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Cost Analysis for a Decentralized Emissions Inspection/Maintenance Program for Massachusetts

Technical Report

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COST ANALYSIS FOR A DECENTRALIZED EMISSIONS INSPECTION/MAINTENANCE PROGRAM FOR MASSACHUSETTS

Final Report

ABSTRACT

This report presents a cost analysis of a decentralized vehicle emissions inspection and maintenance (I/M) program for the Commonwealth of Massachusetts. The analysis was performed on a life-cycle cost basis and considered the effects of inflation, growth in the vehicle fleet and labor rate escalation on the costs of the program. Elements which are specifically addressed include:

- Necessary modifications to the current Massachusetts inspection program to accommodate I/M.
- Incremental capital and operating costs which would be incurred by the State and private garages with the addition of I/M to the current safety inspection.
- Impacts of I/M on the vehicle inspection fee.
- Changes required to upgrade the current safety inspection to meet Federal VIU standards, and the impact of these changes on the inspection fee.

Although certain assumptions made in the course of the analysis may change when the details of the program design are complete, the results presented here reflect a reasonable estimate of the costs of a certified garage I/M program.

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L I S T O F F I G U R E S

I. INTRODUCTION

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Inspection/maintenance (I/M) is a term used to denote the periodic inspection of motor vehicles for emissions. The purpose of an I/M program is to identify vehicles which need remedial maintenance or adjustment to significantly reduce their emissions and to require repair of these vehicles. The reported benefits of an I/M program include reduced emissions, improved fuel economy, and improved vehicle performance. On the other hand, the implementation of an I/M program has significant cost implications as well. These include the construction of buildings, the purchase of new equipment and the addition of new staff to handle increased program administration, data analysis, and program surveillance requirements.

With the passage of the Clean Air Act Amendments of 1977, the States are now required to achieve certain ambient air quality standards by December 31, 1982. While there are a number of ways to accomplish this, if a State cannot demonstrate attainment of the standards by that date, the State must include in its State Implementation Plan (SIP) revisions of January 1, 1979, a specific schedule for the implementation of I/M. To assist the Commonwealth of Massachusetts in selecting the most suitable alternative for achieving these standards, this report presents an evaluation of the incremental costs of adding an emissions test to the existing safety inspection program in Massachusetts.

The following sections contain a discussion of the objectives and scope of this evaluation, and explain the evaluation methodology.

1. STUDY OBJECTIVES

The primary objective of this study was to provide the Commonwealth of Massachusetts with an in-depth economic analysis of the costs of implementing a decentralized certified garage I/M program. Specific objectives of the study were:

- To determine the incremental capital and operating costs of adding an emissions inspection test to the existing safety inspection program.

- To determine the incremental fee to be charged the consumer of adding an emissions inspection test to the existing safety inspection program.

- To determine the combined safety and emissions inspection fee to be charged the consumer, anticipating that changes would be made to the existing safety program, both to accommodate the added emissions inspection, as well as to improve the existing safety program.

2. STUDY SCOPE

In accordance with the contract scope of work, the analysis was based on implementation of a statewide I/M program superimposed on the existing safety program. The assumed characteristics of the I/M program were:

- Vehicle testing by certified private garages for excessive hydrocarbon and carbon monoxide emissions.

- Mandatory inspection of all light duty vehicles (LDV's)* less than 15 years old as of the start date of the program.

- Use of an idle mode test to check vehicle emissions with an initial inspection failure rate of 20 percent.

- Annual inspection, evenly distributed over the year with a free reinspection for failed vehicles at the same station.

- Use of a State-run quality audit and enforcement program (one State inspector for every 100 private inspection stations).

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* For the purpose of this report, light duty vehicles are defined as vehicles with a gross vehicle weight of 10,000 pounds or less.

- Use of State-owned and operated challenge garages to handle consumer complaints and to check the quality of garage inspections.

- Use of mobile vans as auxiliary inspection facilities in outlying areas and for spot-checking vehicles on the highway.

- Inclusion of a four-week training course for inspectors to be run by the State, and a State-operated mechanic training course with costs borne by the students.

- Expansion of the current inspection administration staff to handle increased program administration, data analysis and program surveillance requirements.

The assumed start-up date for the program was January 1, 1982.

3. EVALUATION METHODOLOGY

The methodology employed in carrying out the above study objectives is shown in Figure I-1. As shown in the figure, the methodology consisted of four tasks, as follows:

- Task 1: Determination of Emissions Test Program Requirements. This task involved analysis of the existing safety inspection program with respect to the modifications necessary to expand this program to include an emissions test. The task involved discussions with key personnel at the Vehicle Inspection Section, Registry of Motor Vehicles, discussions with key personnel at the U.S. Environmental Protection Agency involved in providing States with direction on I/M program implementation, and a review of supporting data (e.g., State inspection manual) on Massachusetts safety inspection procedures.

- Task 2: Analysis of the Incremental Costs of Adding an Emissions Test to Massachusetts' Existing Safety Program. This task involved analysis of the incremental capital and operating costs which would be incurred by both the State and private garages with the addition of an emissions test to the existing safety inspection program. This analysis involved evaluation of

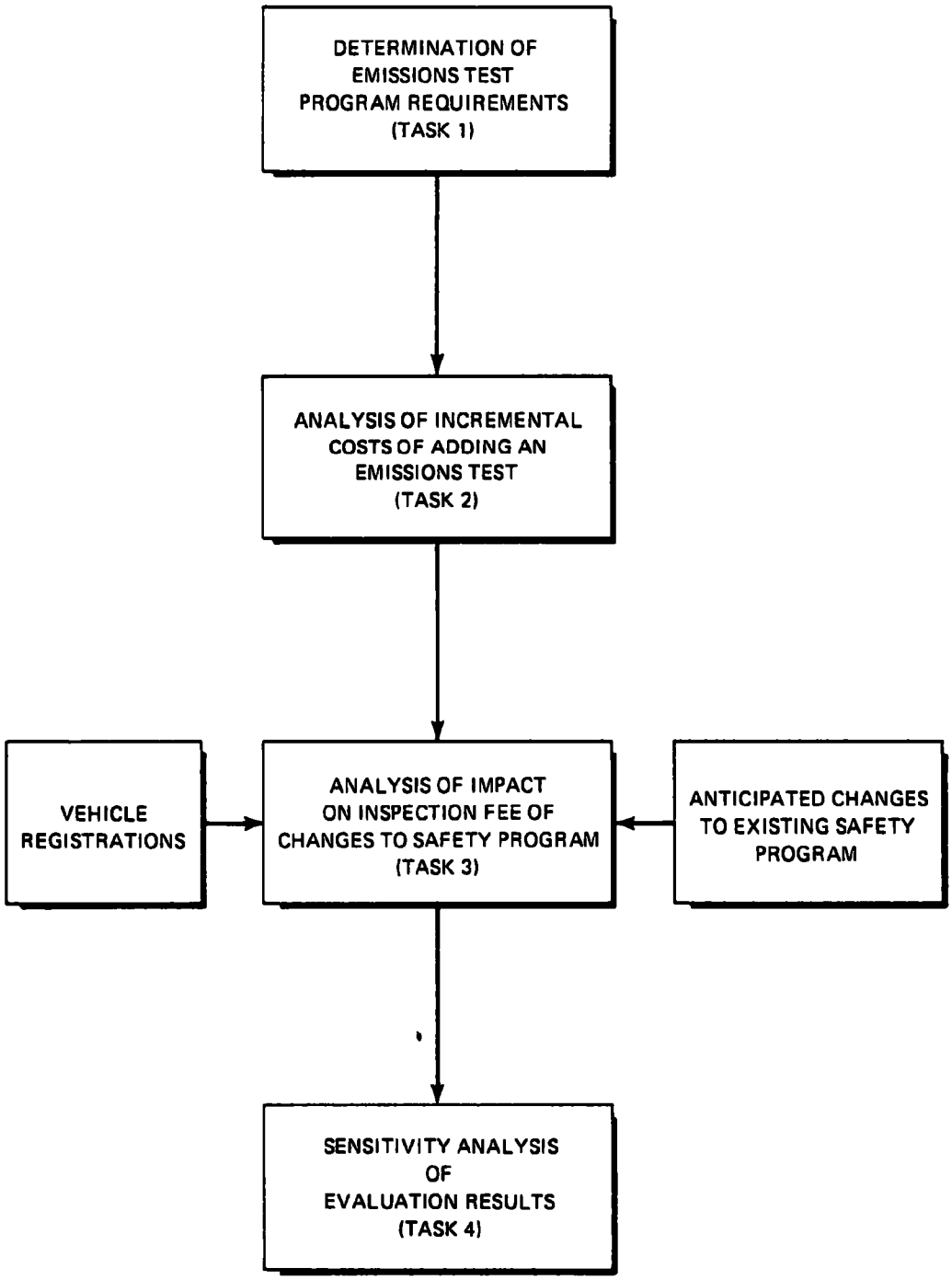

FIGURE I-1
Overview of Evaluation Methodology

the life cycle costs associated with the development, implementation and operation of the proposed I/M program.

- Task 3: Analysis of the Impact on the Inspection Fee of Changes to the Safety Program. This task involved calculation of the incremental fee to be charged the motorist as a result of (1) conducting an emissions test, (2) combining an emissions test with the existing safety inspection and (3) upgrading the safety inspection to meet Federal standards and combining the modified safety inspection with an emissions test.

- Task 4: Sensitivity Analysis of the Incremental Costs and Fee. This task involved analysis of the sensitivity of the results of Task 2 and 3 to changes in the major assumptions used in carrying out those analyses. The assumptions which were tested include the interest rate, inflation rate, program life, number of certified garages, and use of a manual data processing system in lieu of an automated system.

The results of each of these analyses are presented in detail in Chapters II through V. Data and supporting calculations for each analysis are provided in separate appendices.

II. COMBINING SAFETY AND EMISSIONS TESTING IN MASSACHUSETTS

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Given the well established periodic safety inspection in Massachusetts, a logical way to meet EPA's requirements for a transportation pollution control program is to superimpose an emissions test onto the existing safety inspection. To make such a combined program work effectively, however, certain provisions must be made to meet EPA's requirements for I/M and to protect Massachusetts consumers from improper or fraudulent testing. This chapter describes the existing Massachusetts safety inspection program and some of the modifications necessary to expand this inspection to include an emission test.

1. MASSACHUSETTS EXISTING SAFETY INSPECTION PROGRAM

In Massachusetts, automobile safety inspections are administered semi-annually by the Vehicle Inspection Section of the Registry of Motor Vehicles, during two 6-week periods. During these time periods, inspections of more than 3 million vehicles are performed. A fee of $2.00 is charged for each safety inspection, all of which is retained by the garage. Since no portion of the inspection fee is returned to the State, the program as presently structured is not self-supporting. The program has an annual budget of $950,000, and employs a staff of approximately 57, including 50 inspectors, a program director and six persons in in clerical and secretarial positions. All expenses incurred in the program are paid for from the State general fund, including the printing and distribution of stickers, forms and other materials to the approximately 4,200 certified garages.

