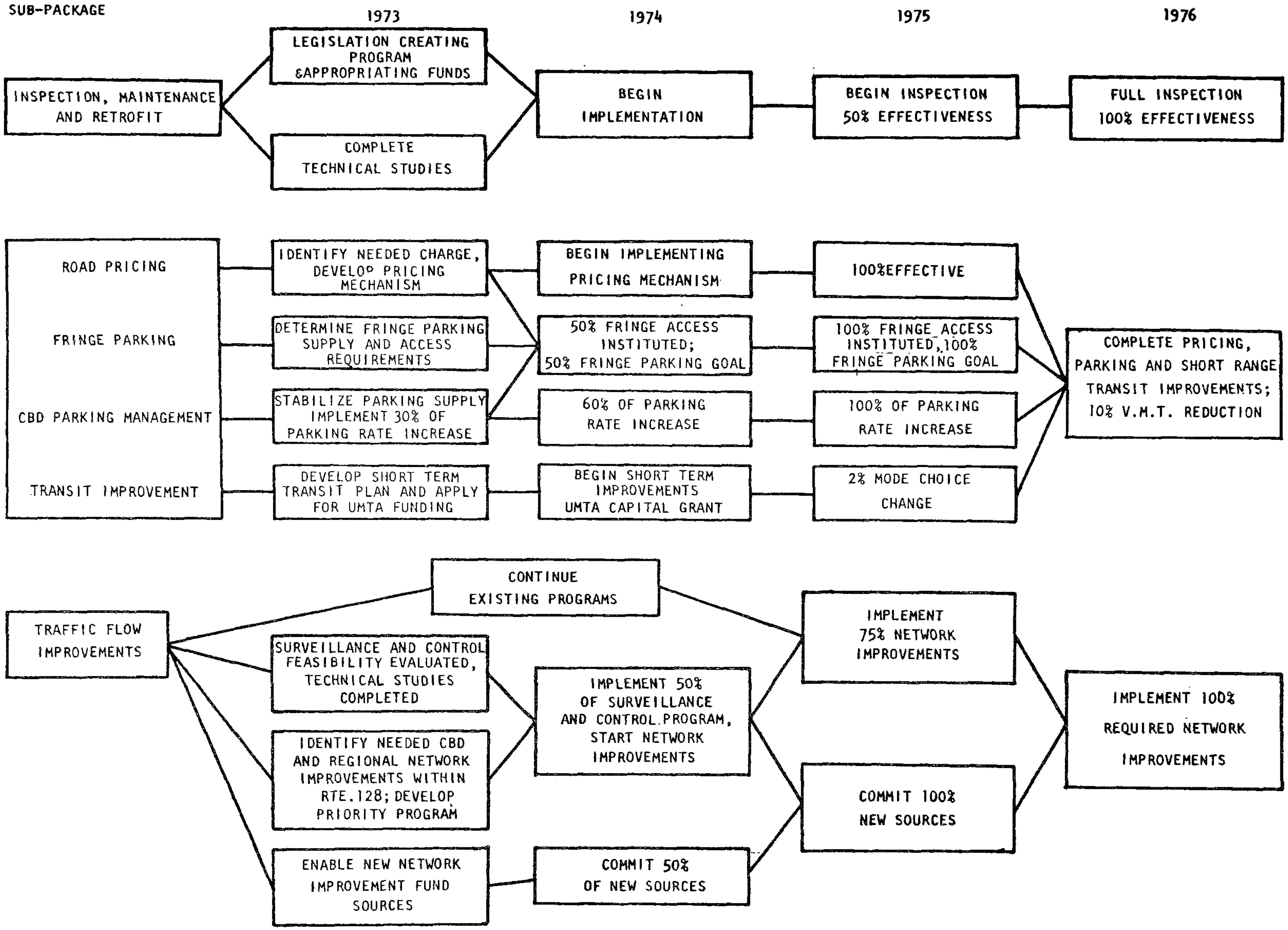


FIGURE VI-I

IMPLEMENTATION SCHEDULE FOR RECOMMENDED TRANSPORTATION CONTROL PROGRAM

The implementation schedule shown in Figure VI-1 indicates that the primary strategies included in the emissions reduction program can be grouped into three independent sub-packages, whose implementation processes are not necessarily a function of the implementation of the other measures. For example, the implementation of the traffic flow improvement strategy is not specifically related to progress on the other recommended strategies. However, the recommended strategies of CBD parking management, peripheral parking, short term mass transit improvements, and road pricing are closely related and tend to complement each other. The source control sub-package is independent of the other two in terms of implementation but since source controls are the primary component of the program package, the implementation should be closely coordinated with other sub-packages to assure that the needed reduction is achieved.

B. SURVEILLANCE PROGRAM

It is highly probable that the objectives of any emission reduction program will, by 1977, vary significantly from objectives now adopted or adopted in the near future. At least two significant factors contribute to this likelihood:

- The definition of the problem may change. As surveillance devices and techniques are improved, entirely new parameters of air quality may be defined. For example, it is expected that very localized measurements of air quality will be routine in the near future. The mere disaggregation of the geographic area considered as a single unit for the measurement of air quality will change the nature of any air quality improvement objective drastically. Thus, it is possible that air quality may eventually be defined on the basis of areas smaller than a conventional city block, rather than on the presently used zones of more than a square mile.

- The programmed activities may not occur, and activities not programmed at present may be included. Some uncertainty must be assumed along with most activities in the implementation program for Boston. These uncertainties arise primarily from the fact that the technical effectiveness of most suggested strategies is not accurately known at this point. Hence, the assumption of a certain reduction in emissions as a result of the adoption of a strategy is only an estimate at this point. In addition to uncertainties concerning technical effectiveness, there are also uncertainties involving the political feasibility of adopting any recommended measure.

As noted earlier, it is also possible that air quality improvements measures not now considered may prove to be feasible in the near future. Furthermore, it is also possible that measures not presently known or considered as emission control strategies will be developed by 1977.

In addition to continuing the surveillance of the problem definition and the effect of the control measures, the mechanics of the plan must be monitored to assure a fulfillment of the implementation schedule (Figure VI-1). It is probable that unless this is done, the entire plan will not be executed on time. The plan is divided into three sections. These are source control, traffic flow control and rapid transit improvements. So that the source control section is 100% effective by 1976, the Massachusetts Legislature must in 1973 pass legislation to create and fund the retrofit, inspection and maintainence program. Also, the supportive technical studies necessary to the program must be completed by the end of 1973. Implementation begins in 1974 and in 1975 inspection will be 50% effective. By 1976 the inspection program will be fully effective.

The section of the program to reduce travel into the City is divided into four parts. Two of these place an economic penalty on driving to the CBD while the others improve the mass transit alternative. Since this section relies on four interrelated parts, the completion of each succeeding task is dependent upon the timely completion of all preceeding tasks as detailed below. By placing a fee on all automobile travel into Bsoton, raising the parking rates and holding the supply of parking spaces constant, a decrease in traffic volume can be realized. To achieve this goal the legislature must stabilize the supply of parking spaces, determine and implement a parking rate increase in 1973. Also, the road use fee and its method of collection will have to be set by the Municipal Government. In 1974 and 1975, the road use fee and the parking rate increase will be completely implemented. The second two parts allow traffic volume to be further decreased by extending the rapid transit system and constructing inexpensive fringe parking. In order to accomplish this, the fringe parking requirements and a short term rapid transit improvement plan must be specified by the end of 1973. Also, by this time the application for the funds for the transit plan must be filed. In the 1974 to 1975 period, the transit improvements and the fringe parking facilities must be completed. The combined effect of the travel charge, the CBD parking changes, the fringe parking and the transit improvements will reduce the VMT in Boston by 10%.

The third section of the transportation control program is implementing traffic flow improvements. In 1973 the Legislature must, in addition to existing programs, complete studies on future road improvements and traffic rerouting systems, and locate sources of funds for these improvements. During the period 1974 to 1976, the results of these studies must be implemented. The proposed schedule calls for 50% completion of road improvements by the end of 1974, 75% completion by 1975 and 100% by 1976.

The results of these transportation controls are shown for CO and oxidants on Figures VI-2 and VI-3. These figures can be used to monitor the implementation progress and air quality impact by the recommended strategies.

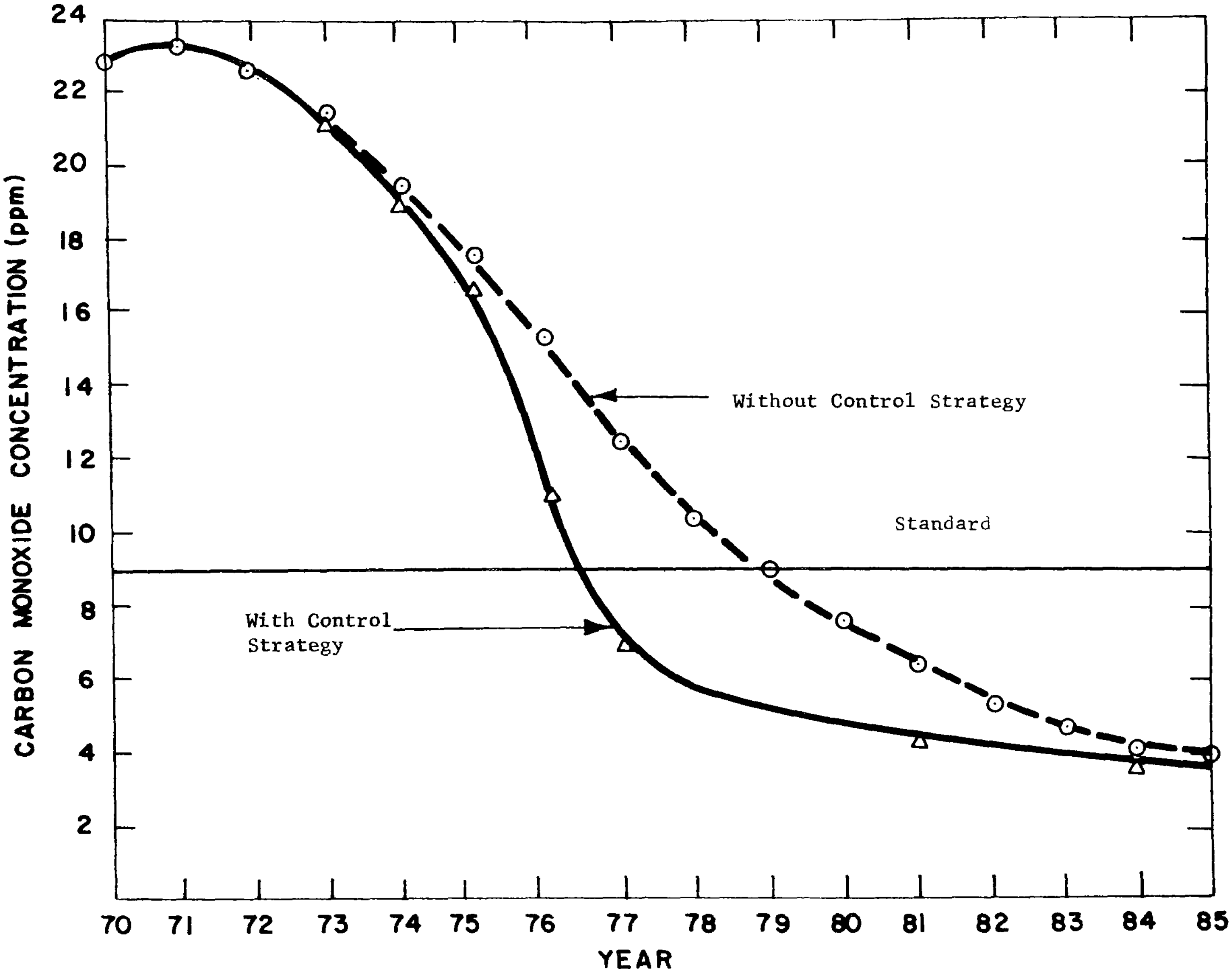


Figure VI-2. Carbon monoxide concentration estimates at Kenmore Square with and without control strategies.