During the inspection, the following vehicle components and systems are inspected:

- Brakes - Inspector operates the vehicle to test the parking and service brakes.
- Lights - Inspector conducts a visual inspection of front headlamp aim, rear lamps and marker lights for proper operation.

- Muffler and Exhaust - Inspector conducts a visual and audio check for excessive smoke, unnecessary noise, and exhaust leaks.

- Steering - Inspector checks for excessive wear and play and for free steering. Inspector also conducts a visual check of the front end while the vehicle is lifted.

- Horn - Inspector conducts a check for adequate signal and secure fastening to the vehicle.

- Glazing - Inspector checks that the windshields are free of cracks or stone bruises in the area of the wiper blade, and that the rear windows are clear.

- Tires - Inspector conducts a check for adequate tread depth, condition and wear.

- Body, Fenders and other External Parts - Inspector conducts a check for holes, corrosion or broken mouldings with sharp edges. Inspector also checks that front and rear fenders are in place.

A verification check is also made of the registration certificate against the registration plates and vehicle identification number.

If the vehicle passes the inspection, the inspector completes a station report form, fills out the sticker and attaches the sticker to the windshield. If the vehicle fails the inspection, the inspector notifies the vehicle owner, completes a rejected report form, fills out a "rejected" sticker and attaches it to the windshield. A motorist may obtain a free reinspection from the station which rejected his vehicle. If the motorist chooses to go to another station after being rejected, however, he is required to pay another fee. Inspection report sheets are required to be kept by the garage owner and are subject to examination by Registry Inspectors for at least two years following the date of the inspection.

2. MODIFICATIONS NECESSARY TO SUPPLEMENT THE SAFETY INSPECTION WITH AN EMISSION TEST

Existing Massachusetts legislation does not provide for a self-supporting vehicle inspection program, nor are there provisions for penalties for infractions of the vehicle inspection laws by garage owners and operators. In addition, the current semi-annual safety inspection schedule is not compatible with the change to an annual emissions I/M program. Changes in the legislation and in administration of the safety program will be necessary to incorporate these requirements as part of a combined safety/emissions inspection. Other anticipated changes include:

- Developing additional requirements for inspection facility licensing
- Developing a system for monitoring the effectiveness of the emissions I/M program (i.e., record maintenance system)
- Developing a quality audit and enforcement program for monitoring the quality of inspections performed by garages
- Developing a program which trains mechanics in the inspection, diagnosis and repair of emissions related vehicle problems
- Developing a program which informs the public of the new inspection requirements and of licensed garage operating hours, the inspection fee and the purpose of the challenge garages on a continuing basis
- Constructing state referee stations (i.e., challenge garages) for the purpose of handling consumer complaints about the program
- Purchasing mobile inspection units to act as auxiliary inspection stations in outlying areas or for spot-checking vehicles on the highway.

A discussion of each of these changes is presented below.

(1) Inspection Facility Licensing

A fundamental requirement for adding an emissions test to the existing safety inspection is to institute new inspection facility licensing requirements. Garages which are presently licensed to perform safety inspections will have to purchase an approved emissions analyzer and employ an inspector with demonstrated proficiency in conducting emissions tests. In addition, a garage applying for certification should also be required to:

- Maintain inspection records
- Submit the facility to periodic inspections and audits by the State.

All official inspection facilities should meet these requirements, and the appropriate Massachusetts agency should have provisions for penalizing facilities which fail to uphold the licensing regulations.

(2) Records Maintenance System

The collection of detailed information on the results of emissions testing will be indispensable in adjusting the emission standards and stringency levels to the Massachusetts vehicle population. A second important program modification, therefore, is ensuring that on each vehicle inspected there is a record indicating the emissions test result, and the frequency with which the garage's analyzer has been calibrated. Such information will be useful in (1) monitoring the overall effectiveness of the program and (2) evaluating the accuracy of vehicle test results.

The development of a records maintenance system, however, will require:

- Providing the garages with standard data collection forms
- Checking the records periodically to ascertain their accuracy and completeness
- Purchasing appropriate data handling and processing equipment.

(3) Quality Audit and Enforcement Program

Because of the necessity of accurate emissions testing and proper maintenance for reducing air pollution levels, the emissions testing and equipment

calibration procedures in the garages must be carefully monitored. With as many as 4,200 garages performing inspections in Massachusetts, extensive divergence in these procedures may result unless the facilities are regularly visited and their procedures checked by representatives of the monitoring agency. Currently, garage inspections are performed randomly or in response to specific consumer complaints. With the addition of emissions testing to the safety inspection, the frequency of garage checks should be increased to approximately once every 30 days for each garage, and should include a check of the calibration of the emission analyzer as well as a review of the testing procedures. Unscheduled/unannounced garage inspections are effective as a routine surveillance measure and as a complaint investigation procedure. The correlation of instrument readings among inspection facilities can also be checked at this time.

(4) Mechanic Training Program

Adjustment of pollution control devices and the reduction of vehicle emissions are comparatively recent concerns of the automobile service industry. Consequently many mechanics have had no instruction in the downward adjustment of emission levels or the correction of pollution control defects. Since emissions repairs and maintenance are the actual sources of motor vehicle emission reductions, even the most elaborate testing program would be ineffective in Massachusetts without capable and informed auto mechanics to correct the emissions problems. A mechanic training program therefore needs to be made available and the mechanics should be encouraged to attend well in advance of the program implementation. Some training courses for emissions repairing and adjustment have already been developed. In the future, if necessary, EPA may issue guidelines for determining the adequacy of a mechanic training program. For the present, Massachusetts may adopt training packages from other states or develop its own program.

(5) Public Information Program

The citizens of Massachusetts have been subject to vehicle inspection for nearly fifty years (the program began in 1930), and by now they are adjusted to the concept of periodic inspection. The addition of an emissions test to this long-standing safety inspection, however, should be accompanied by a public

awareness campaign adequate to instill an understanding of the test, its expected benefits for Massachusetts, and any additional program components designed to ensure the protection of Massachusetts consumers (challenge garages, waivers, etc.) This is critical to the success of the program. The elements of this program should include as a minimum:

- Organization of a consumer affairs office
- Establishment of information seminars for repair establishment management
- Development of a media campaign to inform the public about the program, including the names and locations of garages licensed to perform the inspections, their hours and the inspection fee.

(6) Referee Inspection Stations (Challenge Garages)

Providing a referee station will give Massachusetts motorists an opportunity for an objective inspection, independent of any special interests of the repair industry. The referee station may also be a center for handling consumer complaints relating to the diagnosis and repair of vehicle malfunctions relating to emissions. Six such garages will be required in Massachusetts as follows:

- Boston (3)
- Springfield (1)
- Worcester (1)
- Southeastern Massachusetts (1)

(7) Mobile Van Units

Many I/M programs use vans as auxiliary inspection stations or for spot-checking vehicles on the highway. Highway spot-checks are useful in:

- Determining the effectiveness of inspection and maintenance emissions levels, particularly during the initial phases of an I/M program
- Deterring vehicles from operating on public roads if they do not comply with applicable emissions standards

- Assisting in the garage inspection and surveillance effort by conducting reinspections of vehicles which were recently inspected by a State certified garage.

Although it is presently illegal for Massachusetts police to stop a motor vehicle without probable cause of violation, a legislative change could be made to permit highway spot-checks in the future. Such vans could also be used as auxiliary inspection stations to serve outlying areas such as:

- Marthas Vineyard
- Nantucket
- Berkshires.

* * * * * * * *

The costs associated with the above changes and their impact on the inspection fee are described in the following chapters.

III. ANALYSIS OF THE INCREMENTAL COSTS OF ADDING AN EMISSIONS TEST TO MASSACHUSETTS EXISTING SAFETY PROGRAM

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The approach employed in determining the incremental capital and operating costs as well as incremental fee of adding an emissions inspection test to the existing safety inspection program is shown in Figure III-1. As shown in the figure, the basic approach employed was based on the concept of life cycle costs. This means that all expenditures associated with the development, implementation, and operation of the proposed I/M program were considered in determining the incremental inspection fee. This chapter describes the life cycle cost analysis conducted in determining the State and private garage costs. Chapter IV which follows describes the life cycle vehicle registration and inspection fee analysis.

1. OVERVIEW OF APPROACH

Life cycle costs are normally determined by adding the maintenance and operating costs each year to the yearly investment cost (interest plus amortization payment of the initial cost) and then totaling these for the life of the program. In lieu of this procedure, however, it is convenient to first calculate the individual life cycle cost for each component of total cost, and then to total these in order to determine the total life cycle cost. It is this latter procedure which was employed in carrying out the analysis. The basic life cycle cost equation employed was as follows:

$$\text{Life Cycle Costs} = ICC + SUC + PAC + ETC + USC + MRC - SVC$$

where:

ICC = Life cycle investment costs
SUC = Life cycle start-up costs
PAC = Life cycle program administration costs
ETC = Life cycle emissions testing costs
USC = Life cycle utilities and supplies costs
MRC = Life cycle maintenance and repair costs
SVC = Salvage value of building and land at end of life cycle.