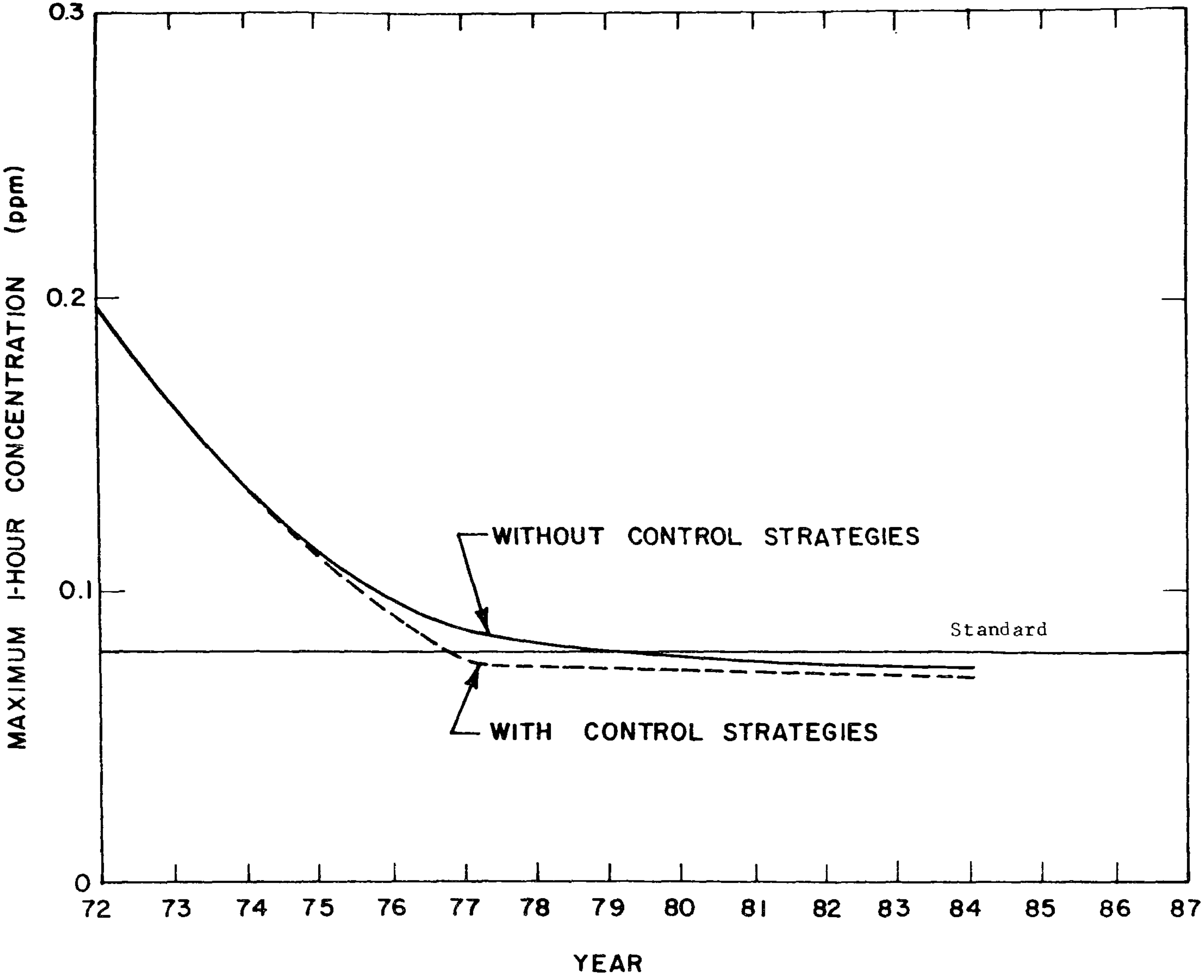


Figure VI-3. Oxidant concentration estimates within Route 128 area with and without control strategies.

List of References

1. Alan M. Voorhees & Associates, Inc., Feasibility and Evaluation Study of Reserved Lanes for Buses and Car Pools, prepared for U. S. Department of Transportation, January,1971.

2. Alan M. Voorhees & Associates, Inc., A Guide for Reducing Automotive Air Pollution, November, 1971.

3. Alan M. Voorhees & Associates, Inc., A Guide for Reducing Air Pollution Through Urban Planning, December, 1971.

4. Alan M. Voorhees & Associates, Inc., A System Sensitive Approach For Forecasting Urbanized Area Travel Demands, December, 1971.

5. Arthur D. Little, Inc., The Benefits and Risks Associated with Gaseous Fueled Vehicles, May, 1972.

6. Automobile Manufacturers Association, Inc., 1971 Motor Truck Facts.

7. Boston Redevelopment Authority, Transportation Facts for the Boston Region, 1968/1969 Edition.

8. Boston Transportation Planning Review, Regional Framework, October, 1972.

9. Burns, Robert E., "Urban Pricing Through Selective Parking Taxes", Transportation Engineering Journal, A.S.C.E., November, 1972.

10. The Conservation Foundation, A Citizen's Guide to Clean Air, January, 1972.

11. Domencich, Thomas A., Kraft, Gerald, Valette, Jean-Paul, Estimation of Urban Passenger Travel Behavior: An Economic Demand Model, Charles River Associates, Cambridge, Massachusetts.

12. EPA National Primary and Secondary Ambient Air Quality Standards, Federal Register, 36:84, April 30, 1971.

13. EPA Requirements for Preparation, Adoption, and Submittal of Implementation Plans, Federal Register, 36:158, August 14, 1971.

14. Hanna, S.R., "A Simple Method of Calculating Dispersion from Urban Area Sources," J. APCA 21, 774-777 (December 1971).

15. Gifford, F.A., "Applications of a Simple Urban Pollution Model," (paper presented at the Conference on Urban Environment and Second Conference on Biometeorology of the Amer. Meteor. Soc., October 31-November 2, 1972 Philadelphia, Pa.).

16. Highway Research Board, Highway Capacity Manual, Special Report No. 87, 1965.

17. Institute of Public Administration, Teknekron, TRW Inc., Evaluating Transportation Controls to Reduce Motor Vehicle Emissions in Major Metropolitan Areas, An Interim Report, March, 1972.

18. Institute of Traffic Engineers, Traffic Engineering Handbook, Wash., 1965.

19. Massachusetts Bay Transportation Authority, Seventh Annual Report, 1971.

20. Metropolitan Atlanta Rapid Transit Authority, "Atlanta's Reduced Transit Fare Experience," prepared for presentation of the Urban Mass Transportatio Administration UTPS User Symposium, July 27-28, 1972.

21. de Nevers, Noel, Rollback Modelling, Basic and Modified Draft Document, EPA, Durham, N.C., August, 1972.

22. Northrup Corporation, Mandatory Emission Vehicle Inspection and Maintenance Final Report, Volume 1, Summary, Anaheim, California, 1972.

23. Wilbur Smith & Associates, 1963 Boston Origin and Destination Study.

24. Governor Francis W. Sargent, "Policy Statement on Transportation in the Boston Region", November 30, 1972.

APPENDIX A

VEHICLE MILES OF TRAVEL (VMT)

The data contained in the following tables was provided as input to the emissions model. Total district VMT was estimated by facility type as described in Chapter II.C of the text. VMT by vehicle type was factored, as described in the text. It should be noted that the estimates for heavy duty vehicles (trucks) and diesel vehicles (non-gasoline) are based on regional and area factors, as real data for this level of detail is not available. These figures provide the best estimates of regional travel prorated to a district level for purposes of analysis.

APPENDIX A-1

1971 VMT

Vehicle Miles of Travel (VMT)

Metropolitan Area Boston - Inner City

Year 1971

Time Period 24-Hour

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
1-1	Freeway		0	0	0	
	Arterial	16	14,700	1,500	800	
	Collector	15	12,800	1,300	700	
	Local	15	8,100	800	450	
	TOTAL		35,600	3,600	1,950	.47
1-2	Freeway		0	0	0	
	Arterial	16	16,950	1,700	900	
	Collector	15	14,750	1,500	800	
	Local	15	9,350	1,000	500	
	TOTAL		41,050	4,200	2,200	.47
1-3	Freeway		0	0	0	
	Arterial	16	12,800	1,300	700	
	Collector	15	11,100	1,100	600	
	Local	15	7,050	700	400	
	TOTAL		30,950	3,100	1,700	.47
1-4	Freeway	30	10,000	1,000	550	
	Arterial	23	5,400	500	300	
	Collector	21	14,200	1,400	800	
	Local	15	6,850	700	400	
	TOTAL		36,450	3,600	2,050	.47
1-5	Freeway	30	15,800	1,600	900	
	Arterial	23	8,600	900	500	
	Collector	21	22,450	2,250	1,250	
	Local	15	10,850	1,100	600	
	TOTAL		57,700	5,850	3,250	.47
	Freeway	30	5,600	600	300	
	Arterial	23	3,000	300	200	
	Collector	21	7,900	800	400	
	Local	15	3,800	400	200	
	TOTAL		20,300	2,100	1,100	.47

District	Facility Type	Avg Speed (mph)	VMT			Area (sq. mi.)
			LD	HD	Diesel	
1-7	Freeway	30	7,200	700	400	
	Arterial	23	3,900	400	200	
	Collector	21	10,200	1,000	600	
	Local	15	4,900	500	300	
	TOTAL		26,200	2,600	1,500	.47
2-1	Freeway		0	0	0	
	Arterial	16	15,700	1,600	900	
	Collector	15	13,650	1,400	800	
	Local	15	8,700	900	500	
	TOTAL		38,050	3,900	2,200	.47
2-2	Freeway		0	0	0	
	Arterial	16	9,250	900	500	
	Collector	15	8,000	800	450	
	Local	15	5,100	500	300	
	TOTAL		22,350	2,200	1,250	.47
2-3	Freeway		0	0	0	
	Arterial	16	19,400	1,950	1,100	
	Collector	15	16,900	1,700	900	
	Local	15	10,700	1,100	600	
	TOTAL		47,000	4,750	2,600	.47
2-4	Freeway	19	94,000	9,400	5,200	
	Arterial	19	47,600	4,800	2,650	
	Collector	8	5,050	500	300	
	Local	7	16,300	1,600	900	
	TOTAL		162,950	16,300	9,050	.47
2-5	Freeway	20	2,100	200	100	
	Arterial	10	300	50	0	
	Collector	8	500	50	50	
	Local	7	600	50	50	
	TOTAL		3,500	350	200	.47
2-6	Freeway	30	28,650	2,900	1,600	
	Arterial	23	15,600	1,550	850	
	Collector	21	40,700	4,100	2,250	
	Local	15	19,700	1,950	1,100	
	TOTAL		104,650	10,500	5,800	.47

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
2-7	Freeway	30	8,250	800	500	
	Arterial	23	4,500	450	250	
	Collector	21	11,700	1,200	650	
	Local	15	5,700	600	300	
	TOTAL		30,150	3,050	1,700	.47
3-1	Freeway		0	0	0	
	Arterial	16	12,500	1,300	700	
	Collector	15	10,900	1,100	600	
	Local	15	6,900	700	400	
	TOTAL		30,300	3,100	1,700	.47
3-2	Freeway		0	0	0	
	Arterial	16	23,600	2,400	1,300	
	Collector	15	20,500	2,100	1,100	
	Local	15	13,000	1,300	700	
	TOTAL		57,100	5,800	3,100	.47
3-3	Freeway	26	32,500	3,300	1,800	
	Arterial	11	8,700	900	500	
	Collector	13	4,500	450	250	
	Local	10	1,400	100	100	
	TOTAL		47,100	4,750	2,650	.47
3-4	Freeway	19	44,400	4,450	2,500	
	Arterial	19	22,500	2,250	1,250	
	Collector	8	2,400	200	100	
	Local	7	7,700	800	400	
	TOTAL		77,000	7,700	4,250	.47
3-5	Freeway	20	76,800	7,700	4,300	
	Arterial	10	11,400	1,150	600	
	Collector	8	17,050	1,700	950	
	Local	7	22,900	2,300	1,300	
	TOTAL		128,150	12,850	7,150	.47
4-1	Freeway	23	6,500	650	400	
	Arterial	16	9,500	950	500	
	Collector	15	9,600	950	500	
	Local	12	4,700	450	300	
	TOTAL		30,300	3,000	1,700	.47

District	Facility Type	Avg Speed (mph)	VMT			Area (sq. mi.)
			LD	HD	Diesel	
4-2	Freeway	23	29,700	3,000	1,650	
	Arterial	16	43,350	4,350	2,400	
	Collector	15	43,750	4,400	2,400	
	Local	12	21,250	2,100	1,200	
	TOTAL		138,050	13,850	7,650	.47
4-3	Freeway	26	80,500	8,100	4,500	
	Arterial	11	21,600	2,200	1,200	
	Collector	13	11,200	1,100	600	
	Local	10	3,500	350	200	
	TOTAL		116,800	11,750	6,500	.47
4-4	Freeway	27	45,100	4,500	2,500	
	Arterial	13	21,700	2,200	1,200	
	Collector	13	22,300	2,200	1,200	
	Local	7	11,800	1,200	700	
	TOTAL		100,900	10,100	5,600	.47
4-5	Freeway	20	43,400	4,350	2,400	
	Arterial	10	6,450	650	400	
	Collector	8	9,600	950	500	
	Local	7	13,000	1,300	700	
	TOTAL		72,450	7,250	4,000	.47
5-1	Freeway	23	3,600	3,550	200	
	Arterial	16	5,200	5,200	300	
	Collector	15	5,200	5,250	300	
	Local	12	2,550	2,550	100	
	TOTAL		16,550	16,550	900	.47
5-2	Freeway	23	12,200	1,200	700	
	Arterial	16	17,850	1,800	1,000	
	Collector	15	18,000	1,800	1,000	
	Local	12	8,750	900	500	
	TOTAL		56,800	5,700	3,200	.47
5-3	Freeway	23	12,750	1,300	700	
	Arterial	16	18,600	1,900	1,000	
	Collector	15	18,800	1,900	1,050	
	Local	12	9,100	900	500	
	TOTAL		59,250	6,000	3,250	.47

Boston Inner City 1971

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
5-4	Freeway	27	47,700	4,800	2,700	
	Arterial	13	22,900	2,300	1,300	
	Collector	13	23,600	2,400	1,300	
	Local	7	12,500	1,250	700	
	TOTAL		106,700	22,000	6,000	.47
5-5	Freeway	23	5,350	500	300	
	Arterial	16	7,800	800	450	
	Collector	5	7,900	800	450	
	Local	12	3,800	400	200	
	TOTAL		24,850	2,500	1,400	.47
5-6	Freeway	23	2,800	300	150	
	Arterial	16	4,100	400	250	
	Collector	15	4,100	400	250	
	Local	12	2,000	200	100	
	TOTAL		13,000	1,300	750	.47
6-1	Freeway	25	20,300	2,000	1,100	
	Arterial	16	13,500	1,400	750	
	Collector	17	18,400	1,850	1,000	
	Local	17	8,700	900	500	
	TOTAL		60,900	6,150	3,350	.47
6-2	Freeway	23	10,300	1,050	600	
	Arterial	16	15,000	1,500	800	
	Collector	15	15,100	1,500	800	
	Local	12	7,350	750	400	
	TOTAL		47,750	4,800	2,600	.47
6-3	Freeway	23	12,500	1,300	700	
	Arterial	16	18,300	1,800	1,000	
	Collector	15	18,450	1,850	1,000	
	Local	12	8,950	900	500	
	TOTAL		58,200	5,850	3,200	.47
6-4	Freeway	23	17,950	1,800	1,000	
	Arterial	16	26,250	2,600	1,500	
	Collector	15	26,500	2,700	1,500	
	Local	12	12,850	1,300	700	
	TOTAL		83,550	8,400	4,700	.47

District	Facility Type	Avg Speed (mph)	VMT			Area (sq. mi.)
			LD	HD	Diesel	
6-5	Freeway	23	5,400	500	300	
	Arterial	16	7,900	800	400	
	Collector	15	8,000	800	450	
	Local	12	3,900	400	200	
	TOTAL		25,200	2,500	1,350	.47
6-6	Freeway	23	2,300	250	100	
	Arterial	16	3,400	350	200	
	Collector	15	3,400	350	200	
	Local	12	1,700	150	100	
	TOTAL		10,800	1,100	600	.47
7-1	Freeway	25	13,250	1,300	700	
	Arterial	16	8,800	900	500	
	Collector	17	12,000	1,200	700	
	Local	17	5,700	600	300	
	TOTAL		39,750	4,000	2,200	.47
7-2	Freeway	25	12,500	1,250	700	
	Arterial	16	8,300	850	500	
	Collector	17	11,350	1,150	600	
	Local	17	5,400	550	300	
	TOTAL		37,550	3,800	2,100	.47
7-3	Freeway	25	10,650	1,050	600	
	Arterial	16	7,100	700	400	
	Collector	17	9,650	950	550	
	Local	17	4,600	450	250	
	TOTAL		32,000	3,150	1,800	.47
7-4	Freeway	25	5,800	600	300	
	Arterial	16	3,800	400	200	
	Collector	17	5,200	500	300	
	Local	17	2,500	250	150	
	TOTAL		17,300	1,750	950	.47
7-5	Freeway	25	31,600	3,150	1,750	
	Arterial	16	21,050	2,100	1,150	
	Collector	17	28,650	2,900	1,600	
	Local	17	13,550	1,350	750	
	TOTAL		94,850	9,500	5,250	.47

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
	Freeway Arterial Collector Local		TOTAL	TOTAL	TOTAL	VMT TOTAL For All Vehicle Types
	TOTAL		2,240,050	251,300	124,450	2,615,800
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					

Vehicle Miles of Travel (VMT)

Metropolitan Area Boston - Inner Suburb

Year 1971

Time Period 24-Hour

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
1-1	Freeway		0	0	0	
	Arterial	40	9,950	1,000	550	
	Collector	30	52,300	5,250	2,900	
	Local	20	18,700	1,900	1,050	
	TOTAL		80,950	8,150	4,500	3.47
1-2	Freeway		0	0	0	
	Arterial	40	77,250	7,750	4,300	
	Collector	30	36,200	3,650	2,000	
	Local	20	34,050	3,400	1,900	
	TOTAL		147,500	14,800	8,200	3.47
1-3	Freeway		0	0	0	
	Arterial	40	32,900	3,300	1,850	
	Collector	30	54,950	5,500	3,050	
	Local	20	26,400	2,650	1,450	
	TOTAL		114,250	11,450	6,350	3.47
2-1	Freeway		0	0	0	
	Arterial	40	67,350	6,750	3,750	
	Collector	30	39,450	3,950	2,200	
	Local	20	32,100	3,200	1,800	
	TOTAL		138,900	13,900	7,750	3.47
2-2	Freeway	50	81,750	8,200	4,550	
	Arterial	40	129,500	13,000	7,200	
	Collector	30	61,200	6,150	3,400	
	Local	20	81,350	8,150	4,550	
	TOTAL		353,800	35,500	19,700	3.47
2-3	Freeway		0	0	0	
	Arterial	40	44,050	4,400	2,450	
	Collector	30	58,550	5,900	3,250	
	Local	20	30,800	3,100	1,700	
	TOTAL		133,400	13,400	7,400	3.47

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
2-4	Freeway	50	158,400	15,900	8,850	
	Arterial	40	54,450	5,450	3,050	
	Collector	30	10,150	1,000	550	
	Local	20	66,600	6,700	3,700	
	TOTAL		289,600	29,050	16,150	3.47
2-5	Freeway		0	0	0	
	Arterial	40	100,400	10,100	5,600	
	Collector	30	31,550	3,150	1,750	
	Local	20	39,400	3,950	2,200	
	TOTAL		171,350	17,200	9,550	3.47
3-1	Freeway		0	0	0	
	Arterial		0	0	0	
	Collector	30	37,300	3,700	2,100	
	Local	20	11,200	1,100	600	
	TOTAL		48,500	4,800	2,700	3.47
3-2	Freeway		0	0	0	
	Arterial	40	109,850	11,000	6,100	
	Collector	30	44,000	4,400	2,450	
	Local	20	46,250	4,600	2,600	
	TOTAL		200,100	20,000	11,150	3.47
3-3	Freeway		0	0	0	
	Arterial	40	19,200	1,900	1,050	
	Collector	30	84,900	8,500	4,700	
	Local	20	31,300	3,100	1,750	
	TOTAL		135,400	13,500	7,500	2.15
3-4	Freeway		0	0	0	
	Arterial	40	26,400	2,650	1,450	
	Collector	30	17,600	1,800	1,000	
	Local	20	13,250	1,300	750	
	TOTAL		57,250	5,750	3,200	2.15
3-5	Freeway	50	52,850	5,300	2,950	
	Arterial	40	40,900	4,100	2,300	
	Collector	30	37,800	3,800	2,100	
	Local	20	39,500	3,950	2,200	
	TOTAL		171,050	17,150	9,550	2.15

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
3-6	Freeway		0	0	0	
	Arterial	40	9,300	950	500	
	Collector	30	55,900	5,600	3,100	
	Local	20	19,600	1,950	1,100	
	TOTAL		84,800	8,500	4,700	3.47
4-1	Freeway	50	89,700	9,000	5,000	
	Arterial		0	0	0	
	Collector	30	83,200	8,350	4,650	
	Local	20	51,950	5,200	2,900	
	TOTAL		224,850	22,550	12,550	3.47
4-2	Freeway	50	98,500	9,900	5,500	
	Arterial	40	25,500	2,550	1,400	
	Collector	30	48,150	4,800	2,700	
	Local	20	51,750	5,200	2,900	
	TOTAL		223,900	22,450	12,500	3.47
4-3	Freeway		0	0	0	
	Arterial		0	0	0	
	Collector	30	16,150	1,600	900	
	Local	20	4,850	500	250	
	TOTAL		21,000	2,100	1,150	3.47
5-1	Freeway		0	0	0	
	Arterial	40	57,100	5,750	3,200	
	Collector	30	30,600	3,050	1,700	
	Local	20	26,500	2,650	1,500	
	TOTAL		114,200	11,450	6,400	3.47
5-2	Freeway		0	0	0	
	Arterial	40	57,250	5,750	3,200	
	Collector	30	36,750	3,700	2,050	
	Local	20	28,050	2,800	1,550	
	TOTAL		122,050	12,250	6,800	3.47
6-1A	Freeway		0	0	0	
	Arterial	40	29,000	2,900	1,600	
	Collector	30	19,400	1,950	1,100	
	Local	20	14,550	1,450	800	
	TOTAL		62,950	6,300	3,500	3.47

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
6-1	Freeway		0	0	0	
	Arterial	40	89,500	9,000	5,000	
	Collector	30	3,900	400	200	
	Local	20	28,050	2,800	1,550	
	TOTAL		121,450	12,200	6,750	3.47
6-2	Freeway		0	0	0	
	Arterial	40	23,400	2,350	1,300	
	Collector	30	51,200	5,150	2,850	
	Local	20	22,550	2,250	1,250	
	TOTAL		97,150	9,750	5,400	3.47
6-3	Freeway	50	177,600	17,800	9,900	
	Arterial	40	44,400	4,450	2,500	
	Collector	30	46,850	4,700	2,600	
	Local	20	80,750	8,100	4,500	
	TOTAL		349,600	35,050	19,500	3.47
	Freeway					
	Arterial					
	Collector					
	Local					
	TOTAL					
	Freeway					
	Arterial					
	Collector					
	Local					
	TOTAL					
	Freeway					
	Arterial					
	Collector					
	Local					
	TOTAL					
	Freeway Arterial Collector Local		TOTAL	TOTAL	TOTAL	VMT Total For All Vehicle Types
	TOTAL		3,464,000	347,250	192,950	4,004,200

Vehicle Miles of Travel (VMT)

Metropolitan Area Boston - Outer Suburb

Year 1971

Time Period 24-Hour

District	Facility Type	Avg Speed (mph)	VMT			Area (sq. mi.)
			LD	HD	Diesel	
1-1	Freeway	50	281,200	28,200	14,450	
	Arterial	40	19,600	1,950	1,000	
	Collector	30	44,650	4,500	2,300	
	Local	20	105,300	10,550	5,400	
	TOTAL		450,750	45,200	23,150	7.53
1-2	Freeway		0	0	0	
	Arterial		0	0	0	
	Collector	30	97,050	9,750	5,400	
	Local	20	29,150	2,950	1,600	
	TOTAL		126,200	12,700	7,000	10.42
1-3	Freeway	50	174,400	12,500	9,700	
	Arterial		0	0	0	
	Collector	30	52,050	5,200	2,900	
	Local	20	67,650	6,800	3,750	
	TOTAL		294,100	29,500	16,350	10.62
1-4	Freeway		0	0	0	
	Arterial	40	163,400	16,400	9,100	
	Collector	30	61,100	6,100	3,400	
	Local	20	67,400	6,750	3,750	
	TOTAL		291,900	29,250	16,250	10.62
1-5	Freeway		0	0	0	
	Arterial		0	0	0	
	Collector	30	116,350	11,650	6,500	
	Local	20	34,950	3,500	1,950	
	TOTAL		151,300	15,150	8,450	10.62
2-1	Freeway	50	213,400	21,400	11,900	
	Arterial	40	140,500	14,100	7,800	
	Collector	30	90,800	9,100	5,050	
	Local	20	133,600	13,400	7,450	
	TOTAL		578,300	58,000	32,200	15.251

District	Facility Type	Avg Speed (mph)	VMT			Area (sq. mi.)
			LD	HD	Diesel	
2-2	Freeway		0	0	0	
	Arterial	40	42,900	4,300	2,400	
	Collector	30	12,550	1,250	700	
	Local	20	16,650	1,650	900	
	TOTAL		72,100	7,200	4,000	4.63
2-3	Freeway	50	106,600	10,700	5,950	
	Arterial	40	34,050	3,400	1,900	
	Collector	30	7,300	750	400	
	Local	20	44,450	4,450	2,450	
	TOTAL		192,400	19,300	10,700	6.95
3-1	Freeway	50	316,250	31,750	17,600	
	Arterial		0	0	0	
	Collector	30	135,800	13,650	7,550	
	Local	20	135,800	13,650	7,550	
	TOTAL		587,850	59,050	32,700	11.89
4-1	Freeway	50	338,000	33,900	18,850	
	Arterial	40	92,850	9,300	5,150	
	Collector	30	82,150	8,250	4,600	
	Local	20	155,000	15,550	8,650	
	TOTAL		668,000	67,000	37,250	9.19
5-1	Freeway	50	102,100	10,250	5,700	
	Arterial		0	0	0	
	Collector		0	0	0	
	Local	20	30,650	3,100	1,700	
	TOTAL		132,750	13,350	7,400	2.05
6-1	Freeway	50	227,700	22,850	12,700	
	Arterial	40	139,450	14,000	7,800	
	Collector	30	70,600	7,100	3,950	
	Local	20	131,500	13,200	7,350	
	TOTAL		569,250	57,150	31,800	8.49
6-2	Freeway		0	0	0	
	Arterial	40	23,900	2,400	1,350	
	Collector	30	74,500	7,450	4,150	
	Local	20	29,400	2,950	1,650	
	TOTAL		127,800	12,800	7,150	9.65

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
6-3	Freeway	50	236,850	23,750	13,200	
	Arterial	40	62,800	6,400	3,550	
	Collector	30	33,000	3,300	1,850	
	Local	20	98,950	9,950	5,500	
	TOTAL		431,600	43,400	24,100	9.65
6-4	Freeway		0	0	0	
	Arterial	40	44,800	4,500	2,500	
	Collector	30	47,550	4,750	2,650	
	Local	20	27,750	2,800	1,550	
	TOTAL		120,100	12,050	6,700	5.79
7-1	Freeway	50	235,300	23,600	13,100	
	Arterial	40	63,300	6,350	3,550	
	Collector	30	7,550	750	400	
	Local	20	91,950	9,250	5,100	
	TOTAL		398,100	39,950	22,150	3.01
7-2	Freeway	50	255,850	25,700	14,250	
	Arterial		0	0	0	
	Collector	30	31,750	3,200	1,750	
	Local	20	85,900	8,600	4,800	
	TOTAL		373,500	37,500	20,800	8.49
7-3	Freeway	50	270,000	27,100	15,050	
	Arterial		0	0	0	
	Collector	30	36,250	3,650	2,000	
	Local	20	92,000	9,250	5,100	
	TOTAL		398,250	40,000	22,150	8.19
7-4	Freeway	50	427,950	42,950	23,850	
	Arterial		0	0	0	
	Collector	30	28,500	2,850	1,600	
	Local	20	137,100	13,750	7,650	
	TOTAL		593,550	59,550	33,100	4.83
7-5	Freeway	50	254,450	25,550	14,200	
	Arterial		0	0	0	
	Collector	30	121,850	12,250	6,800	
	Local	20	113,050	11,350	6,300	
	TOTAL		489,350	49,150	27,300	3.78