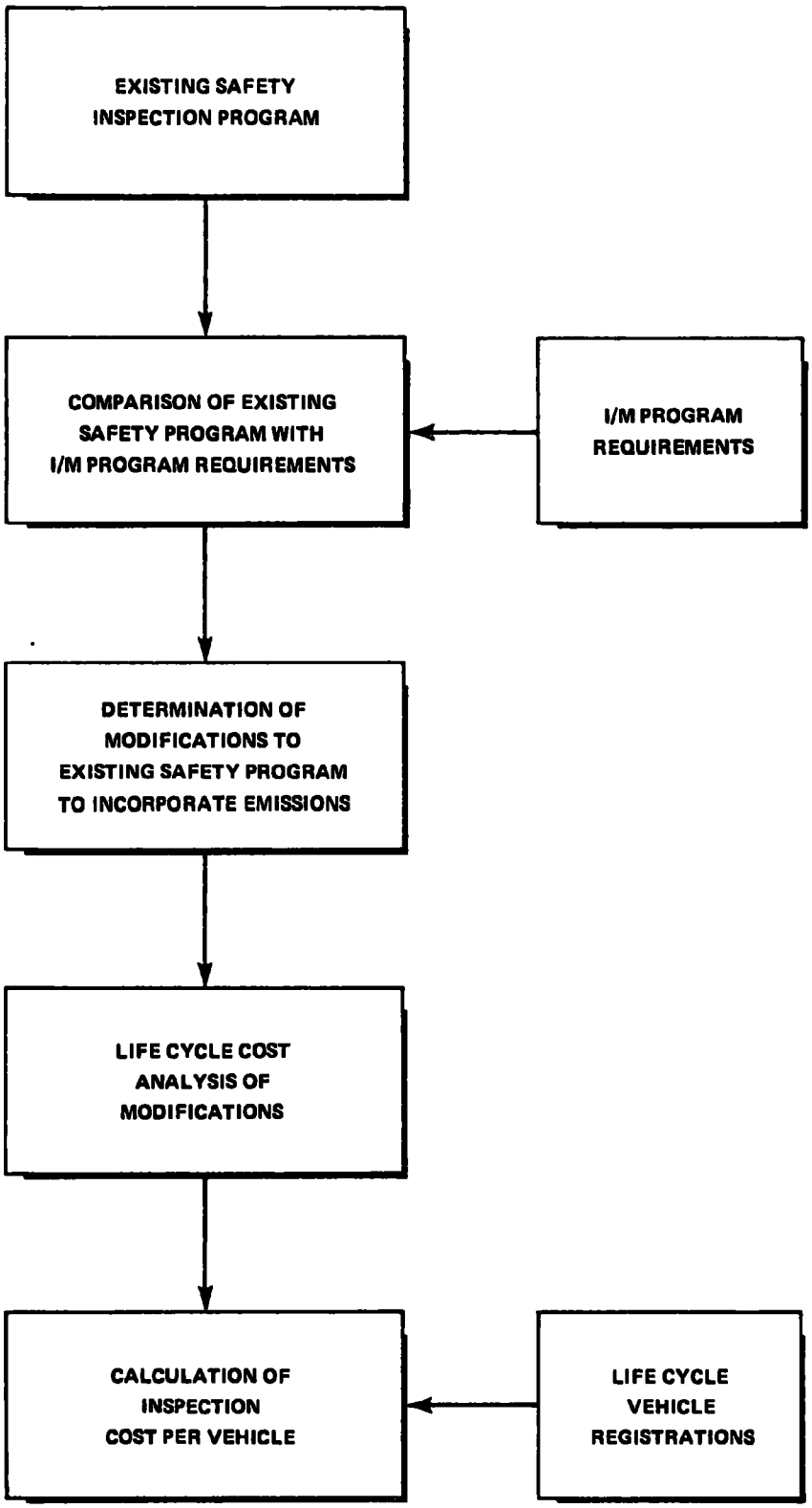

FIGURE III-1

Overview of Approach for Estimating Incremental Inspection Fee

The variables PAC, ETC, USC, and MRC are all components of annual operating costs. Variables ICC, SUC and SVC represent costs that are incurred only once during the life cycle. All costs were based on a program life of five years starting with calendar year 1982 as the year of program initiation and ending in December, 1986.* Costs were originally estimated in 1978 dollars and were then inflated to reflect actual costs during the life cycle (1982-1986). A common annual inflation factor of 5 percent was assumed for all costs.

The following sections describe the specific methods used in calculating each of the components of life cycle costs.

2. INVESTMENT COSTS ANALYSIS

Life cycle investment costs are the initial outlay of capital costs associated with an I/M program plus the interest paid on the money borrowed to finance these costs. Initial investment costs usually include the construction of buildings and the purchase of land and equipment. They can also include those "one time" costs associated with start-up of the I/M program, such as mechanic/inspector training costs and public relations costs. However, because of the different possibilities for potentially funding capital and start-up costs, the calculation of life cycle start-up costs were handled separately in this analysis.

Life cycle investment costs were determined by multiplying the initial investment costs (I) by the product of program life (n) and a factor which amortizes the initial costs over the life of the program (Y). The factor Y was derived by assuming that the required capital was borrowed at the beginning of the first year of the program's life, and repaid in equal yearly principal and interest payments throughout the life of the program. The formula used to compute life cycle investment costs was as follows:

$$\text{Life Cycle Investment Costs} = I \times n \times Y$$

where:

I = Total initial investment costs
n = Life of the program
Y = Yearly principal and interest cost on one dollar, equal to:

$$\frac{i(1+i)^n}{(1+i)^n-1}$$

where i equals the annual interest rate.

* It was assumed that capital investment and start-up costs would be incurred in 1981.

Initial investment costs for the proposed I/M program included:

- The construction of six challenge garages (building and land costs) for the metropolitan areas of Boston (3), Springfield (1), Worcester (1), and Southeastern Massachusetts (1) for the purpose of handling consumer complaints about the program.

- The purchase of up to five mobile inspection units operated by State Inspectors as auxiliary inspection stations, for example, in areas such as the Berkshires, Martha's Vineyard, and Nantucket, or for spot checking vehicles on the highway.

- The purchase of exhaust emission analyzers by the State (four for each of the six challenge garages plus one for each of the five mobile vans for a total of 29) and by the private garages (4,200, the existing number of garages certified to perform safety inspection).

- The purchase of computer equipment by the State (four data entry devices) for the purpose of analyzing the collected vehicle emissions test data.

Estimates of these costs are summarized in Table III-1.

The land cost data shown in the table was obtained through conversations with real estate brokers in Massachusetts, while building cost data was estimated using conventional engineering cost estimating procedures. Details of the procedures for estimating building and land costs are described in Appendix A. Equipment cost data (emissions analyzers, computer equipment and mobile vans) were obtained from conversations with the major equipment manufacturers and vendors.

The life cycle investment costs shown in the table are based on an interest rate of 10 percent for the State and 12 percent for the private garages. The TOTAL life-cycle cost shown reflects the worth (salvage value) of the land and buildings at the end of the 5 years. That is, the remaining value of the land and buildings at the end of 5 years was estimated and subtracted from the total life-cycle investment. Details on this analysis are presented in Appendix B.

TABLE III-1
Summary of Initial and Life Cycle Investment Costs

Item	Cost Per Facility** (1981 Dollars)	Number Required	Total Initial Cost (1981 Dollars)	Life Cycle Cost (1982 - 1986)
Challenge Garage				
Building	$ 108,000	6	$ 648,000	$ 855,000
Land	21,000	6	126,000	166,000
Emissions Analyzers				
State	2,550	29	74,000	98,000
Private Garages	2,550	4,200	10,710,000	14,887,000
Computer Equipment	1,740	4	7,000	9,000
Mobile Units*	12,000	5	60,000	83,000
Salvage Value Credit				(730,000)
TOTAL			$ 11,625,000	$ 15,368,000

* Includes hand-held tools needed for safety inspection plus one generator per van.
** Based on 1978 estimates escalated to 1981 dollars at an annual rate of 5%.

3. START-UP COST ANALYSIS

Life cycle start-up costs are those costs other than the initial investment costs, described above, necessary to establish the program, plus (as with initial investment costs) the interest paid on the money borrowed to finance these costs. The start-up costs considered in developing the prcposed I/M program included:

- Initial State Labor Charges—Cost for a small group of State employees to lay the foundation for the program during the year prior to start-up.
- Program Design Costs— Technical support to the State for actual design of the program.
- Public Information Costs—Costs of the initial stages of a public information program, i.e. media campaign to inform the public about the program, informational seminars for repair establishment management, and organization of consumer affairs office.*

* Because of the importance of public information to the success of the I/M program, it was assumed that the public information program would commence two years prior to program start-up.

Inspector/Mechanic Training Costs—Costs associated with organization of the training program, of supplies (i.e., books) and the initial training of inspectors/mechanics and the State enforcement staff.

Life cycle start-up costs were computed in the same manner as investment costs. Namely, as follows:

Life Cycle Start-up Costs = S x n x Y

where:

S = Total start-up costs

n = Life of the program

Y = Yearly principal and interest costs on one dollar, equal to:

$$\frac{i(1+i)^n}{(1+i)^n-1}$$

where i equals the interest rate.

Initial labor, program design, public information and inspector/mechanic training costs were estimated based on extrapolations of start-up data obtained from contacts with existing I/M programs in Arizona and Rhode Island. A summary of this data is presented in Table III-2.

TABLE III-2
Summary of Initial and Life-Cycle Start-up Costs

Start-up Cost Component	Initial Cost** (1981 Dollars)	Life-Cycle Cost (1982-1986)
Labor	$ 198,000	$ 261,000
Program Design	116,000	153,000
Public Information*	1,346,000	1,777,000
Training		
State	51,000	67,000
Private Garage	768,000	1,068,000
TOTAL	$ 2,479,000	$ 3,326,000

* Costs incurred during 2 years prior to program start-up

** Based on 1978 estimates escalated to 1981 dollars at an annual rate of 5%.

The life cycle costs shown in the table are based on an interest rate of ten percent for the State and 12 percent for the garage. The start-up training costs shown for the private garages are based on a "baseline" case of 4,200 garages certified to conduct inspections. The start-up cost per garage is estimated to be approximately $180. Details and supporting data on the start-up cost analysis conducted are presented in Appendix C.

4. PROGRAM ADMINISTRATION COSTS ANALYSIS

Program administration costs are those costs incurred by the State in administering the I/M program. They include the salaries of personnel involved in program enforcement, consumer protection, program evaluation, mechanic/inspector training, clerical support, garage licensing, data processing, program surveillance, and program management. They can also include utilities and supplies costs; however, these costs were considered separately in the methodology.

A potential organization plan for the program staff is shown in Appendix D. Calculation of the life cycle program administration costs were determined as follows:

$$\text{Life Cycle Program Administration Costs} = \sum_{j=0}^{n-1} \left[L(1+w)^j + PI\ (1+e)^j \right]$$

where:

PI = Annual public information costs, equal to the number of vehicles times ten cents per vehicle (1978 costs) escalated to 1982 costs at a rate of five percent per year

L = Base year (i.e., year of program initiation) labor costs of personnel associated with the I/M program, equal to:

$$F + \sum_k NP_k \times w_k$$

where NP_k equals the number of personnel in personnel category k (e.g., secretary, engineer, inspector, supervisor, etc.), w_k equals the average annual salary of a person in category k, and F equals fringe benefits

w = Composite annual wage escalation factor

e = Annual inflation factor

n = Life of the program

j = Year of the program, where j=0 represents the first year, j=1 represents the second year, and so on.

Personnel requirements (NP_k) were determined based on analysis of data obtained from the existing I/M programs of Arizona and Rhode Island, and inputs obtained from discussions with key personnel at the Registry of Motor Vehicles. Public information costs were based on data received from the Arizona I/M program and have been estimated at a high rate to ensure strong support for the program. Average annual salaries by category (w_k) and the wage escalation factor were determined based on analysis of the State of Massachusetts salary schedules for the past five years. A summary of this data is presented in Table III-3.

The wage escalation rate used in computing the life cycle cost figures shown in the table was 5 percent. The public information costs which were calculated separately were estimated to average $614,000 annually and to total $3,070,000 over the life of the program. Background information on the table is contained in Appendix D.

5. EMISSIONS TESTING COSTS ANALYSIS

In a private garage I/M program, the labor and overhead costs associated with performing the inspections are not borne by the State but rather by the private garage and are passed directly to the motorist as part of the inspection fee. This part of the fee is determined by the length of time required to conduct the inspection, the garage's service rate, and the number of inspections performed (life cycle emissions testing costs). Calculation of these costs were determined as follows:

$$\text{Life Cycle Emissions Testing Costs} = NI \times \sum_{j=0}^{n-1} IC \times (1+W)^j$$

TABLE III-3
Summary of Personnel Requirements and Costs

Labor Cateogry	Number Required	Annual Salary** (1982 Dollars)	Annual Costs** (1982 Dollars)	Life-Cycle Costs (1982-1986)
Director	1	$29,000	$ 29,000	$ 160,000
Field Manager	1	25,400	25,400	140,000
Statistician	1	18,800	18,800	104,000
Public Information Officer*	1	-	-	-
Computer Programmer	1	20,000	20,000	110,000
Training Officer	1	20,000	20,000	110,000
Field Supervisors	5	19,400	97,000	535,000
Maintenance Technician	1	16,900	16,900	93,000
Field Officers	70	16,300	1,141,000	6,298,000
Data Entry Clerks	3	11,300	33,900	187,000
Secretary	1	11,100	11,100	61,000
Data Clerks	3	10,300	30,900	171,000
Fringe Benefits (30 percent)			433,000	2,391,000
TOTAL	84		$1,877,000	$10,360,000

* Costed separately as part of public information costs.

** Based on 1978 estimates escalated to 1982 dollars at an annual rate of 5 percent.

where:

NI = Number of inspections performed over the life of the program

IC = Labor cost per inspection, equal to:

$$IT \times LR$$

where IT is the time per inspection, and LR is the average garage service rate

W = Composite wage escalation factor

n = Life of the program

j = Year of the program, where j=0 represents the first year, j=1 represents the second year, and so on

The average garage service rate was determined based on analysis of garage service rates gathered in a random survey of repair facilities in different parts of Massachusetts, while the wage escalation factor was based on analysis of the State of Massachusetts salary rate schedule for mechanics for the past 5 years. A summary of the 1978 service rates gathered from the survey by facility type, together with the average service rate computed is presented in Table III-4. The average service rate computed for 1982 based on a 5 percent annual wage escalation rate from 1978 was $18.15.

TABLE III-4
Summary of Garage Service Rates
By Type of Facility By Geographic Location
(1978 Dollars)

Garage Type	Boston	Springfield	Worcester	Average
Independent Garage	$14.00	$15.00	$10.00	$13.00
New Car Dealer	16.00	15.00	18.00	16.00
Average	$15.00	$15.00	$14.00	$15.00

6. UTILITIES AND SUPPLIES COST ANALYSIS

These costs are associated with the purchase of office supplies, computer charges and the operation of State challenge garages (heating oil and electricity) and mobile vans (gasoline and oil). The life cycle cost equation for computing life cycle utilities and supplies costs is as follows:

$$\text{Life Cycle Utilities and Supplies Costs} = \sum_{j=0}^{n-1} (U + M + S) \times (1 + e)^j$$

where:

U = Total average annual utilities cost (heating oil and electricity) associated with operation of the State challenge garages in the base year

M = Total average annual utilities cost (gasoline and oil) associated with the operation of the mobile vans in the base year

S = Total average annual supplies cost in the base year

e = Annual inflation factor

n = Life of the program

j = Year of the program, where j=0 represents the first year, j=1 represents the second year, and so on

Average annual utility costs were estimated based on conventional engineering cost estimating procedures (see Appendix D). Average annual supplies costs were based on data supplied by the Vehicle Inspection Section of the Registry of Motor Vehicles and include costs for printing and computer charges. Fuel and oil costs for the mobile vans were estimated at an average cost of $.14 per mile from analysis of "Hertz Estimates of Vehicle Operating Costs, October, 1977" and U.S. Department of Commerce Publication "Personal Consumption Expenditures for Transportation: 1976." Figures from these documents were escalated to 1982 dollars. A summary of the utilities and supplies costs estimated is presented in Table III-5.

TABLE III-5
Summary of Utilities and
Supplies Costs to the State

Utilities and Supplies Cost Components	Annual Costs (1982 Dollars)**	Life Cycle Costs (1982 - 1986)
Utilities*		
Heating Oil	$ 8,000	$ 44,000
Electricity	6,000	33,000
Gasoline and Oil (Mobile Vans)	2,000	11,000
Supplies		
Printing	42,000	232,000
Computer	12,000	66,000
TOTAL	$ 70,000	$ 386,000

* Represents total for the six challenge garages.

** Based on 1978 estimates escalated to 1982 dollars at an annual rate of 5 percent.

7. MAINTENANCE AND REPAIR COST ANALYSIS

These are costs assoicated with the upkeep of the State challenge garages and mobile vans, and private garage emissions analyzers. Like utilities and supplies costs, calculation of maintenance and repair life-cycle costs is as follows:

$$\text{Life Cycle Maintenance and Repair Costs} = \sum_{j=0}^{n-1} (CG+MV+EA)\ (1+e)^j$$

where:

CG = Total average annual maintenance and repair costs associated with challenge garages in the base year

MV = Total average annual maintenance and repair costs associated with mobile vans in the base year

EA = Total average annual maintenance and repair costs associated with emissions analyzers in the base year

e = Annual inflation factor

n = Life of the program

j = Year of the program, where j=0 represents the first year, j=1 represents the second year, and so on.

Estimates of maintenance and repair costs for exhaust emissions analyzers were based on data received from the major manufacturers of this equipment including the cost of calibration gases. A summary of these costs both per analyzer and total, as well as annual versus life cycle, is presented in Table III-6. Details are presented in Appendix D. Annual maintenance and repair costs for the State challenge garages including analyzers, were found to be slightly less than $10,000. Maintenance costs for mobile vans include parts and labor for vehicle repairs as well as emission analyzer maintenance costs.

TABLE III-6
Summary of Maintenance
and Repair Costs

Maintenance and Repair Cost Components	Annual Costs (1982 Dollars)*	Life Cycle Costs (1982-1986)
Private Garages		
Emission Analyzer Per Garage	$ 61	$ 337
For 4,200 Garages	$256,000	$1,414,000
State Facilities		
Challenge Garages	$ 10,000	$ 55,000
Mobile Vans 5 @ $600	$ 3,000	$ 17,000
Total	$269,000	$1,486,000

* Based on 1978 estimates escalated to 1982 dollars at an annual rate of 5 percent.

8. ANNUAL LICENSING FEE

Having repair facilities licensed to perform inspections is an aid to the consumer whose vehicle requires emissions related inspection and/or maintenance. For the proposed I/M program it was assumed that the criteria for a repair establishment to obtain certification was having a certified mechanic on the staff and purchasing a State approved emissions analyzer. The costs of satisfying these two requirements were considered elsewhere in the methodology. In addition to these requirements, however, it was also assumed that the garage would be required to pay to the State an annual license renewal fee.

Based on data from the States of New York, Rhode Island, and New Hampshire, which presently have a periodic safety and/or emissions inspection program and conversations with key personnel at the Registry of Motor Vehicles, it was assumed that an annual licensing fee of $25 would be charged the garages. These costs, however, were not included in the inspection fee calculation discussed in Chapter IV, since the program cost is not affected by this fee. While these costs were not included in the inspection fee calculation, the State will receive approximately $105,000 per year from this fee.

9. SUMMARY OF COST ANALYSIS RESULTS

The cost analysis results described in the previous sections are presented in Table III-7. As shown in the table, the private garages bear the major economic burden. The analysis indicates that the average garage would have an initial capital investment of approximately $2,550 and a start-up cost of approximately $182 (primarily for training). The average annual operating cost per garage would be approximately $2,264.

As also shown in the table, capital investment and start-up costs for the I/M program taken together exceed average annual operating costs. This results in a high initial program expenditure rate as shown in Figure III-2. When funds to cover this initially high investment are borrowed (at 10 percent for Massachusetts and at 12 percent for private garages) then actual program costs are as shown in Figure III-3. Included in these costs are interest and principal costs, salvage values and annual operating costs. The sum of these annual costs is the life-cycle cost.

TABLE III-7
Summary of Capital Investment, Start-up and Operating Costs for Both State and Private Garages for an Inflation Rate of 5 Percent

COST ELEMENT	STATE	PRIVATE GARAGES (TOTAL)	PRIVATE GARAGES (Individually)
CAPITAL INVESTMENT			
Initial Costs (1981 Dollars)	$ 915,000	$10,710,000	$ 2,550
Life-Cycle Costs (1982-1986)	481,000*	14,887,000	3,545
START-UP			
Initial Costs (1981 Dollars)	1,711,000	768,000	182
Life-Cycle Costs (1982-1986)	2,258,000	1,068,000	254
OPERATING			
Average Annual Costs (1982-1986)	2,778,000	9,510,000	2,264
Life-Cycle Costs (1982-1986)	13,888,000	47,548,000	11,321
TOTAL PROGRAM			
Initial Costs (1981 Dollars)	2,626,000	11,478,000	2,732
Life-Cycle Costs (1982-1986)	$16,627,000	$63,503,000	$15,120

* Includes salvage value credit of $730,000.