Boston - Outer Suburb - 1971 - 24-Hour

District	Facility Type	Avg Speed (mph)	VMT			Area (sq. mi.)
			LD	HD	Diesel	
	Freeway Arterial Collector Local		TOTAL	TOTAL	TOTAL	VMT TOTAL for all Vehicle Types
	TOTAL		7,047,150	707,250	390,700	8,145,100
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					

APPENDIX A-2

1977 VMT WITHOUT TRANSPORTATION CONTROL STRATEGIES

Vehicle Miles of Travel (VMT)

Metropolitan Area Boston - Inner City

Year 1977

Time Period 24-Hour

Grid	Facility Type	Avg Speed (mph)	VMT			Area (sq. mi.)
			LD	HD	Diesel	
1-1	Freeway	34	10,150	1,000	600	
	Arterial	15	9,050	900	500	
	Collector	16	8,200	850	450	
	Local	15	6,550	650	350	
	TOTAL		33,950	3,400	1,900	.47
1-2	Freeway	34	8,700	900	500	
	Arterial	15	7,800	800	450	
	Collector	16	7,050	700	400	
	Local	15	5,600	550	300	
	TOTAL		29,150	2,950	1,650	.47
1-3	Freeway	34	11,050	1,100	600	
	Arterial	15	9,900	1,000	550	
	Collector	16	8,950	900	500	
	Local	15	7,100	700	400	
	TOTAL		37,000	3,700	2,050	.47
1-4	Freeway	29	23,900	2,400	1,350	
	Arterial	23	10,000	1,000	550	
	Collector	21	27,850	2,800	1,550	
	Local	17	12,750	1,300	700	
	TOTAL		74,500	7,500	4,150	.47
1-5	Freeway	29	18,950	1,900	1,050	
	Arterial	23	7,900	800	450	
	Collector	21	22,050	2,200	1,250	
	Local	17	10,100	1,000	550	
	TOTAL		59,000	5,900	3,300	.47
1-6	Freeway	29	6,400	650	350	
	Arterial	23	2,650	250	150	
	Collector	21	7,450	750	400	
	Local	17	3,400	350	200	
	TOTAL		19,900	2,000	1,100	.47

	Facility Type	Avg Speed (mph)	VMT			Area (sq. mi.)
			LD	HD	Diesel	
1-7	Freeway	29	8,200	800	450	
	Arterial	23	3,400	350	200	
	Collector	21	9,500	950	500	
	Local	17	4,350	450	250	
	TOTAL		25,450	2,550	1,400	.47
2-1	Freeway	34	11,150	1,100	650	
	Arterial	15	9,950	1,000	550	
	Collector	16	9,050	900	500	
	Local	15	7,150	750	400	
	TOTAL		37,300	3,750	2,100	.47
2-2	Freeway	34	6,200	650	400	
	Arterial	15	5,550	550	300	
	Collector	16	5,050	500	300	
	Local	15	4,000	400	150	
	TOTAL		20,800	2,100	1,150	.47
2-3	Freeway	34	9,300	950	550	
	Arterial	15	8,350	850	450	
	Collector	16	7,550	750	400	
	Local	15	6,000	600	350	
	TOTAL		31,200	3,150	1,750	.47
2-4	Freeway	25	157,800	15,850	8,800	
	Arterial	25	38,750	3,900	2,150	
	Collector	9	6,200	600	350	
	Local	8	18,600	1,850	1,050	
	TOTAL		221,350	22,200	12,350	.47
2-5	Freeway	21	1,950	200	100	
	Arterial	10	200			
	Collector	9	300	50		
	Local	8	450	50	50	
	TOTAL		2,900	300	150	.47
2-6	Freeway	29	44,800	4,500	2,500	
	Arterial	23	18,700	1,900	1,050	
	Collector	21	52,200	5,200	2,900	
	Local	17	23,850	2,400	1,350	
	TOTAL		139,550	14,000	7,800	.47

Boston - Inner City - 1977

District	Facility Type	Avg Speed (mph)	VMT			Area (sq. mi.)
			LD	HD	Diesel	
2-7	Freeway	29	14,050	1,400	800	
	Arterial	23	5,850	600	350	
	Collector	21	16,400	1,650	900	
	Local	17	7,500	750	400	
	TOTAL		43,800	4,400	2,450	.47
3-1	Freeway	34	10,000	1,000	550	
	Arterial	15	8,950	900	500	
	Collector	16	8,100	800	450	
	Local	15	6,400	650	350	
	TOTAL		33,450	3,350	1,850	
3-2	Freeway	34	17,450	1,750	950	
	Arterial	15	15,550	1,550	850	
	Collector	16	14,100	1,400	800	
	Local	15	11,200	1,150	650	
	TOTAL		58,300	5,850	3,250	.47
3-3	Freeway	32	35,500	3,550	1,950	
	Arterial	10	6,850	700	400	
	Collector	16	5,000	500	300	
	Local	8	1,200	100	50	
	TOTAL		48,550	4,850	2,700	.47
3-4	Freeway	25	62,500	6,250	3,500	
	Arterial	25	15,350	1,550	850	
	Collector	9	2,450	250	150	
	Local	8	7,350	750	400	
	TOTAL		87,650	8,800	4,900	.47
3-5	Freeway	21	111,550	11,200	6,200	
	Arterial	10	10,350	1,050	600	
	Collector	9	17,450	1,750	950	
	Local	8	25,150	2,500	1,400	
	TOTAL		164,500	16,500	9,150	.47
4-1	Freeway	28	8,050	800	450	
	Arterial	18	10,500	1,050	600	
	Collector	14	10,000	1,000	500	
	Local	13	4,900	500	300	
	TOTAL		33,450	3,350	1,850	.47

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
4-2	Freeway	28	36,300	3,650	2,000	
	Arterial	18	47,350	4,700	2,600	
	Collector	14	45,100	4,500	2,500	
	Local	13	22,300	2,300	1,300	
	TOTAL		151,050	15,150	8,400	.47
4-3	Freeway	32	94,550	9,500	5,250	
	Arterial	10	18,250	1,850	1,000	
	Collector	16	13,300	1,350	750	
	Local	8	3,250	300	200	
	TOTAL		129,350	13,000	7,200	.47
4-4	Freeway	26	55,900	5,600	3,100	
	Arterial	14	23,600	2,350	1,300	
	Collector	14	23,000	2,300	1,300	
	Local	8	12,000	1,200	650	
	TOTAL		114,500	11,450	6,350	.47
4-5	Freeway	21	56,350	5,650	3,150	
	Arterial	10	5,250	500	300	
	Collector	9	8,800	900	500	
	Local	8	12,700	1,300	700	
	TOTAL		83,100	8,350	4,650	.47
5-1	Freeway	28	4,400	450	250	
	Arterial	18	5,700	550	300	
	Collector	14	5,450	550	300	
	Local	13	2,700	250	150	
	TOTAL		18,250	1,800	1,000	.47
5-2	Freeway	28	14,250	1,450	800	
	Arterial	18	18,550	1,850	1,000	
	Collector	14	17,650	1,750	1,000	
	Local	13	8,750	850	500	
	TOTAL		59,200	5,900	3,300	.47
5-3	Freeway	28	13,500	1,350	750	
	Arterial	18	17,600	1,750	1,000	
	Collector	14	16,750	1,650	950	
	Local	13	8,300	850	450	
	TOTAL		56,150	5,600	3,150	.47

District	Facility Type	Avg Speed (mph)	VMT			Area (sq. mi.)
			LD	HD	Diesel	
5-4	Freeway	26	57,850	5,800	3,200	
	Arterial	14	24,400	2,450	1,350	
	Collector	14	23,850	2,400	1,350	
	Local	8	12,450	1,250	700	
	TOTAL		118,550	11,900	6,600	.47
5-5	Freeway	28	6,300	650	350	
	Arterial	18	8,200	800	450	
	Collector	14	7,850	800	450	
	Local	13	3,850	400	200	
	TOTAL		26,200	2,650	1,450	.47
5-6	Freeway	28	3,350	350	200	
	Arterial	18	4,400	450	250	
	Collector	14	4,150	400	250	
	Local	13	2,050	200	100	
	TOTAL		13,950	1,400	800	.47
6-1	Freeway	25	24,500	2,450	1,350	
	Arterial	19	13,200	1,300	750	
	Collector	17	18,300	1,850	1,000	
	Local	15	8,450	850	500	
	TOTAL		64,450	6,450	3,600	.47
6-2	Freeway	28	12,800	1,300	700	
	Arterial	18	16,650	1,600	900	
	Collector	14	15,850	1,600	900	
	Local	13	7,850	800	450	
	TOTAL		53,150	5,300	2,950	.47
6-3	Freeway	28	11,850	1,200	650	
	Arterial	18	15,450	1,550	850	
	Collector	14	14,700	1,450	850	
	Local	13	7,300	750	400	
	TOTAL		49,300	4,950	2,750	.47
6-4	Freeway	28	22,850	2,300	1,250	
	Arterial	18	29,800	3,000	1,650	
	Collector	14	28,400	2,850	1,600	
	Local	13	14,050	1,400	800	
	TOTAL		95,100	9,550	5,300	.47

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
6-5	Freeway	28	6,600	650	350	
	Arterial	18	8,650	850	500	
	Collector	14	8,200	800	450	
	Local	13	4,050	450	200	
	TOTAL		27,500	2,750	1,500	.47
6-6	Freeway	28	2,700	250	150	
	Arterial	18	3,500	350	200	
	Collector	14	3,300	350	200	
	Local	13	1,650	150	100	
	TOTAL		11,150	1,100	650	.47
7-1	Freeway	25	19,250	1,900	1,050	
	Arterial	19	10,350	1,050	600	
	Collector	17	14,350	1,450	800	
	Local	15	6,600	650	350	
	TOTAL		50,550	5,050	2,800	.47
7-2	Freeway	25	14,000	1,450	800	
	Arterial	19	7,550	750	400	
	Collector	17	10,500	1,050	600	
	Local	15	4,850	450	250	
	TOTAL		36,900	3,700	2,050	.47
7-3	Freeway	25	12,550	1,250	700	
	Arterial	19	6,750	650	400	
	Collector	17	9,350	950	500	
	Local	15	4,350	450	250	
	TOTAL		33,000	3,300	1,850	.47
7-4	Freeway	25	7,350	750	400	
	Arterial	19	3,950	400	200	
	Collector	17	5,550	550	300	
	Local	15	2,550	250	150	
	TOTAL		19,400	1,950	1,050	.47
7-5	Freeway	25	41,700	4,200	2,300	
	Arterial	19	22,500	2,250	1,250	
	Collector	17	31,150	3,100	1,750	
	Local	15	14,350	1,450	800	
	TOTAL		109,700	11,000	[illegible],100	.47

BOSTON - Inner City - 1977

District	Facility Type	Avg Speed (mph)	VMT			Area (sq. mi.)
			LD	HD	Diesel	
	Freeway Arterial Collector Local		TOTAL	TOTAL	TOTAL	VMT TOTAL For All Vehicle Types
	TOTAL		2,522,250	252,900	140,500	2,915,650
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					

Vehicle Miles of Travel (VMT)

Metropolitan Area Boston - Inner Suburb

Year 1977

Time Period 24-Hour

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
1-1	Freeway		0	0	0	
	Arterial	40	10,950	1,100	600	
	Collector	30	57,600	5,800	3,200	
	Local	20	20,600	2,050	1,150	
	TOTAL		89,150	8,950	4,950	3.47
1-2	Freeway		0	0	0	
	Arterial	40	85,050	8,550	4,750	
	Collector	30	39,800	4,000	2,200	
	Local	20	37,500	3,750	2,100	
	TOTAL		162,350	16,300	9,050	3.47
1-3	Freeway		0	0	0	
	Arterial	40	36,250	3,650	2,000	
	Collector	30	60,550	6,100	3,400	
	Local	20	29,050	2,900	1,600	
	TOTAL		125,850	12,650	7,000	3.47
2-1	Freeway		0	0	0	
	Arterial	40	74,150	7,450	4,150	
	Collector	30	43,400	4,350	2,900	
	Local	20	35,300	3,550	1,950	
	TOTAL		152,850	15,350	9,000	3.47
2-2	Freeway	50	90,000	9,050	5,000	
	Arterial	40	142,600	14,300	7,950	
	Collector	30	67,400	6,750	3,650	
	Local	20	89,600	9,000	5,000	
	TOTAL		389,600	39,100	21,600	3.47
2-3	Freeway		0	0	0	
	Arterial	40	48,500	4,850	2,700	
	Collector	30	64,500	6,450	3,600	
	Local	20	33,950	3,400	1,900	
	TOTAL		146,950	14,700	8,200	3.47