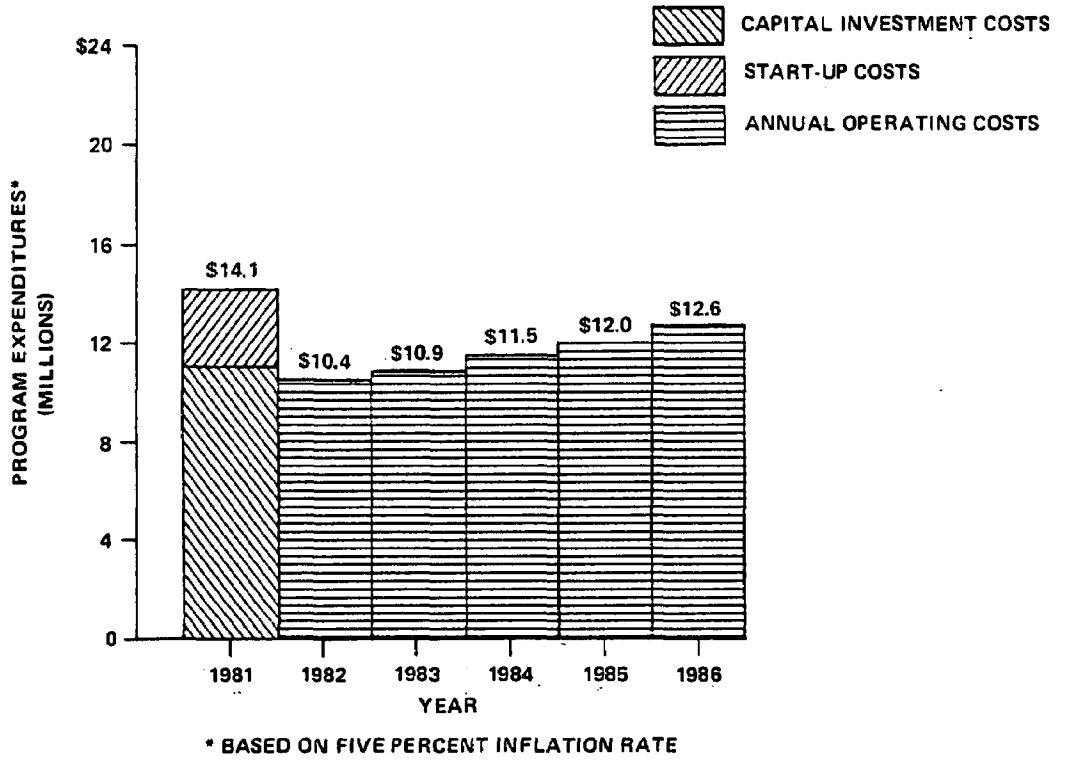

FIGURE III-2
Comparison of Program Expenditures Over the Life Cycle

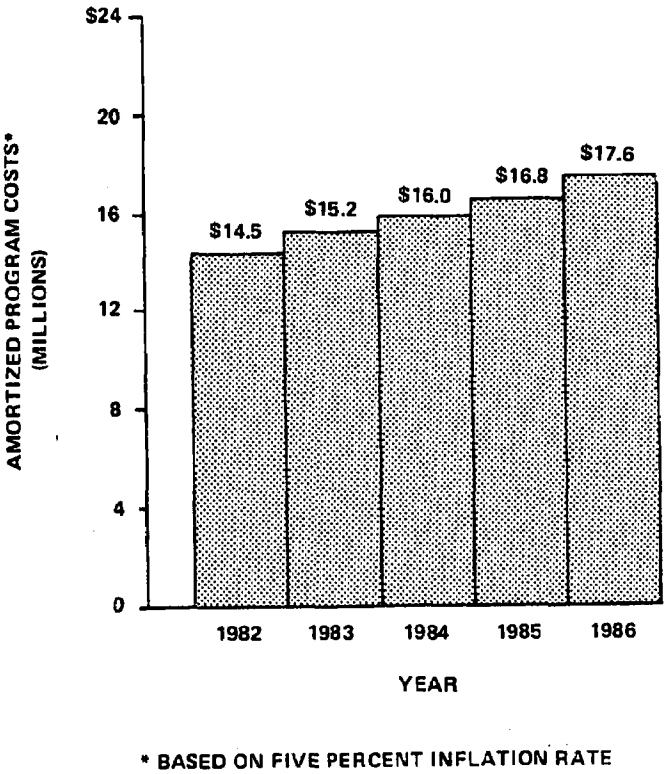

FIGURE III-3
Comparison of Actual Program Costs Over the Life Cycle

IV. ANALYSIS OF THE IMPACT ON THE INSPECTION FEE OF CHANGES TO MASSACHUSETTS EXISTING SAFETY PROGRAM

IV. ANALYSIS OF THE IMPACT ON THE INSPECTION FEE OF CHANGES TO MASSACHUSETTS EXISTING SAFETY PROGRAM

Calculation of the inspection fee to be charged per vehicle for emissions inspection is determined by dividing the State and private garage life-cycle costs by the total number of vehicles inspected over the life of the program. The previous chapter summarized the life-cycle costs which would be incurred by both the State and the private garages by inclusion of an emissions inspection test as part of the annual safety inspection. This chapter describes the impact on the inspection fee of adding an emissions test to the existing safety inspection. The chapter also describes the impact on the following program types:

- Combined annual emissions and existing safety inspection program
- Combined annual emissions and upgraded safety inspection program.

1. CALCULATION OF INCREMENTAL INSPECTION FEE ASSOCIATED WITH EMISSIONS INSPECTION

As was shown in Figure III-1, life cycle vehicle registrations are a major input to the calculation of the per vehicle inspection fee. Life cycle vehicle registrations are defined as annual vehicle registrations summed over the life of the program. They are calculated by multiplying the number of vehicles registered in the base year (1982) by a factor which accounts for the growth in the vehicle population over the life of the program. Expressed mathematically, life cycle vehicle registrations are calculated as follows:

Life Cycle Vehicle Registrations = VR x VG

where:

VR = Total number of registered vehicles in the base year (e.g.,1982)

VG = Life cycle vehicle growth rate factor, equal to:

$$\sum_{j=0}^{n=1} (1+AVG)^{j}$$

where AVG equals the annual vehicle growth rate, n equals the life of the program, and j equals the year of the program; where j=0 represents the first year, j=1 represents the second year, and so on.

In carrying out this analysis for the proposed I/M program, the following was performed:

- Vehicle registration data was obtained from the Registry of Motor Vehicles for the 10 year period, 1969-1978. Based on analysis of this data, an annual vehicle growth rate factor of 4.3 percent was computed.

- Data was obtained from the U.S. Bureau of Census on the distribution of truck weights and the Motor Vehicle Manufacturers Association on the distribution of vehicles by age. Based on analysis of this national data, the number of light duty vehicles less than 15 years old was computed for the State of Massachusetts.

The results of the above analyses broken down by vehicle class for 1982, together with an estimate of the number of vehicles estimated to be inspected over the life of the program (1982-1986) are presented in Table IV-1. The life cycle vehicle registration data shown in the table is based on a linear extrapolation of the vehicle registration data from 1978 to 1986 at an annual rate of 4.3 percent. Supporting documentation is presented in Appendix E.

TABLE IV-1

Summary of Light Duty Vehicles
Less Than 15 Years Old By Vehicle Class

Vehicle Class	Vehicle Registrations (1982)	Life Cycle Vehicle Registrations (1982-1986)
Passenger Vehicle	3,742,000	20,500,000
Motorcycles	103,000	600,000
Commercial Vehicles	289,000	1,600,000
State and Municipal Vehicle	38,000	200,000
TOTAL	4,172,000	22,900,000

Using the data presented in Table IV-1, the incremental fee to be charged the consumers as a result of adding an emissions inspection test to the existing safety inspection program can now be calculated. This is determined by dividing the total program life cycle costs (State and private garage) from Table III-7 by the total number of vehicles estimated to be inspected over the life of the program from Table IV-1. To summarize,

$$\text{Incremental Inspection Fee} = \frac{\text{Total Program Life Cycle Costs}}{\text{Life Cycle Vehicle Registrations}}$$

A summary of this fee calculation is presented in Table IV-2.

TABLE IV-2

Summary of Fee Calculation

	Total Program Life Cycle Costs	Life Cycle Vehicle Registration	Average Annual Inspection Fee	Percent of total Fee
State	$16,627,000	22,900,000	$0.73	21%
Private Garage	63,503,000	22,900,000	2.77	79%
TOTAL	$80,130,000	22,900,000	$3.50	100%

As shown in the table, the incremental fee to be charged the consumer by adding an emissions test to the existing safety inspection program would be $3.50; $0.73 of which would go to the State to cover amortization and other annual operating costs, and $2.77 of which would go to the private garage to cover the garage owner's equipment amortization and operating costs. As also shown, the bulk of the fee (79 percent) goes to cover the costs of private garages. These costs are primarily labor costs. For this reason, the required fee would probably have to be increased in 1987 because of increased mechanic labor rates if the program continued. Figure IV-1 displays the rate at which the required break-even fee for the emissions I/M program increases over the 5 year program period.

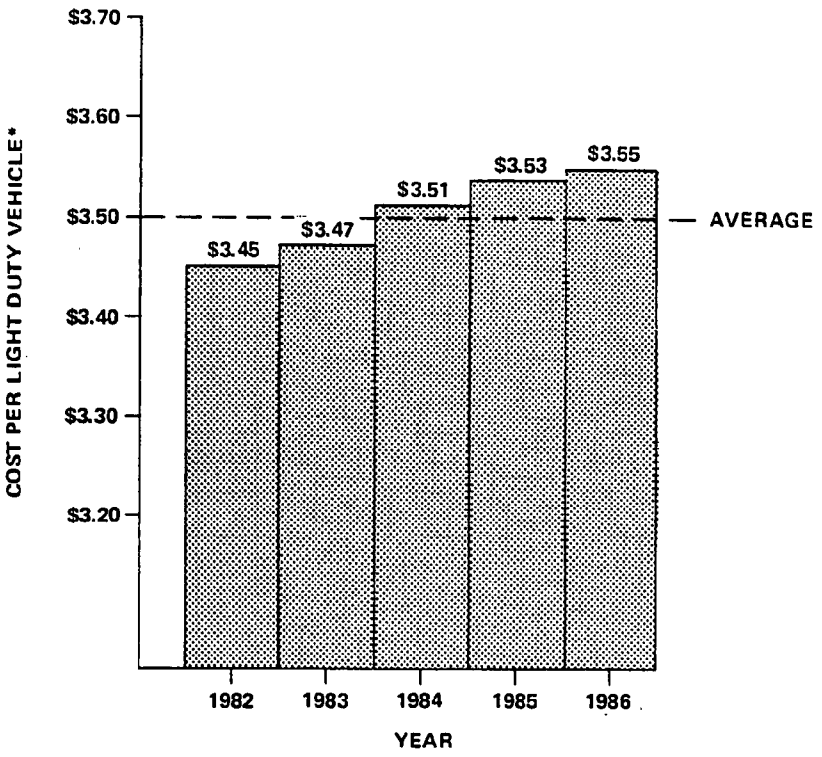

FIGURE IV-1

Comparison of Incremental Cost
Per LDV Over the Life Cycle

2. COMBINED ANNUAL EMISSIONS AND EXISTING SAFETY INSPECTION PROGRAM

The preceeding analysis of emissions inspection costs was based on the assumption that all costs incurred by either the State or private garage in development, implementation and operation of the I/M program would be passed on to the consumer through the inspection fee. In order to determine the fee for a combined emissions and safety inspection program, the safety program must also assume a self-supporting posture. This is primarily true for the following reasons:

- The $2.00 fee for the existing safety program goes entirely to the private garage, with no funds collected to support government administration of the program.

- Analysis of the emissions inspection fee covered the entire cost incurred by the garage in performing the inspection (i.e., 5 minutes times the average garage service rate). This is not the case for the present safety program where the garage is only allowed to charge $2.00 for an inspection estimated to take 10 minutes.

In addition to the above, the existing fee of $2.00 for the safety inspection has not changed since 1930. As was illustrated in Figure IV-1, and as will be discussed in greater detail in Chapter V, the inspection fee is sensitive to program life, primarily due to inflation. Thus an argument can be made that the $2.00 fee which was established back in 1930 is obviously outdated. According to people at the Vehicle Inspection Section of the Registry of Motor Vehicles, this in fact has been the major argument of the auto repair industry for some time.

To determine the combined annual emissions/safety inspection fee, a life cycle cost analysis was requred where both segments of the inspection were self-supporting and projected garage service rates over the 1982-1986 timeframe were included. To accomplish this, the following analyses were conducted:

- The existing annual safety inspection budget of $950,000 was inflated to 1982 dollars and the life-cycle operating costs over the 1982-1986 time period calculated.

- The life-cycle costs which would be incurred by the private garages in conducting safety inspections on all eligible vehicles over the timeframe 1982 - 1986 were calculated. This was accomplished assuming a ten minute safety inspection and a $15.00 per hour (1978 costs) average garage service rate inflated over the 1982 - 1986 time period.

- The above costs were divided by the anitcipated number of vehicles to be inspected (from Table IV-1) over the five-year life of the program (i.e., 22,900,000) to determine the average annual safety inspection fee. This figure was added to the computed emissions inspection fee for the same time period to arrive at a combined annual emissions/safety inspection program fee.

The results of this analysis are presented in Table IV-3.

TABLE IV-3
Inspection Cost Per Vehicle of a Combined
Annual Emissions and Existing Safety Inspection Program

COST ELEMENT	Life Cycle Costs (1982-1986)	Life Cycle Vehicle Registration (1982-1986)	Average Annual Safety Inspection Cost Per Vehicle	Average Annual Emission Inspection Fee Cost Per Vehicle	Average Combined Safety/ Emissions Cost Per Vehicle
State Safety Inspection Operating Cost	$ 6,345,000	$22,900,000	$0.28	$0.73	$1.01
Private Garage Safety Inspection Labor Cost	92,124,000	22,900,000	4.02	2.77	6.79
TOTAL	$98,469,000	$22,900,000	$4.30	$3.50	$7.80

As shown in the table, the average annual cost per vehicle for a self-supporting safety inspection was calculated to be $4.30. By adding this fee to the annual costs per vehicle for a self-supporting emissions test, the total fee for a self-supporting combined emissions/existing safety inspection was calculated to be $7.80.

3. COMBINED ANNUAL EMISSIONS AND SAFETY INSPECTION PROGRAM UPGRADED TO NHTSA VIU GUIDELINES

In addition to implementing emissions testing, the State of Massachusetts is contemplating changes in the existing safety program. These changes include:

- The inclusion of a wheel pull to inspect brakes.
- The inclusion of other tests which are either recommended now or will be required by the National Highway Traffic Safety Administration (NHTSA) to improve the safety of vehicles-in-use (VIU).

As a result of these changes, an increase in the vehicle inspection fee can be anticipated. Thus, one of the objectives of the study was to estimate the potential impact of such changes to the existing safety program on the inspection fee. Prior to estimating the adjustment in fee, the exact changes which are needed to upgrade the safety inspection were identified through the following steps:

- NHTSA VIU standards were reviewed and compared with the Massachusetts inspection procedures and standards.
- NHTSA planning documents and recent testimony on inspection were reviewed to identify future inspection requirements.

With the information gained from these analyses, the potential impact of the changes on the inspection fee was calculated. First, the fees and procedures of 13 states in the New England and Mid-Atlantic regions were analyzed to gain information on normal fees in other states. Second, cost estimates for the extra inspection tests were developed.

(1) Comparison of NHTSA VIU Standards and Procedures With Massachusetts Inspection Standards and Procedures

A comparison of the NHTSA VIU and Massachusetts inspection standards is presented in Table IV-4. As shown in the table, NHTSA VIU standards prescribe tests only for those systems which have been shown to be major causal or contributing factors to accidents, i.e., brakes, steering, alignment, suspension, tires and wheel assembly. In contrast, Massachusetts standards prescribe inspection of three of the systems recommended by NHTSA (brakes, steering and tires) plus five others which are safety-related, but not included in the NHTSA standards (headlights, muffler and exhaust, horn, glazing and body). Massachusetts inspection regulations do not presently require:

- Visual inspection of:
  - Brake failure indicators
  - Brake pedal reserve
  - Brake hoses and assemblies
  - Brake power unit
  - Power steering system
  - Suspension and shock absorber condition
  - Tread type
  - Wheel mounting and integrity.
- Mechanical inspection of wheel alignment using a bar-type, scuff gauge or other toe-in measuring device.
- The removal of one front wheel and one rear wheel to inspect disc and drum condition, friction materials, structural and mechanical parts.

Thus, to upgrade Massachusetts safety inspection to the NHTSA VIU guidelines, it was found that the above inspection tests would have to be added to the safety inspection program.

(2) Review of NHTSA Planning Documents for Future Vehicle Inspection Standards

Recent NHTSA planning documents were reviewed to identify any potential future vehicle-in-use

TABLE IV-4

Comparison of NHTSA and Massachusetts
Vehicle System/Component Inspection Requirements

Vehicle System/Component	NHTSA	Massachusetts
Service Brake System	X	X
Failure Indicator	X	
Brake System Integrity	X	X
Brake Pedal Reserve	X	
Service Brake Performance	X	X
Brake Hoses and Assemblies	X	
Disc and Drum Condition	X	
Friction Materials	X	
Structural and Mechanical Parts	X	
Parking Brake		X
Brake Power Unit	X	
Steering	X	X
System Play	X	X
Linkage Play	X	X
Free Turning	X	X
Alignment	X	
Power Steering System	X	
Suspension	X	
Suspension Condition	X	
Shock Absorber Condition	X	
Tires	X	X
Tread Depth	X	X
Tread Type	X	
General Condition	X	X
Damage	X	X
Wheel Assembly	X	
Wheel Integrity	X	
Deformation	X	
Mounting	X	
Lights		X
Headlamp Aim		X
Rear Lamps		X
Marker Lights		X
Exhaust System		X
Horn		X
Glazing		X
Windshield		X
Rear Windows		X
Bumpers, Fenders and Body		X

inspection standards. A major document, the "Five Year Plan for Motor Vehicle Safety and Fuel Economy Rulemaking (March, 1978)" describes planned rulemaking activities intended for the regulation of new motor vehicles but do not specify standards for periodic inspection of vehicles-in-use. A more recent publication, "Evaluation of Diagnostic Analysis and Test Equipment for Small Automotive Repair Establishments (July, 1978)"* contains a discussion of current and future motor vehicle inspection standards. This report points out that no Federal standards or guidelines comparable to new car standards for emissions and fuel economy are planned for vehicles-in-use. However, in addition to the emissions inspection requirements mandated by EPA, the report identifies three areas where states may be developing future inspection standards:

- Noise. The Noise Control Act of 1972 authorizes the Administrator of the EPA to develop, issue and enforce environmental noise standards. The agency has completed and issued regulations on some types of construction equipment and on medium and heavy duty trucks. Although no noise standards have to date been issued for passenger automobiles, light trucks or motorcycles, the EPA has proposed (March, 1978) rules to reduce noise from new motorcycles and replacement mufflers for motorcycles.

- Fuel Economy. There is an urgent national need to conserve petroleum based fuels. While the only fuel economy standards that now exist are set for new cars, it is expected that periodic inspections can assist motorists to improve their fuel economy by inspecting vehicle components which significantly affect fuel consumption, such as the ignitiion system, carburetor, air filter, PCV valve, etc.

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* U.S. Department of Transportation, "Evaluation of Diagnostic Analysis and Test Equipment for Small Automotive Repair Establishments, A Report to the Congress," July, 1978.

- Crashworthiness. Recent developments in passive restraints and improved bumpers may eventually result in vehicle safety inspection standards to maintain the effectiveness of these improved safety components and assure their ready-state condition.

In summary, while no new inspection standards are presently contemplated by NHTSA, the agency is investigating vehicle noise, fuel economy and crashworthiness as potential areas for motor vehicle standards.

(3) Analysis of the Fees and Procedures of 13 States in the New England and Mid-Atlantic Regions

An examination of the inspection fees of 13 States in the New England and Mid-Atlantic Region which have safety and/or emission inspection programs provided information on the normal fees charged for comparable inspections in other states. Through the process of elimination, the 13 programs were reduced to four which were most comparable to the type of garage-based inspection program anticipated for Massachusetts. A summary of the 13 State programs reviewed is presented in Table IV-5. Reasons for elimination from analysis of 9 of the States are given below.

- Connecticut and Maryland. A fundamental characteristic of the Massachusetts program is that it requires periodic inspection. Two of the States reviewed, Connecticut and Maryland, only require vehicle inspection upon change of ownership. A change of ownership inspection program is considerably less of an administrative and operating burden to the repair industry than an annual or semi-annual program; thus, the fees in these States were eliminated from further comparison with Massachusetts.

- Delaware and New Jersey. Delaware and New Jersey require periodic vehicle inspections, but the inspections are performed in State-operated central facilities.

TABLE IV-5

Summary of Inspection Programs in Northeastern and Mid-Atlantic States

STATE	FEE	TYPE OF FACILITY		FREQUENCY			TYPE OF INSPECTION		
		STATE LANES	CERTIFIED GARAGE	SEMI-ANNUAL	ANNUAL	CHANGE OF OWNERSHIP	SAFETY ONLY	INCLUDES WHEEL PULL	SAFETY & EMISSIONS
Connecticut	$2.00	X				X	X		
Delaware	Free	X			X		X		
Maine	$2.00		X	X			X		
Maryland	*		X			X		X	
New Hampshire	*		X	X				X	
New Jersey	$2.50	X			X		X		
New York	$3.00		X		X			X	
North Carolina	$3.10		X		X		X		
Pennsylvania	*		X	X				X	
Rhode Island	$4.00		X		X			X	X
Vermont	*		X	X			X		
Virginia	$4.00		X	X				X	
West Virginia	$4.62		X		X			X	

* Inspection fee is variable depending upon the hourly service rate charged by the inspection station.

State-operated inspection lanes may realize economies in their operation which certified garages do not, such as high volume throughput and centralized training and data collection. The fees for these programs (Delaware, free and New Jersey, $2.50) were therefore eliminated from comparison with the fees for inspection programs which are operated by commercial repair businesses.

- Maine, North Carolina and Vermont. These States were eliminated from comparison with Massachusetts on the basis that they do not require a wheel pull during the inspection. The addition of a wheel pull to the current safety inspection in Massachusetts may increase the inspection time by 9 to 11 minutes. States which do not pull a wheel charge 20 percent less for inspection than States which do.*

- New Hampshire and Pennsylvania. These States do not have a uniform fee; that is, they allow each inspection garage to determine the fee based on a posted hourly service rate. As a result, the best available information on the inspection fees of these States are estimates made by the program administrators based on personal and professional experience with the inspection program. These types of estimates are insufficient for detailed comparison with a program charging a uniform fee, such as Massachusetts.

Of the 13 States surveyed, 4 (New York, Rhode Island, Virginia, and West Virginia) were found to have periodic inspection programs broadly similar to the type of program contemplated for Massachusetts. All 4 require a wheel pull as part of the brake test, are operated by certified garages and have a standardized inspection fee. Only Rhode Island, however, has an annual emissions inspection test. A summary of the fees for these 4 programs is shown in Table IV-6.