Boston - Inner Suburb - 1977 24-Hour

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
2-4	Freeway	50	174,450	17,500	9,700	
	Arterial	40	59,950	6,000	3,350	
	Collector	30	11,150	1,100	600	
	Local	20	73,350	7,350	4,100	
	TOTAL		318,900	31,950	17,750	3.47
2-5	Freeway		0	0	0	
	Arterial	40	110,550	11,100	6,150	
	Collector	30	34,700	3,500	1,950	
	Local	20	43,400	4,350	2,400	
	TOTAL		188,650	18,950	10,500	3.47
3-1	Freeway		0	0	0	
	Arterial		0	0	0	
	Collector	30	41,100	4,100	2,300	
	Local	20	12,350	1,250	700	
	TOTAL		53,450	5,350	3,000	3.47
3-2	Freeway		0	0	0	
	Arterial	40	120,950	12,150	6,750	
	Collector	30	48,500	4,850	2,700	
	Local	20	50,900	5,100	2,850	
	TOTAL		220,350	22,100	12,300	3.47
3-3	Freeway		0	0	0	
	Arterial	40	21,150	2,100	1,200	
	Collector	30	93,500	9,400	5,200	
	Local	20	34,450	3,450	1,900	
	TOTAL		149,100	14,950	8,300	2.15
3-4	Freeway		0	0	0	
	Arterial	40	29,050	2,900	1,600	
	Collector	30	19,400	1,950	1,100	
	Local	20	14,550	1,450	800	
	TOTAL		63,000	6,300	3,500	2.15
3-5	Freeway	50	58,200	5,850	3,250	
	Arterial	40	45,050	4,500	2,500	
	Collector	30	41,650	4,200	2,300	
	Local	20	43,500	4,350	2,450	
	TOTAL		188,400	18,900	10,500	2.15

District	Facility Type	Avg Speed (mph)	VMT			Area (sq. mi.)
			LD	HD	Diesel	
3-6	Freeway		0	0.	0	
	Arterial	40	10,250	1,050	550	
	Collector	30	61,550	6,200	3,450	
	Local	20	21,600	2,150	1,200	
	TOTAL		93,400	9,400	5,200	3.47
4-1	Freeway	50	98,800	9,900	5,500	
	Arterial		0	0	0	
	Collector	30	91,600	9,200	5,100	
	Local	20	57,200	5,750	3,200	
	TOTAL		247,600	24,850	13,800	3.47
4-2	Freeway	50	108,500	10,900	6,050	
	Arterial	40	28,100	2,800	1,550	
	Collector	30	53,000	5,300	2,950	
	Local	20	56,950	5,700	3,150	
	TOTAL		246,550	24,700	13,700	3.47
4-3	Freeway		0	0	0	
	Arterial		0	0	0	
	Collector	30	17,750	1,800	1,000	
	Local	20	5,350	550	300	
	TOTAL		23,100	2,350	1,300	3.47
5-1	Freeway		0	0	0	
	Arterial	40	62,850	6,300	3,500	
	Collector	30	33,700	3,400	1,900	
	Local	20	29,150	2,950	1,650	
	TOTAL		125,700	12,650	7,050	3.47
5-2	Freeway		0	0	0	
	Arterial	40	63,050	6,300	3,500	
	Collector	30	40,450	4,050	2,250	
	Local	20	30,900	3,100	1,700	
	TOTAL		134,400	13,450	7,450	3.47
6-1A	Freeway		0	0	0	
	Arterial	40	31,950	3,200	1,800	
	Collector	30	21,350	2,150	1,200	
	Local	20	16,000	1,600	900	
	TOTAL		69,300	6,950	3,900	3.47

Boston Inner Suburb 1977 - 24-Hour

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
6-1	Freeway		0	0	0	
	Arterial	40	98,550	9,900	5,500	
	Collector	30	4,300	450	250	
	Local	20	30,900	3,100	1,700	
	TOTAL		133,750	13,450	7,450	3.47
6-2	Freeway		0	0	0	
	Arterial	40	25,750	2,600	1,450	
	Collector	30	56,350	5,650	3,150	
	Local	20	24,800	2,500	1,400	
	TOTAL		106,900	10,750	6,000	3.47
6-3	Freeway	50	195,550	19,600	10,900	
	Arterial	40	48,900	4,900	2,700	
	Collector	30	51,600	5,200	2,900	
	Local	20	88,950	8,900	4,950	
	TOTAL		385,000	38,600	21,450	3.47
	Freeway					
	Arterial					
	Collector					
	Local					
	TOTAL					
	Freeway					
	Arterial					
	Collector					
	Local					
	TOTAL					
	Freeway					
	Arterial					
	Collector					
	Local					
	TOTAL					
	Freeway Arterial Collector Local		TOTAL	TOTAL	TOTAL	TOTAL VMT All Vehicle Types
	TOTAL		3,814,300	382,700	212,950	4,409,950

Vehicle Miles of Travel (VMT)

Metropolitan Area Boston - Outer Suburb

Year 1977

Time Period 24-hour

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
1-1	Freeway	50	339,850	34,050	18,950	
	Arterial	40	23,700	2,400	1,300	
	Collector	30	54,000	5,400	3,000	
	Local	20	127,250	12,750	7,100	
	TOTAL		544,800	54,600	30,350	7.53
1-2	Freeway		0	0	0	
	Arterial		0	0	0	
	Collector	30	117,150	11,750	6,550	
	Local	20	35,200	3,550	1,950	
	TOTAL		152,350	15,300	8,500	10.42
1-3	Freeway	50	210,500	21,100	11,750	
	Arterial		0	0	0	
	Collector	30	62,800	6,300	3,500	
	Local	20	81,650	8,200	4,550	
	TOTAL		354,950	35,600	19,800	10.62
1-4	Freeway		0	0	0	
	Arterial	40	197,250	19,800	11,000	
	Collector	30	73,600	7,400	4,100	
	Local	20	81,350	8,150	4,550	
	TOTAL		352,200	35,350	19,650	10.62
1-5	Freeway		0	0	0	
	Arterial		0	0	0	
	Collector	30	140,400	14,100	7,800	
	Local	20	42,200	4,250	2,350	
	TOTAL		182,600	18,350	10,150	10.62
2-1	Freeway	50	257,550	25,850	14,350	
	Arterial	40	169,600	17,000	9,450	
	Collector	30	109,600	11,000	6,100	
	Local	20	161,200	16,200	9,000	
	TOTAL		697,950	70,050	38,900	15.251

Boston Outer Suburb - 1977

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
2-2	Freeway		0	0	0	
	Arterial	40	51,800	5,200	2,900	
	Collector	30	15,150	1,500	850	
	Local	20	20,100	2,000	1,100	
	TOTAL		87,050	8,700	4,850	4.63
2-3	Freeway	50	128,550	12,900	7,150	
	Arterial	40	41,050	4,100	2,300	
	Collector	30	8,800	900	500	
	Local	20	53,600	5,400	3,000	
	TOTAL		232,000	23,300	12,950	6.95
3-1	Freeway	50	381,650	38,300	21,250	
	Arterial		0	0	0	
	Collector	30	163,850	16,450	9,150	
	Local	20	163,850	16,450	9,150	
	TOTAL		709,350	71,200	39,550	11.89
4-1	Freeway	50	407,950	40,950	22,750	
	Arterial	40	112,050	11,250	6,250	
	Collector	30	99,150	9,950	5,550	
	Local	20	187,050	18,750	10,400	
	TOTAL		806,200	80,900	44,950	9.19
5-1	Freeway	50	123,250	12,350	6,850	
	Arterial		0	0	0	
	Collector		0	0	0	
	Local	20	37,000	3,700	2,050	
	TOTAL		160,250	16,050	8,900	2.05
6-1	Freeway	50	274,800	27,600	15,300	
	Arterial	40	168,300	16,900	9,400	
	Collector	30	85,200	8,550	4,750	
	Local	20	158,700	15,950	8,850	
	TOTAL		687,000	69,000	38,300	8.49
6-2	Freeway		0	0	0	
	Arterial	40	28,850	2,900	1,600	
	Collector	30	89,900	9,000	5,000	
	Local	20	35,450	3,550	2,000	
	TOTAL		154,200	15,450	8,600	9.65

District	Facility Type	Avg Speed (mph)	VMT			Area (sq. mi.)
			LD	HD	Diesel	
6-3	Freeway	50	286, 300	28, 750	15, 950	
	Arterial	40	77, 150	7, 750	4, 300	
	Collector	30	39, 850	4, 000	2, 200	
	Local	20	119, 600	12, 000	6, 650	
	TOTAL		622, 900	52, 500	29, 100	9. 65
6-4	Freeway		0	0	0	
	Arterial	40	54, 050	5, 450	3, 000	
	Collector	30	57, 400	5, 750	3, 200	
	Local	20	33, 500	3, 350	1, 850	
	TOTAL		144, 950	14, 550	8, 050	5. 79
7-1	Freeway	50	283, 950	28, 500	15, 800	
	Arterial	40	76, 400	7, 650	4, 250	
	Collector	30	9, 150	900	500	
	Local	20	111, 000	11, 150	6, 200	
	TOTAL		480, 500	48, 200	26, 750	3. 01
7-2	Freeway	50	308, 800	31, 000	17, 200	
	Arterial		0	0	0	
	Collector	30	38, 300	3, 850	2, 150	
	Local	20	103, 700	10, 400	5, 800	
	TOTAL		450, 800	45, 250	25, 150	8. 49
7-3	Freeway	50	325, 850	32, 700	18, 150	
	Arterial		0	0	0	
	Collector	30	43, 750	4, 400	2, 450	
	Local	20	111, 050	11, 150	6, 200	
	TOTAL		480, 650	48, 250	26, 800	8. 19
7-4	Freeway	50	516, 500	51, 850	28, 800	
	Arterial		0	0	0	
	Collector	30	34, 400	3, 450	1, 900	
	Local	20	165, 500	16, 600	9, 200	
	TOTAL		716, 400	71, 900	39, 900	4. 83
	Freeway	50	307, 100	30, 800	17, 100	
	Arterial		0	0	0	
	Collector	30	147, 050	14, 750	8, 200	
	Local	20	136, 450	13, 700	7, 600	
	TOTAL		590, 600	59, 250	32, 900	3. 78

Boston - Outer Suburb - 1977

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
	Freeway Arterial Collector Local		TOTAL	TOTAL	TOTAL	VMT TOTAL For All Vehicle Types
	TOTAL		8,607,700	853,750	474,100	9,935,550
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					

APPENDIX A-3

1977 VMT WITH TRANSPORTATION

CONTROL STRATEGIES

REVISED

Vehicle Miles of Travel (VMT)

Metropolitan Area Boston - Inner City

Year 1977

Time Period 24-Hour

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
1-1	Freeway	34.7	8802	NO CHANGE	NO CHANGE	NO CHANGE
	Arterial	15.3	7848			
	Collector	16.3	7111			
	Local	15.3	5680			
	TOTAL		29441			
1-2	Freeway	34.7	7545			
	Arterial	15.3	6764			
	Collector	16.3	6114			
	Local	15.3	4856			
	TOTAL		25279			
1-3	Freeway	34.7	9583			
	Arterial	15.3	8585			
	Collector	16.3	7761			
	Local	15.3	6157			
	TOTAL		32086			
1-4	Freeway	29.6	20726			
	Arterial	23.5	8772			
	Collector	21.4	24151			
	Local	17.3	11057			
	TOTAL		64706			
1-5	Freeway	29.6	16433			
	Arterial	23.5	6851			
	Collector	21.4	19122			
	Local	17.3	8759			
	TOTAL		51165			
1-6	Freeway	29.6	5550			
	Arterial	23.5	2298			
	Collector	21.4	6461			
	Local	17.3	2948			
	TOTAL		17257			

District	Facility Type	Avg Speed (mph)	VMT			Area (sq. mi.)
			LD	HD	Diesel	
1-7	Freeway	29.6	7112			
	Arterial	23.5	2948			
	Collector	21.4	8238			
	Local	17.3	3772			
	TOTAL		22070			
2-1	Freeway	34.7	9669			
	Arterial	15.3	8629			
	Collector	16.3	7849			
	Local	15.3	6200			
	TOTAL		32347			
2-2	Freeway	34.7	5377			
	Arterial	15.3	4813			
	Collector	16.3	4378			
	Local	15.3	3469			
	TOTAL		18037			
2-3	Freeway	34.7	8065			
	Arterial	15.3	7242			
	Collector	16.3	6547			
	Local	15.3	5203			
	TOTAL		27057			
2-4	Freeway	25.5	136844			
	Arterial	25.5	33604			
	Collector	9.2	5377			
	Local	8.2	16130			
	TOTAL		191955			
2-5	Freeway	21.4	1692			
	Arterial	10.2	173			
	Collector	9.2	260			
	Local	8.2	390			
	TOTAL		2515			
2-6	Freeway	29.6	38851			
	Arterial	23.5	16217			
	Collector	21.4	45268			
	Local	17.3	20682			
	TOTAL		121018			

District	Facility Type	Avg Speed (mph)	VMT			Area (sq. mi.)
			LD	HD	Diesel	
2-7	Freeway	29.6	12184			
	Arterial	23.5	5073			
	Collector	21.4	14222			
	Local	17.3	6504			
	TOTAL		37983			
3-1	Freeway	34.7	8672			
	Arterial	15.3	7762			
	Collector	16.3	7024			
	Local	15.3	5550			
	TOTAL		29008			
3-2	Freeway	34.7	15133			
	Arterial	15.3	13484			
	Collector	16.3	12228			
	Local	15.3	9713			
	TOTAL		50558			
3-3	Freeway	32.6	30786			
	Arterial	10.3	5940			
	Collector	16.3	4336			
	Local	8.2	1041			
	TOTAL		42103			
3-4	Freeway	25.5	54200			
	Arterial	25.5	13311			
	Collector	9.2	2125			
	Local	8.2	6374			
	TOTAL		76010			
3-5	Freeway	21.4	96735			
	Arterial	10.2	8976			
	Collector	9.2	15133			
	Local	8.2	21810			
	TOTAL		142654			
4-1	Freeway	28.6	6981			
	Arterial	18.4	9106			
	Collector	14.3	8672			
	Local	13.3	4249			
	TOTAL		29008			