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* The average fee for Maine, North Carolina and Vermont (no wheel pull) is $3.00, while the average for New York, Virginia and West Virginia (require wheel pull) is $3.83, excluding tax in West Virginia.

TABLE IV-6
Summary of Inspection Fees for
Inspection Programs Similar to Massachusetts

State	Inspection Fee
New York	$3.00
Rhode Island	$4.00
Virginia	$4.00
West Virginia	$4.62*

The average of the 4 fees is $3.90, and the most frequent fee is $4.00. However, because these fees do not contain all the inspection requirements contemplated by Massachusetts, it was determined that it would be inappropriate to extrapolate these fees to the Massachusetts situation.

(4) Estimate of the Cost Per Vehicle of a Combined Annual Emissions and Upgraded Safety Inspection

To determine the cost per vehicle of upgrading the Massachusetts safety inspection program to NHTSA VIU guidelines, two analyses were conducted:

- An estimate was made of the time required to perform the additional safety inspection items required to meet NHTSA VIU safety standards.
- The life-cycle costs which would be incurred by the private garages in conducting such an inspection were calculated.

To obtain an estimate of the incremental time required for the additional inspection items, Chilton's and Glenn's automotive flat rate manuals, the Motor Vehicle Manufacturer Association (MVMA) inspection

* In West Virginia, a 3 percent tax is levied on the garage inspection fee of $4.00. In addition, the motorist pays a $0.50 surcharge to the State. $4.00 + $0.12 + $0.50 = $4.62.

manual, and NHTSA reports on vehicle testing were reviewed. Based on this review, it was found that neither the Chilton and Glenn Flat Rate Manuals nor the MVMA's Vehicle Inspection Handbook provided any estimates of the time required to perform inspections of individual vehicle components. Reports published by NHTSA, however, did provide some information on the incremental time required for the additional testing procedures.

The following incremental testing times were developed from the analysis:

- Visual inspection of eight additional components was estimated to require 5 minutes.

- A test for alignment using a scuff gauge or other toe-in measuring device was estimated to require 2 minutes.

- A wheel pull to inspect disc and drum condition, friction materials, structural and mechanical parts was estimated to require 10 minutes.

Using these test times, the life-cycle costs which would be incurred in conducting an upgraded safety inspection and the inspection cost per vehcile were calculated. The results of the analysis are shown in Table IV-7. As shown, the cost per vehicle for modifications to the safety inspection to meet NHTSA VIU standards was calculated as $6.73. When added to the cost for the combined emissions/existing safety inspection which was developed in Section 2 of this chapter, the total upgraded fee was determined. Thus, the total cost per vehicle for the combined and upgraded annual safety/emissions inspection was found to be $14.64.

TABLE IV-7
Inspection Cost Per Vehicle of a Combined Annual Emissions and Upgraded Safety Inspection Program

	5 Percent Inflation
Life-Cycle Cost of NHTSA VIU Modifications	$156,612,000
Life-Cycle Vehicle Registrations	22,900,000
Cost Per Vehicle of NHTSA VIU Modifications	$6.84
Cost Per Vehicle of Existing Safety Inspection	4.30
Cost Per Vehicle of Annual Emission Inspection	3.50
Combined Annual Emissions/ Upgraded Safety Inspection Program	$14.64

4. COMPARISON OF ANNUAL INSPECTION COSTS PER MOTOR VEHICLE FOR SELF-SUSTAINING EMISSIONS AND SAFETY I/M PROGRAMS

Table IV-8 presents the results of life-cycle cost calculations for three I/M programs for Massachusetts as follows:

Emissions I/M Program Only. Table IV-8 displays the self-sustaining program cost of emissions I/M, if it were totally separated from safety inspection. The cost per vehicle inspected is shown in the 1982-1986 time frame for an inflation rate of 5 percent.

TABLE IV-8
A Comparison of the Worst Case Annual Inspection Cost Per Motor Vehicle for Self-Sustaining Emissions And/Or Safety Inspection and Maintenance Programs (1982-1986 Time Frame at a 5 Percent Inflation Rate)

PROGRAM DESCRIPTION	REQUIRED FEE VEHICLE/YEAR (Self-Sustaning)
1. Emissions I/M Program Only	$ 3.50
2. Emissions I/M and Safety Inspection to Current Standards (Annual)	$ 7.80
3. Emissions I/M and Upgraded Safety Inspection Standards (Annual)	$14.64

. Emissions I/M and Annual Safety Inspection to Current Massachusetts Standards. This self-sustaining program combines emissions and safety inspection as a single annual inspection. The fee shown in Table IV-8 represents a worst case in which:

- All costs, both public and private, are accounted for in the fee.
- A 10 minute safety inspection to current Massachusetts standards is assumed and all garage costs are covered by the fee*

* The current fee of $2.00 per safety inspection was established at a time when garage labor rates were considerably lower than they are at present. For garages to be self-sustaining with the current fee, inspections must be performed in 5 minutes or less.

- No administrative economies are assumed in the public sector in the combined program administration.

Emissions I/M and Upgraded Annual Safety Inspection Standards. This is also a self-sustaining program. Again the result of detailed calculations shown in Table IV-8 represents a worst case. The assumptions are the same as those listed above with one addition. Upgrading current Massachusetts inspection standards to the level of those recommended by the U.S. Department of Transportation, National Highway Traffic Safety Administration is assumed (see Table IV-4). This increases garage inspection time from about 10 minutes to 27 minutes. The additional inspection tasks, which together require the additional 17 minutes, include wheel pulling to check brakes, front end alignment and additional visibility items. This additional inspection time is based on worst case assumptions.

Because of the worst case assumptions included in the detailed calculations, and the projected inflation rate, the projected self-sustaining inspection fee is high compared to those of current programs. This is to be expected!! It is a worst case fee and is inappropriate for consideration except as an interim step in the calculation.

In reality, the combined emissions and safety inspection takes advantage of two key economies as follows:

- Public sector costs are reduced by combining joint administrative functions related to both safety and emissions inspections.

- Private sector inspection charges are less than those which are calculated on a strict time and standard labor charge basis.

Overall costs as reflected in the required fee for a self-sustaining program can be reduced only a few percent by economies in the public sector. On the other hand, private sector charges must include appropriate reductions possible as a result of opportunities for other garage business generated by the inspection process. As a worst case, Table IV-8 assumes for cost analysis purposes a situation where an individual garage is not permitted to perform any repairs on automobiles it inspects. Table IV-8

results also assume that a garage serving as an inspection station cannot perform any repairs on any automotive components that failed inspection at another inspection station. Such assumptions are inherent in any calculation which assumes that each inspection must pay for itself totally.

Table IV-9 presents the final results of the analysis of required fee if public sector economies and current private sector business practices relative to inspection in Massachusetts* are taken into account.

TABLE IV-9
A Comparison of the Expected Annual Inspection Cost Per Motor Vehicle for Self-Sustaining Emissions And/Or Safety Inspection and Maintenance Programs (1982-1986 Time Frame, for 5 Percent Inflation Rate)

Program Description	Require Fee/ Vehicle/Year
1. Emissions I/M Program Only	$2.00 to $ 2.75
2. Emissions I/M and Safety Inspection to Current Standards (Annual)	$4.35 to $ 6.10
3. Emissions I/M and Upgraded Safety Inspection Standards (Annual)	$7.76 to $11.13

Because the final combined program for emissions and safety I/M is not precisely defined, the required fee must be presented as a range. The fees shown in Table IV-9, however, are based upon the fact that private garages will be permitted to repair items which fail inspections. A comparison of Tables IV-8 and IV-9 indicates that this is a very important aspect of the program if costs to the consumer are to be acceptable. Program costs as

* Fee estimates in Table IV-9 related to private sector costs assume that garages continue to recover the same percentage of their costs for each inspection as they do today at the lower number, but capture 25 percent more of their costs than currently permitted at the upper number.

reflected in the fees shown in Table IV-9 include adequate public sector surveillance, facility inspection, and challenge garage provisions to assure consumers that they are receiving appropriate inspection results.

V. SENSITIVITY ANALYSIS RESULTS

V. SENSITIVITY ANALYSIS RESULTS

Because of the uncertainties involved in estimating certain cost components, the final task of the study was to determine the sensitivity of the final cost analysis results to changes in some of the major program assumptions. As a result of this requirement, six of the major assumptions used in the cost analysis were varied and the analysis redone. The assumptions which were varied were:

- Interest rate
- Inflation rate
- Program life cycle
- Number of certified garages
- Method used for data handling.

This chapter presents the results of these analyses. Details of the analyses calculations are presented in Appendix G.

1. INTEREST RATE

The standard interest rate for funds borrowed by a State agency is 10 percent. This rate may vary, however, depending on the prime interest rate which is a function of many uncontrollable variables. To accomodate potential changes in this rate, the costs of the program were analyzed using alternative State borrowing interest rates of 8 percent, 10 percent and 12 percent, respectively. The effect of varying this rate on the average annual cost of inspection per vehicle is shown in Figure V-1. As apparent in the figure, the effect is negligible. Using all three rates, the fee to the motorist remains at approximately $3.50.

2. INFLATION RATE

Due to fluctuations in economic, political and other variables, forecasts of annual inflation rates over an eight year period are rarely accurate. Thus, the annual inflation rate of 5 percent assumed for this study may or may not be realistic. To study the effect of changes in

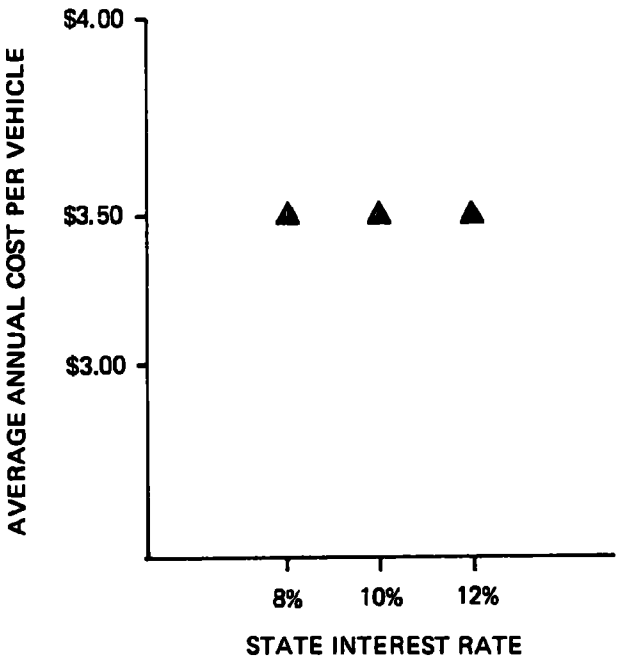

FIGURE V-1

Cost Comparison: Interest Rate

this rate on the average annual cost of inspection per vehicle, sensitivity analyses using annual inflation rates of 3 and 10 percent respectively were conducted. The results of these analyses are displayed in Figure V-2.