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
4-2	Freeway	28.6	31479			
	Arterial	18.4	41062			
	Collector	14.3	39111			
	Local	13.3	19339			
	TOTAL		130991			
4-3	Freeway	32.6	81994			
	Arterial	10.2	15826			
	Collector	16.3	11554			
	Local	8.2	2818			
	TOTAL		112192			
4-4	Freeway	26.5	48476			
	Arterial	14.3	20466			
	Collector	14.3	19946			
	Local	8.2	10406			
	TOTAL		99294			
4-5	Freeway	21.4	48867			
	Arterial	10.2	4553			
	Collector	9.2	7631			
	Local	8.2	11013			
	TOTAL		72064			
5-1	Freeway	28.6	3816			
	Arterial	18.4	4943			
	Collector	14.3	4726			
	Local	13.3	2341			
	TOTAL		15826			
5-2	Freeway	28.6	12358			
	Arterial	18.4	16086			
	Collector	14.3	15306			
	Local	13.3	7588			
	TOTAL		51338			
5-3	Freeway	28.6	11706			
	Arterial	18.4	15263			
	Collector	14.3	14526			
	Local	13.3	7198			
	TOTAL		48693			

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
5-4	Freeway	26.5	50167			
	Arterial	14.3	21160			
	Collector	14.3	20683			
	Local	8.2	10797			
	TOTAL		102807			
5-5	Freeway	28.6	5463			
	Arterial	18.4	7111			
	Collector	14.3	6808			
	Local	13.3	3339			
	TOTAL		22721			
5-6	Freeway	28.6	2904			
	Arterial	18.4	3816			
	Collector	14.3	3599			
	Local	13.3	1778			
	TOTAL		12097			
6-1	Freeway	28.6	21246			
	Arterial	19.4	11447			
	Collector	17.3	15870			
	Local	15.3	7328			
	TOTAL		55891			
6-2	Freeway	28.6	11100			
	Arterial	18.4	14439			
	Collector	14.3	13745			
	Local	13.3	6808			
	TOTAL		46092			
6-3	Freeway	28.6	10276			
	Arterial	18.4	13398			
	Collector	14.3	12748			
	Local	13.3	6331			
	TOTAL		42753			
6-4	Freeway	28.6	19816			
	Arterial	18.4	25843			
	Collector	14.3	24628			
	Local	13.3	12184			
	TOTAL		82471			

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
6-5	Freeway	28.6	5724			
	Arterial	18.4	7501			
	Collector	14.3	7111			
	Local	13.3	3512			
	TOTAL		23848			
6-6	Freeway	28.6	2341			
	Arterial	18.4	3035			
	Collector	14.3	2862			
	Local	13.3	1431			
	TOTAL		9669			
7-1	Freeway	25.5	16694			
	Arterial	19.4	8976			
	Collector	17.3	12444			
	Local	15.3	5724			
	TOTAL		43838			
7-2	Freeway	25.5	12141			
	Arterial	19.4	6547			
	Collector	17.3	9106			
	Local	15.3	4206			
	TOTAL		32000			
7-3	Freeway	25.5	10884			
	Arterial	19.4	5854			
	Collector	17.3	8108			
	Local	15.3	3772			
	TOTAL		28618			
7-4	Freeway	25.5	6375			
	Arterial	19.4	3425			
	Collector	17.3	4813			
	Local	15.3	2211			
	TOTAL		16824			
7-5	Freeway	25.5	36163			
	Arterial	19.4	19512			
	Collector	17.3	27013			
	Local	15.3	12444			
	TOTAL		95132			

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
	Freeway Arterial Collector Local		TOTAL	TOTAL	TOTAL	VMT TOTAL FOR ALL VEHICLES
	TOTAL		2,187,416	252,900	140,500	2,580,816
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					
	Freeway Arterial Collector Local					
	TOTAL					

REVISED

Vehicle Miles of Travel (VMT)

Metropolitan Area Boston - Inner Suburb

Year 1977

Time Period 24-Hour

District	Facility Type	Avg Speed (mph)	VMT			Area (sq. mi.)
			LD	HD	Diesel	
1-1	Freeway		0			
	Arterial	40.8	10467			
	Collector	30.6	55054			
	Local	20.4	19689			
	TOTAL		85210			
1-2	Freeway		0			
	Arterial	40.8	81291			
	Collector	30.6	38041			
	Local	20.4	35842			
	TOTAL		155174			
1-3	Freeway		0			
	Arterial	40.8	34647			
	Collector	30.6	57874			
	Local	20.4	27766			
	TOTAL		120287			
2-1	Freeway		0			
	Arterial	40.8	70873			
	Collector	30.6	41482			
	Local	20.4	33740			
	TOTAL		146095			
2-2	Freeway	51.0	86022			
	Arterial	40.8	136297			
	Collector	30.6	64421			
	Local	20.4	85640			
	TOTAL		372380			
2-3	Freeway		0			
	Arterial	40.8	46357			
	Collector	30.6	61649			
	Local	20.4	32449			
	TOTAL		140455			

District	Facility Type	Avg Speed (mph)	VMT			Area (sq. mi.)
			LD	HD	Diesel	
2-4	Freeway	51.0	166739			
	Arterial	40.8	57301			
	Collector	30.6	10657			
	Local	20.4	70108			
	TOTAL		304805			
2-5	Freeway		0			
	Arterial	40.8	105664			
	Collector	30.6	33166			
	Local	20.4	41482			
	TOTAL		180312			
3-1	Freeway		0			
	Arterial		0			
	Collector	30.6	39284			
	Local	20.4	11804			
	TOTAL		51088			
3-2	Freeway		0			
	Arterial	40.8	115604			
	Collector	30.6	46356			
	Local	20.4	48650			
	TOTAL		210610			
3-3	Freeway		0			
	Arterial	40.8	20216			
	Collector	30.6	89367			
	Local	20.4	32927			
	TOTAL		142510			
3-4	Freeway		0			
	Arterial	40.8	27765			
	Collector	30.6	18543			
	Local	20.4	13907			
	TOTAL		60215			
3-5	Freeway	51.0	55628			
	Arterial	40.8	43059			
	Collector	30.6	39809			
	Local	20.4	41577			
	TOTAL		180073			

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
3-6	Freeway		0			
	Arterial	40.8	9798			
	Collector	30.6	58829			
	Local	20.4	20645			
	TOTAL		89272			
4-1	Freeway	51.0	94433			
	Arterial		0			
	Collector	30.6	87551			
	Local	20.4	54672			
	TOTAL		236656			
4-2	Freeway	51.0	103704			
	Arterial	40.8	26858			
	Collector	30.6	50657			
	Local	20.4	54433			
	TOTAL		235652			
4-3	Freeway		0			
	Arterial		0			
	Collector	30.6	16965			
	Local	20.4	5114			
	TOTAL		22079			
5-1	Freeway		0			
	Arterial	40.8	60072			
	Collector	30.6	32210			
	Local	20.4	27862			
	TOTAL		120144			
5-2	Freeway		0			
	Arterial	40.8	60264			
	Collector	30.6	38662			
	Local	20.4	29534			
	TOTAL		128460			
6-1A	Freeway		0			
	Arterial	40.8	30538			
	Collector	30.6	20406			
	Local	20.4	15293			
	TOTAL		66237			

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
6-1	Freeway		0			
	Arterial	40.8	94194			
	Collector	30.6	4110			
	Local	20.4	29534			
	TOTAL		127838			
6-2	Freeway		0			
	Arterial	40.8	24612			
	Collector	30.6	53859			
	Local	20.4	23704			
	TOTAL		102175			
6-3	Freeway	51.0	186907			
	Arterial	40.8	46739			
	Collector	30.6	49319			
	Local	20.4	85018			
	TOTAL		367983			
	Freeway					
	Arterial					
	Collector					
	Local					
	TOTAL					
	Freeway					
	Arterial					
	Collector					
	Local					
	TOTAL					
	Freeway					
	Arterial					
	Collector					
	Local					
	TOTAL					
	Freeway					
	Arterial		TOTAL	TOTAL	TOTAL	VMT TOTAL ALL VEHICLES
	Collector					
	Local					
	TOTAL		3,645,710	382,700	212,950	4,241,360

REVISED

Vehicle Miles of Travel (VMT)

Metropolitan Area Boston - Outer Suburb

Year 1977

Time Period 24-Hour

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
1-1	Freeway	51.0	333087			
	Arterial	40.8	23228			
	Collector	30.6	52925			
	Local	20.4	124718			
	TOTAL		533958			
1-2	Freeway		0			
	Arterial		0			
	Collector	30.6	114818			
	Local	20.4	34500			
	TOTAL		149318			
1-3	Freeway	51.0	206311			
	Arterial		0			
	Collector	30.6	61550			
	Local	20.4	80025			
	TOTAL		347886			
1-4	Freeway		0			
	Arterial	40.8	193325			
	Collector	30.6	72135			
	Local	20.4	79731			
	TOTAL		345191			
1-5	Freeway		0			
	Arterial		0			
	Collector	30.6	137606			
	Local	20.4	41360			
	TOTAL		178966			
2-1	Freeway	51.0	252425			
	Arterial	40.8	166225			
	Collector	30.6	107419			
	Local	20.4	157992			
	TOTAL		684061			

District	Facility Type	Avg Speed (mph)	VMT			Area (sq. mi.)
			LD	HD	Diesel	
2-2	Freeway		0			
	Arterial	40.8	50769			
	Collector	30.6	14849			
	Local	20.4	19700			
	TOTAL		85318			
2-3	Freeway	51.0	125992			
	Arterial	40.8	40233			
	Collector	30.6	8625			
	Local	20.4	52533			
	TOTAL		227383			
3-1	Freeway	51.0	374056			
	Arterial		0			
	Collector	30.6	160589			
	Local	20.4	160589			
	TOTAL		695234			
4-1	Freeway	51.0	399832			
	Arterial	40.8	109820			
	Collector	30.6	97177			
	Local	20.4	183328			
	TOTAL		790157			
5-1	Freeway	51.0	120797			
	Arterial		0			
	Collector		0			
	Local	20.4	36264			
	TOTAL		157061			
6-1	Freeway	51.0	269331			
	Arterial	40.8	164951			
	Collector	30.6	83505			
	Local	20.4	155542			
	TOTAL		673329			
6-2	Freeway		0			
	Arterial	40.8	28275			
	Collector	30.6	88111			
	Local	20.4	34745			
	TOTAL		151131			

District	Facility Type	Avg Speed (mph)	VMT LD	VMT HD	VMT Diesel	Area (sq. mi.)
6-3	Freeway	51.0	280602			
	Arterial	40.8	75615			
	Collector	30.6	39057			
	Local	20.4	117220			
	TOTAL		512,494			
6-4	Freeway		0			
	Arterial	40.8	52974			
	Collector	30.6	56258			
	Local	20.4	32833			
	TOTAL		142065			
7-1	Freeway	51.0	278299			
	Arterial	40.8	74880			
	Collector	30.6	8968			
	Local	20.4	108791			
	TOTAL		470938			
7-2	Freeway	51.0	302655			
	Arterial		0			
	Collector	30.6	37538			
	Local	20.4	101636			
	TOTAL		441829			
7-3	Freeway	51.0	319366			
	Arterial		0			
	Collector	30.6	42879			
	Local	20.4	108840			
	TOTAL		471085			
7-4	Freeway	51.0	506222			
	Arterial		0			
	Collector	30.6	33715			
	Local	20.4	162207			
	TOTAL		702144			
	Freeway	51.0	300988			
	Arterial		0			
	Collector	30.6	144124			
	Local	20.4	133735			
	TOTAL		578847			

District	Facility Type	Avg Speed (mph)	VMT			Area (sq. mi.)
			LD	HD	Diesel	
	Freeway		TOTAL	TOTAL	TOTAL	VMT TOTAL ALL VEHICLES
	Arterial					
	Collector					
	Local					
	TOTAL		8,388,395	853,750	474,100	9,666,245
	Freeway					
	Arterial					
	Collector					
	Local					
	TOTAL					
	Freeway					
	Arterial					
	Collector					
	Local					
	TOTAL					
	Freeway					
	Arterial					
	Collector					
	Local					
	TOTAL					
	Freeway					
	Arterial					
	Collector					
	Local					
	TOTAL					
	Freeway					
	Arterial					
	Collector					
	Local					
	TOTAL					
	Freeway					
	Arterial					
	Collector					
	Local					
	TOTAL					

APPENDIX B

VEHICLE AGE DISTRIBUTION

APPENDIX B

PASSENGER CARS IN OPERATION
AS OF JULY 1, 1971

YEAR	ESSEX COUNTY	MIDDLESEX COUNTY	NORFOLK COUNTY	SUFFOLK COUNTY
1971	17,660	40,805	19,734	9,762
1970	27,880	65,136	31,314	15,553
1969	28,794	67,920	32,282	15,708
1968	30,005	67,926	31,595	15,637
1967	25,670	56,312	25,768	13,357
1966	27,467	58,245	25,981	14,668
1965	27,154	56,107	24,354	14,517
1964	22,200	44,293	19,082	11,971
1963	18,225	34,367	14,660	9,492
1962	12,922	23,837	10,029	7,319
1961	6,887	12,088	5,266	3,861
1960	4,029	7,240	3,125	2,441
1959	1,608	2,794	1,220	1,006
1958	652	1,174	587	395
1957	742	1,349	627	517
1956	626	992	512	392
Prior to 1956	1,869	3,048	1,596	1,264

Source: R. L. Polk & Company.

APPENDIX B

TRUCKS IN OPERATION
AS OF JULY 1, 1971

YEAR	ESSEX COUNTY	MIDDLESEX COUNTY	NORFOLK COUNTY	SUFFOLK COUNTY
1971	1,820	4,274	1,767	1,808
1970	2,177	5,711	2,366	2,672
1969	2,100	4,673	2,272	2,351
1968	1,823	3,796	1,880	2,042
1967	1,538	3,524	1,577	1,941
1966	1,674	3,473	1,730	1,590
1965	1,567	3,382	1,566	1,277
1964	1,455	3,024	1,248	1,124
1963	1,200	2,410	1,046	935
1962	1,026	1,993	840	916
1961	839	1,483	689	590
1960	703	1,353	630	479
1959	471	890	423	383
1958	341	656	262	263
1957	376	636	347	262
1956	401	796	317	202
Prior to 1956	1,545	2,505	1,196	731

Source: R. L. Polk & Company.

APPENDIX C

ADJUSTED VEHICLE AGE DISTRIBUTION

APPENDIX C

AGE DISTRIBUTION BY VEHICLE CLASSIFICATION

AS OF DECEMBER 31, 1971*

Age In Years	Light Duty Vehicle	Heavy Duty Vehicle
0	32,098	3,568
1	110,619	12,203
2	142,292	12,161
3	144,934	10,469
4	133,135	9,061
5	123,734	8,524
6	124,247	7,557
7	109,839	7,322
8	87,145	6,221
9	65,426	5,183
10	41,105	4,188
11	22,469	3,383
12	11,732	2,666
12+	18,396	6,802

* Adjusted from R.L. Polk Company data.

APPENDIX D

VMT CONTRIBUTION BY MODEL YEAR

APPENDIX D

PER CENT CONTRIBUTION TO VMT BY MODEL YEAR

LIGHT DUTY VEHICLES

Model Year	December 1971 Registrations	(1) Fraction Of Vehicles In Use By Model Year	(2) Average* Miles/Year	(1) x (2)	Ave. Fraction Contribution To VMT By Model Year (M)
1972	32,298	.0277	3,600	99.72	.009
1971	110,619	.0948	11,900	1128.12	.100
1970	142,293	.1219	16,100	1962.59	.175
1969	144,934	.1242	13,200	1639.44	.146
1968	133,135	.1140	11,400	1299.60	.116
1967	123,734	.1060	11,700	1240.20	.111
1966	124,247	.1064	10,000	1064.00	.095
1965	109,839	.0941	10,300	969.23	.086
1964	87,145	.0747	8,600	642.42	.057
1963	65,426	.0560	10,900	610.40	.054
1962	41,105	.0352	8,000	281.60	.025
1961	22,469	.0192	6,500	124.80	.011
1960	11,732	.0100	6,500	65.00	.006
1959	4,718	.0040	6,500	102.70	.009
1958	3,022	.0026	-----	------	----
1957	2,879	.0025	-----	------	----
1957**	7,777	.0067	-----	------	----
	1,167,372	1.0000			1.000

* Nationwide Personal Transportation Study, Annual Miles of Automobile Travel, Report No. 2: April 1972, U.S. Department of Transportation, FHWA

**Prior to 1957

APPENDIX D

PER CENT CONTRIBUTION TO VMT BY MODEL YEAR

HEAVY DUTY VEHICLES

Model Year	December 1971 Registrations	(1) Fraction Of Vehicles In Use By Model Year	(2) Average* Miles/Year	(1) x (2)	Ave. Fraction Contribution To VMT By Model Year (M)
1972	3,568	.0359	3,500	125.65	.011
1971	12,203	.1229	11,700	1437.93	.120
1970	12,161	.1225	17,200	2107.00	.176
1969	10,469	.1054	15,800	1665.32	.139
1968	9,061	.0912	15,800	1440.96	.121
1967	8,524	.0858	13,000	1115.40	.093
1966	7,557	.0761	13,000	989.30	.083
1965	7,322	.0737	11,000	810.70	.068
1964	6,221	.0626	11,000	688.60	.058
1963	5,183	.0522	9,000	469.80	.039
1962	4,188	.0422	9,000	379.80	.032
1961	3,383	.0341	5,500	187.55	.016
1960	2,666	.0268	5,500	147.40	.012
1959	6,802	.0685	5,500	376.75	.032

* Nationwide Personal Transportation Study, Annual Miles of Automobile Travel, Report No. 2: April 1972, U.S. Department of Transportation, FHWA.

APPENDIX E-1

EMISSIONS BY ZONE

FOR CARBON MONOXIDE IN 1970 IN THE

INNER CITY OF BOSTON

CITY OF BOSTON CALENDAR YEAR IS 1970

REGION NO. 5 POLLUTANT SPECIES IS CARBON MONOXIDE

MODEL YEARS CONSIDERED IS FROM 1957 TO 1970

LENGTH OF TIME PERIOD IS 24 HOURS

VEHICLE CATEGORY -		LIGHT DUTY		HEAVY DUTY		OTHER		TOTAL	
ZONE NO.	AREA (SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)
1	0.471	2890.99	6137.99	555.70	1179.84	40.49	85.97	3487.19	7403.80
2	0.471	3333.70	7077.92	640.78	1360.47	46.70	99.15	4021.18	8537.54
3	0.471	2510.16	5329.43	482.45	1024.31	35.15	74.62	3027.76	6428.36
4	0.471	3088.64	6557.62	593.65	1260.41	43.25	91.82	3725.54	7909.85
5	0.471	1818.25	3860.40	349.47	741.98	25.47	54.08	2193.19	4656.46
6	0.471	3820.42	8111.30	734.72	1559.91	53.54	113.66	4608.67	9784.86
7	0.471	2464.61	5232.71	473.74	1005.82	34.39	73.02	2972.74	6311.55
8	0.471	4643.55	9858.92	892.58	1895.07	65.03	138.06	5601.15	11892.04
9	0.471	2231.64	4738.09	428.93	910.68	41.45	88.01	2702.02	5736.77
10	0.471	3534.75	7504.78	679.46	1442.59	65.64	139.36	4279.85	9086.72
11	0.471	1250.08	2654.10	240.33	510.25	23.21	49.27	1513.61	3213.62
12	0.471	1599.74	3396.48	307.53	652.94	29.72	63.09	1936.99	4112.51
13	0.471	6403.55	13595.66	1230.84	2613.25	118.93	252.50	7753.32	16461.40
14	0.471	1843.83	3914.71	354.45	752.55	34.25	72.71	2232.53	4739.97
15	0.471	11711.96	24866.16	2251.14	4779.49	185.26	393.34	14148.36	30038.97
16	0.471	5529.35	11739.59	1062.84	2256.57	87.46	185.68	6679.64	14181.83
17	0.471	280.52	595.59	53.88	114.39	4.06	8.62	338.46	718.60
18	0.471	10043.20	21323.15	1930.38	4098.46	145.77	309.49	12119.34	25731.09
19	0.471	5677.11	12053.30	1091.11	2316.58	82.40	174.94	6850.61	14544.81
20	0.471	7559.55	16050.01	1453.06	3085.06	114.77	243.66	9127.38	19378.72
21	0.471	7990.71	16965.41	1535.85	3260.82	121.32	257.57	9647.87	20483.79
22	0.471	3146.46	6680.38	604.83	1284.14	53.64	113.88	3804.93	8078.40
23	0.471	7792.90	16545.43	1497.90	3180.25	132.87	282.10	9423.66	20007.77
24	0.471	2392.21	5079.00	459.82	976.27	34.39	73.02	2886.43	6128.29
25	0.471	10881.28	23102.51	2091.40	4440.35	157.01	333.36	13129.70	27876.21
26	0.471	1303.85	2768.25	2506.09	5320.79	18.82	39.95	3828.76	8128.99
27	0.471	4478.07	9507.57	860.78	1827.55	64.62	137.19	5403.46	11472.31
28	0.471	4673.34	9923.23	898.36	1907.36	67.43	143.17	5639.64	11973.76
29	0.471	1960.30	4162.00	376.80	799.99	28.29	60.06	2365.39	5022.05
30	0.471	1018.69	2162.83	195.80	415.70	14.70	31.20	1229.18	2609.73
31	0.471	3759.55	7982.13	722.65	1534.29	54.25	115.18	4536.48	9631.59
32	0.471	4587.38	9739.66	881.76	1872.10	66.19	140.53	5535.33	11752.29
33	0.471	6587.96	13987.18	1266.25	2688.44	95.05	201.80	7949.26	16877.41
34	0.471	1988.99	4222.91	382.23	811.53	28.70	60.93	2399.92	5095.37
35	0.471	850.26	1805.23	163.49	347.11	12.27	26.04	1026.02	2178.38
36	0.471	4224.71	8969.67	812.07	1724.14	69.23	146.99	5106.02	10840.80
37	0.471	2762.41	5865.00	530.92	1127.22	45.27	96.11	3338.61	7088.34
38	0.471	2608.34	5537.88	501.28	1064.29	42.74	90.74	3152.36	6692.91
39	0.471	2222.19	4718.02	427.10	906.80	36.41	77.31	2685.70	5702.13
40	0.471	1201.56	2551.03	230.90	490.23	19.70	41.82	1452.15	3083.13
41	0.471	6587.79	13986.81	1266.16	2688.24	107.95	229.19	7961.89	16904.23

APPENDIX E-2

EMISSIONS BY ZONE

FOR CARBON MONOXIDE IN 1977 IN THE

INNER CITY OF BOSTON WITHOUT CONTROL STRATEGY

CITY OF BOSTON CALENDAR YEAR IS 1977

REGION NO. 5 POLLUTANT SPECIES IS CARBON MONOXIDE

MODEL YEARS CONSIDERED IS FROM 1964 TO 1977

LENGTH OF TIME PERIOD IS 24 HOURS WITHOUT STRETEGY

VEHICLE CATEGORY -		LIGHT DUTY		HEAVY DUTY		OTHER		TOTAL	
ZONE NO.	AREA (SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)
1	0.471	1143.80	2428.45	339.73	721.29	38.60	81.94	1522.12	3231.68
2	0.471	982.88	2086.80	291.95	619.85	33.17	70.42	1308.00	2777.07
3	0.471	1248.13	2649.97	370.75	787.15	42.13	89.44	1661.01	3526.56
4	0.471	1256.96	2668.71	373.34	792.66	42.41	90.05	1672.72	3551.41
5	0.471	700.75	1487.79	208.17	441.96	23.66	50.22	932.57	1979.98
[illegible]	0.471	1051.70	2232.91	312.40	663.26	35.4[illegible]	75.[illegible]	1399.5[illegible]	2971.53
7	0.471	1127.79	2394.46	334.94	711.12	38.05	80.82	1500.8[illegible]	3186.40
8	0.471	1965.60	4173.25	533.80	1239.49	66.33	140.83	2615.73	5553.57
9	0.471	2153.60	4572.41	655.65	1392.04	84.74	179.92	2894.00	6144.36
10	0.471	1704.87	3619.67	519.03	1101.98	67.09	142.44	2290.98	4864.09
11	0.471	574.93	1220.65	175.03	371.61	22.61	48.01	772.57	1640.27
12	0.471	735.77	1562.14	224.05	475.68	28.94	61.45	988.75	2099.27
13	0.471	4033.91	8564.56	1228.17	2607.58	158.73	337.00	5420.80	11509.14
14	0.471	1265.32	2686.45	385.39	818.24	49.80	105.73	1700.51	3610.43
15	0.471	6446.03	13685.84	1959.98	4161.30	251.74	534.47	8657.74	18381.61
16	0.471	2544.20	5401.69	775.98	1647.51	99.65	211.60	3419.84	7260.80
17	0.471	102.94	218.56	30.34	64.42	3.27	6.93	136.55	289.91
18	0.471	5910.74	12549.34	1739.12	3692.40	187.08	397.19	7836.93	16638.92
19	0.471	2985.77	6339.21	878.51	1865.21	94.50	200.63	3958.78	8405.05
20	0.471	3986.47	8463.85	1178.27	2501.64	130.22	276.47	5294.96	11241.95
21	0.471	4127.96	8764.25	1220.11	2590.47	134.85	286.30	5482.92	11641.02
22	0.471	1333.28	2830.75	409.65	869.75	55.25	117.30	1798.19	3817.81
23	0.471	3549.92	7536.98	1090.67	2315.65	147.12	312.35	4787.70	10164.97
24	0.471	1199.30	2546.28	352.97	749.40	38.06	80.82	1590.33	3376.50
25	0.471	5402.43	11470.13	1590.15	3376.11	171.44	364.00	7164.02	15210.23
26	0.471	653.65	1387.80	192.36	408.40	20.74	44.03	866.75	1840.23
27	0.471	2116.10	4492.77	622.90	1322.51	67.15	142.57	2806.15	5957.84
28	0.471	2006.98	4261.09	590.74	1254.22	63.70	135.24	2661.41	5650.55
29	0.471	938.12	1991.77	276.13	586.27	29.78	63.22	1244.03	2641.26
30	0.471	499.56	1060.63	147.05	312.21	15.86	33.67	662.47	1406.52
31	0.471	1900.43	4034.89	559.41	1187.71	60.31	128.05	2520.16	5350.65
32	0.471	1764.04	3745.31	519.26	1102.46	55.98	118.35	2339.28	4966.63
33	0.471	3401.47	7221.81	1001.20	2125.69	107.95	229.19	4510.62	9576.69
34	0.471	985.21	2091.74	290.01	615.73	31.27	[illegible].39	1306.49	2773.86
35	0.471	399.18	847.52	117.52	249.50	12.67	26.91	529.37	1123.93
36	0.471	2093.63	4445.0[illegible]	625.31	1327.63	73.29	155.61	2792.24	5928.32
37	0.471	1641.82	3485.82	490.43	1041.25	57.47	122.03	2189.72	4649.10
38	0.471	1199.11	2545.88	358.15	760.41	41.98	89.14	1599.24	3395.42
39	0.471	1071.83	2275.65	320.15	679.73	37.51	79.65	1429.49	3035.02
40	0.471	629.99	1337.57	188.16	399.50	22.06	46.84	840.22	1783.91
41	0.471	3562.83	7564.39	1064.26	2259.46	124.73	264.81	4751.75	10088.65

APPENDIX E-3

EMISSIONS BY ZONE

FOR CARBON MONOXIDE IN 1977 IN THE

INNER CITY OF BOSTON WITH CONTROL STRATEGY

CITY OF BOSTON CALENDAR YEAR IS 1977

REGION NO. 5 POLLUTANT SPECIES IS CARBON MONOXIDE

MODEL YEARS CONSIDERED IS FROM 1964 TO 1977

LENGTH OF TIME PERIOD IS 24 HOURS

VEHICLE CATEGORY -		LIGHT DUTY		HEAVY DUTY		OTHER		TOTAL		LIGHT DUTY EMISSION DENSITY AFTER		TOTAL EMISSION DENSITY AFTER CONTROLS
ZONE NO.	AREA (SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	INSPECTION MAINTENANCE 10.% REDCTN	RETROFIT 50.3% REDTN	
1-1 1	0.471	978.88	2078.31	335.87	713.10	38.60	81.94	1353.35	2873.35	1870	930	1725
1-2 2	0.471	840.50	1784.50	288.64	612.81	33.17	70.42	1162.30	2467.73	1606	798	1482
1-3 3	0.471	1066.83	2265.02	366.54	778.21	42.13	89.44	1475.49	3132.68	2039	1013	1881
2-1 4	0.471	1075.50	2283.45	369.10	783.66	42.41	90.05	1487.02	3157.15	2055	1020	1893
2-2 5	0.471	599.74	1273.34	205.80	436.95	23.66	50.22	829.20	1760.51	1146	569	1056
2-3 6	0.471	899.62	1910.01	308.85	655.73	35.49	75.36	1243.96	2641.11	1719	854	1585
3-1 7	0.471	964.49	2047.74	331.14	703.05	38.06	80.82	1333.69	2831.61	1843	916	1700
3-2 8	0.471	1681.00	3569.00	577.17	1225.42	66.33	140.83	2324.51	4935.25	3212	1596	2961
1-4 9	0.471	1837.03	3900.28	646.86	1373.37	84.74	179.92	2568.63	5453.57	3510	1744	3297
1-5 10	0.471	1454.82	3088.78	512.07	1087.20	67.09	142.44	2033.97	4318.41	2780	1382	2611
1-6 11	0.471	490.69	1041.81	172.68	366.62	22.61	48.01	685.99	1456.45	938	466	881
1-7 12	0.471	627.55	1332.37	221.04	469.30	28.94	61.45	877.53	1863.12	1199	595	1125
2-6 13	0.471	3441.07	7305.88	1211.70	2572.61	158.73	337.00	4811.50	10215.49	6575	3268	6177
2-7 14	0.471	1080.02	2293.04	380.22	807.27	49.80	105.73	1510.05	3206.05	2064	1026	1939
2-4 15	0.471	5511.25	11701.18	1937.07	4112.68	251.74	534.47	7700.06	16348.33	10531	5233	9879
3-4 16	0.471	2182.34	4633.41	766.91	1628.26	99.66	211.60	3048.91	6473.27	4170	2072	3911
2-5 17	0.471	89.74	190.52	30.16	64.03	3.27	6.93	123.16	261.49	172	85	156
3-5 18	0.471	5089.90	10806.59	1728.72	3670.33	187.08	397.19	7005.70	14874.09	9725	4833	8900
4-5 19	0.471	2571.25	5459.13	873.26	1854.06	94.50	200.63	3539.01	7513.82	4913	2441	4495
4-4 20	0.471	3405.48	7230.32	1163.30	2469.86	130.22	276.47	4698.99	9976.63	6507	3234	5979
5-4 21	0.471	3525.96	7486.13	1204.61	2557.56	134.85	286.30	4865.42	10329.98	6737	3348	6192
3-3 22	0.471	1145.78	2432.65	406.88	863.86	55.25	117.30	1607.91	3413.81	2129	1088	2069
4-3 23	0.471	3052.61	6481.13	1083.29	2299.98	147.12	312.35	4283.01	9093.44	5833	2899	8511
4-1 24	0.471	1019.98	2165.57	347.28	737.33	38.06	80.82	1405.33	2983.72	1949	969	1787
4-2 25	0.471	4605.93	9779.04	1564.52	3321.71	171.44	364.00	6341.89	13464.73	8801	4374	8060
5-1 26	0.471	556.48	1181.48	189.26	401.82	20.74	44.03	766.47	1627.32	1063	528	974
5-2 27	0.471	1805.16	3832.60	612.86	1301.19	67.15	142.57	2485.17	5276.36	3449	1717	3187
5-3 28	0.471	1721.65	3655.30	581.22	1234.00	63.70	135.24	2366.56	5024.54	3290	1626	3005
5-5 29	0.471	798.92	1696.22	271.68	576.82	29.78	63.22	1100.38	2336.26	1526	759	1399
5-6 30	0.471	425.36	903.09	144.68	307.18	15.86	33.67	585.90	1243.95	813	404	745
6-2 31	0.471	1620.69	3440.97	550.40	1168.57	60.31	128.05	2231.40	4737.58	3097	1639	2836
6-3 32	0.471	1502.30	3189.61	510.89	1084.69	55.98	118.86	2069.18	4393.16	2871	1427	2631
6-4 33	0.471	2898.24	6153.38	985.07	2091.44	107.95	229.19	3991.26	8474.01	5538	2752	8072
6-5 34	0.471	838.55	1780.36	285.33	605.80	31.27	66.39	1155.15	2452.55	1602	796	1468
6-6 35	0.471	339.98	721.83	115.62	245.48	12.65	26.87	468.26	994.18	649	322	594
6-1 36	0.471	1785.62	3791.12	616.58	1309.09	73.29	155.61	2475.49	5255.82	3412	1696	3161
7-1 37	0.471	1400.51	2973.49	483.58	1026.71	57.47	122.03	1941.57	4122.22	2676	1330	3479
7-2 38	0.471	1022.41	2170.71	353.15	749.79	41.98	89.14	1417.54	3009.64	1954	971	1810
7-3 39	0.471	914.29	1941.17	315.68	670.23	37.51	79.65	1267.49	2691.05	1747	869	1618
7-4 40	0.471	537.50	1141.18	185.54	393.92	22.06	46.84	745.10	1581.95	1027	510	951
7-5 41	0.471	3039.29	6452.86	1049.34	2227.90	124.73	264.81	4213.36	8945.56	5808	2936	6399

BIBLIOGRAPHIC DATA SHEET	1. Report No. APTD-1442	2.	3. Recipient's Accession No.
4. Title and Subtitle Transportation Controls to Reduce Motor Vehicle Emissions in Boston, Massachusetts			5. Report Date December 1972
			6.
7. Author(s) Land Use Planning Branch			8. Performing Organization Rept. No.
9. Performing Organization Name and Address GCA Corporation GCA Technology Division Bedford, Massachusetts			10. Project/Task/Work Unit No. DU-72-B895
			11. Contract/Grant No. 68-02-0041
12. Sponsoring Organization Name and Address Environmental Protection Agency Office of Air Quality Planning and Standards Research Triangle Park, N.C. 27711			13. Type of Report & Period Covered Final Report 8/14/72 to 12/15/72
			14.

15. Supplementary Notes Prepared to assist in the development of transportation control plans by those State Governments demonstrating that National Ambient Air Quality Standards cannot be attained by implementing emission standards for stationary sources only.

16. Abstracts

The document demonstrates the nature of the Air Quality problem attributed to motor vehicle operation, the magnitude of the problem and a strategy developed to neutralize these effects in order that National Ambient air quality standard may be attained and maintained.

17. Key Words and Document Analysis. 17a. Descriptors

Motor Vehicle emitted pollutants - air pollutants originating within a motor vehicle and released to the atmosphere.

National Ambient Air Quality Standards - Air Quality Standards promulgated by the Environmental Protection Agency and published as a Federal Regulation in the Federal Register.

17b. Identifiers/Open-Ended Terms

VMT - Vehicle Miles Traveled
Vehicle Mix - distribution of motor vehicle population by age group.
LDV - light duty vehicle - less than 6500 lbs.
HDV - heavy duty vehicle - greater than 6500 lbs.

17c. COSATI Field/Group Environmental Quality Control of Motor Vehicle Pollutants

18. Availability Statement For release to public	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages all
	20. Security Class (This Page) UNCLASSIFIED	22. Price

FORM NTIS-35 (REV. 3-72) USCOMM-DC 14952-P72

INSTRUCTIONS FOR COMPLETING FORM NTIS-35 (10-70) (Bibliographic Data Sheet based on COSATI Guidelines to Format Standards for Scientific and Technical Reports Prepared by or for the Federal Government, PB-180 600).

1. **Report Number.** Each individually bound report shall carry a unique alphanumeric designation selected by the performing organization or provided by the sponsoring organization. Use uppercase letters and Arabic numerals only. Examples FASEB-NS-87 and FAA-RD-68-09.

2. Leave blank.

3. **Recipient's Accession Number.** Reserved for use by each report recipient.

4. **Title and Subtitle.** Title should indicate clearly and briefly the subject coverage of the report, and be displayed prominently. Set subtitle, if used, in smaller type or otherwise subordinate it to main title. When a report is prepared in more than one volume, repeat the primary title, add volume number and include subtitle for the specific volume.

5. **Report Date.** Each report shall carry a date indicating at least month and year. Indicate the basis on which it was selected (e.g., date of issue, date of approval, date of preparation.

6. **Performing Organization Code.** Leave blank.

7. **Author(s).** Give name(s) in conventional order (e.g., John R. Doe, or J.Robert Doe). List author's affiliation if it differs from the performing organization.

8. **Performing Organization Report Number.** Insert if performing organization wishes to assign this number.

9. **Performing Organization Name and Address.** Give name, street, city, state, and zip code. List no more than two levels of an organizational hierarchy. Display the name of the organization exactly as it should appear in Government indexes such as USGRDR-I.

10. **Project/Task/Work Unit Number.** Use the project, task and work unit numbers under which the report was prepared.

11. **Contract/Grant Number.** Insert contract or grant number under which report was prepared.

12. **Sponsoring Agency Name and Address.** Include zip code.

13. **Type of Report and Period Covered.** Indicate interim, final, etc., and, if applicable, dates covered.

14. **Sponsoring Agency Code.** Leave blank.

15. **Supplementary Notes.** Enter information not included elsewhere but useful, such as: Prepared in cooperation with . . . Translation of . . Presented at conference of . . . To be published in . . . Supersedes . . . Supplements . . .

16. **Abstract.** Include a brief (200 words or less) factual summary of the most significant information contained in the report. If the report contains a significant bibliography or literature survey, mention it here.

17. **Key Words and Document Analysis. (a). Descriptors.** Select from the Thesaurus of Engineering and Scientific Terms the proper authorized terms that identify the major concept of the research and are sufficiently specific and precise to be used as index entries for cataloging.
    (b). Identifiers and Open-Ended Terms. Use identifiers for project names, code names, equipment designators, etc. Use open-ended terms written in descriptor form for those subjects for which no descriptor exists.
    (c). COSATI Field/Group. Field and Group assignments are to be taken from the 1965 COSATI Subject Category List. Since the majority of documents are multidisciplinary in nature, the primary Field/Group assignment(s) will be the specific discipline, area of human endeavor, or type of physical object. The application(s) will be cross-referenced with secondary Field/Group assignments that will follow the primary posting(s).

18. **Distribution Statement.** Denote releasability to the public or limitation for reasons other than security for example "Release unlimited". Cite any availability to the public, with address and price.

19 & 20. **Security Classification.** Do not submit classified reports to the National Technical

21. **Number of Pages.** Insert the total number of pages, including this one and unnumbered pages, but excluding distribution list, if any.

22. **Price.** Insert the price set by the National Technical Information Service or the Government Printing Office, if known.

☆U. S. GOVERNMENT PRINTING OFFICE: 1973—746-768/4150—Region 4

ENVIRONMENTAL PROTECTION
Technical Publications Br
Office of Administratio
Research Triangle Park, N. C

OFFICIAL BUSINESS

IE AND FEES PAID
AL PROTECTION AGENCY
EPA - 335

U.S.MAIL

SPECIAL FOURTH CLASS RATE
BOOK

If you do not desire to continue receiving this technical report series, please CHECK HERE ☐, tear off this label, and return it to the above address. Your name will then be promptly removed from the appropriate mailing list.

PUBLICATION NO. APTD-1442