As is illustrated in the figure, the inspection cost per vehicle is significantly sensitive to changes in the inflation rate, i.e.,

- A 40 percent decrease in the inflation rate from 5 to 3 percent causes a 6 percent decrease in the inspection costs per vehicle ($3.50 to $3.28).

- A 100 percent increase in the inflation rate from 5 to 10 percent causes a 29 percent increase in the inspection cost per vehicle ($3.50 to $4.52).

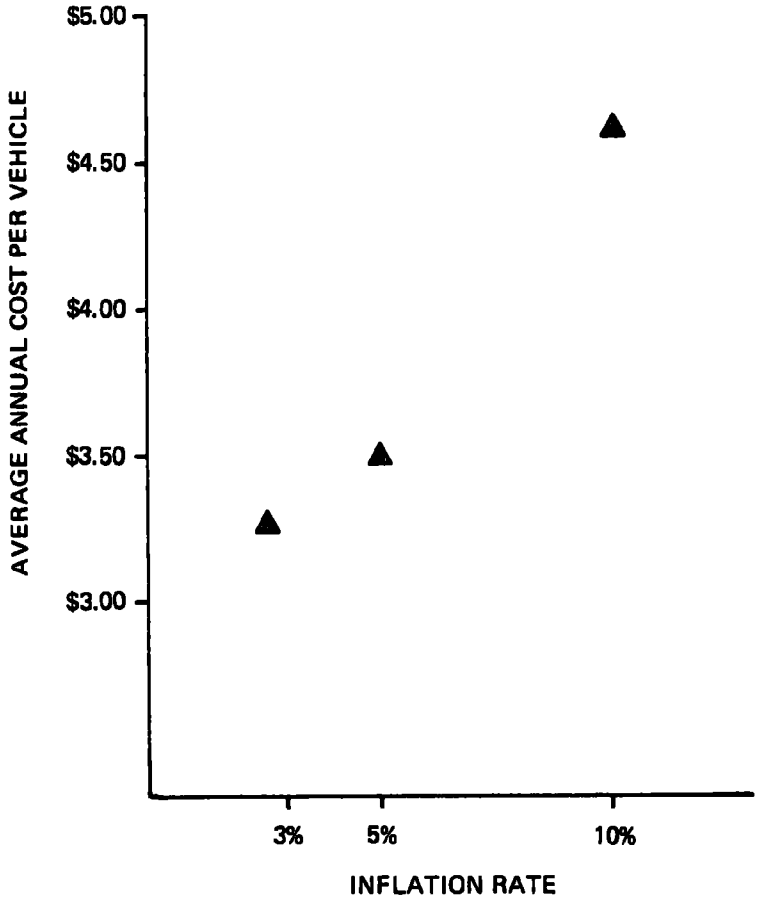

FIGURE V-2

Cost Comparison: Inflation Rate

The reason for this sensitivity is the labor intensive nature of the decentralized program.

3. PROGRAM LIFE CYCLE

In carrying out the "baseline" cost analysis, it was assumed that the life of the program would be 5 years. This assumption was made based on the requirement that attainment of air quality standards in "non-attainment" areas be achieved by January 1, 1987. Based on a start-up date of January 1, 1982 for the proposed Massachusetts I/M program, and assuming attainment will be achieved as required, the life of the program at a minimum would be 5 years.

However, because there is always the possibility that Massachusetts legislators will rescind the program before attainment of the standards or that the program will be extended indefinitely, sensitivity analyses were conducted varying the program life cycle. To accomplish this, analyses of three and ten year life cycles were conducted for comparison with the base case of a five year life cycle. The results of these analyses are shown in Figure V-3.

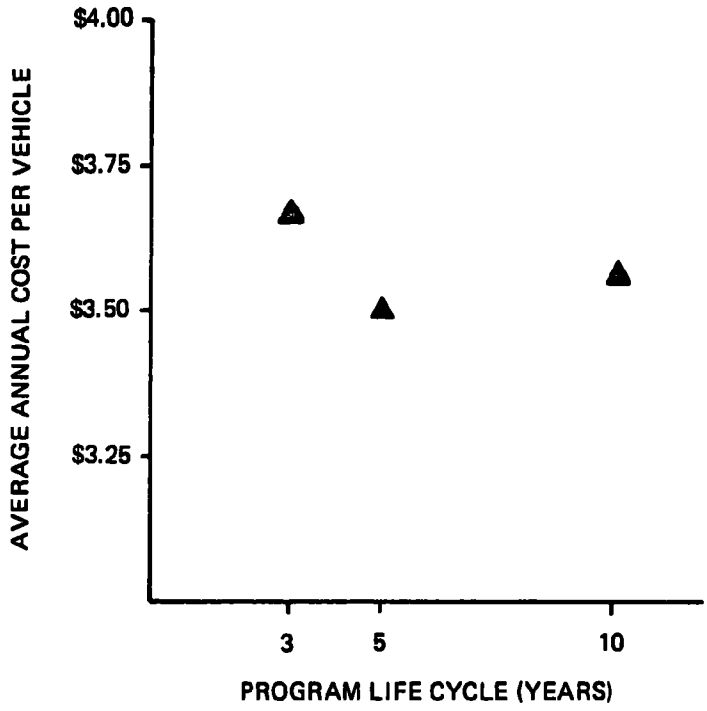

FIGURE V-3
Cost Comparison: Program Life Cycle

To summarize:

- When the program life cycle is changed from five to three years, the cost increases by $0.13, from $3.50 to $3.63. This is explained by the fact that the program debt must be amortized in a shorter timeframe.

- When the program life cycle is changed from five to ten years, the cost increases by $0.07, from $3.50 to $3.57. While a 10 year period for debt repayment might intuitively seem to result in a lower cost per vehicle over the life of the program, costs are increased by inflation and the necessary replacement of emissions analyzers.

Thus, variations in the life-cycle of the program are expected to moderately impact the cost of the inspection program to the individual motorist.

4. NUMBER OF CERTIFIED GARAGES

It is difficult to accurately predict the number of garages which will seek certification as licensed emissions/safety inspection facilities. The number of garages presently licensed for safety inspection is approxiamtely 4,200. After implementation of emissions testing this number may grow or it may decline. Thus, to determine the impact that changes in the number of garages will have on the cost of the program, sensitivity analyses were conducted assuming 3,000 and 5,000 certified garages, respectively. The results of these analyses are illustrated in Figure V-4.

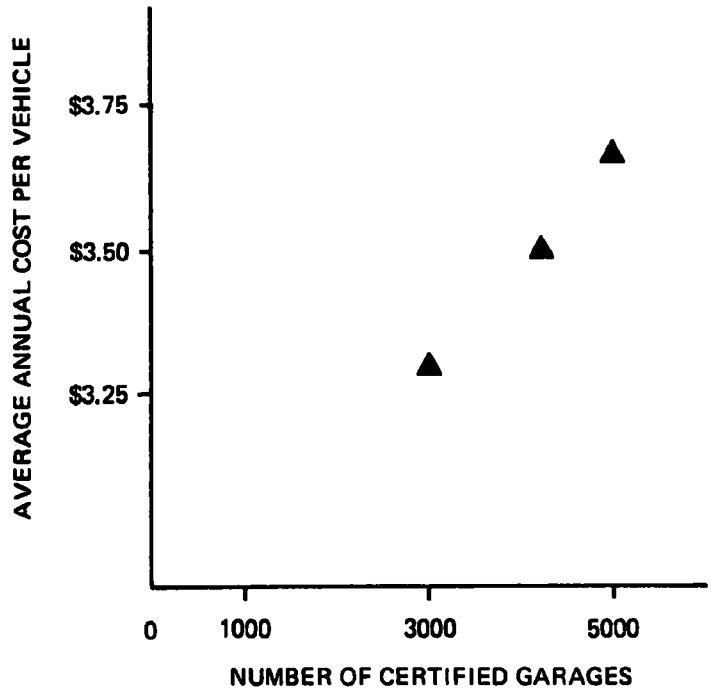

FIGURE V-4

Cost Comparison: Number of Certified Garages

As shown, assuming that the presently licensed 4,200 garages participate in the combined emissions/safety program, the cost per vehicle would be $3.50. This result was discussed earlier in Chapter IV. As for the impact of reducing the number of garages from 4,200 to 3,000 or increasing the number of garages to 5,000, the following results are observed:

- When the number of certified garages is decreased to 3,000, the cost per vehicle decreases to $3.28. This results from the need for less equipment and reduced surveillance, administration and inspection labor requirements.

- When the number of certified garages is increased to 5,000, the cost per vehicle increases to $3.64. This results from the additional costs which will be incurred to process the increased number of licensing applications, to periodically check the equipment in the increased number of garages and to handle the anticipated increase in the number of complaints.

Thus, based on the above, it can be expected that a change in the number of garages will moderately affect the cost of the program.

In addition to conducting a sensitivity analysis on the total number of certified garages, part of the scope of work also called for an analysis of the minimum number of garages that would be necessary to meet certain proximity criteria. These criteria were:

- Within I-495, each garage would be located no more than 5 miles apart

- Outside I-495, each garage would be located no more than ten miles apart.

To accomplish this, the following formula was used:

$$\text{Minimum Stations Required} = \frac{\text{Area Inside I-495}}{\pi \times (2.5)^2} + \frac{\text{Area Outside I-495}}{\pi \times (5)^2}$$

The factors 2.5 and 5 in the formula represent the radius of a 5 mile circle and 10 mile circle, respectively, as is shown graphically in Figure V-5 (i.e., the number of garages required inside I-495 is estimated by determining the number of circles with a 2.5 mile radius that will fit inside the I-495 beltway, while the number of garages required outside I-495 is estimated by determining the number of circles with a 5 mile radius that will fit outside the I-495 beltway). The results of this analysis are as follows:

- Minimum number of stations required inside I-495 beltway: 92
- Minimum number of stations required outside I-495 beltway: 77
- Total minimum number of stations required: 169

When compared with the total requirement for inspections in Massachusetts, each of the 169 stations would have to inspect 30,000 vehicles per year in order to satisfy the demand. This is clearly unrealistic. Although the density of garage locations inside or outside I-495 and the typical waiting time are factors which appear to impact the volume of inspections per garage, closer analysis shows that these factors principally affect the consumer convenience of the program rather than dictating the minimum number of certified garages needed. Factors which are critical to calculation of the minimum number of garages include the following:

- The total volume of vehicles to be inspected each year
- The number of minutes required to perform each inspection
- The number of inspections which a certified garage can realistically be expected to perform in one day
- The number of days per year which a certified garage will be available for inspecting cars.

The assumptions and supporting calculations for each of these factors are presented below:

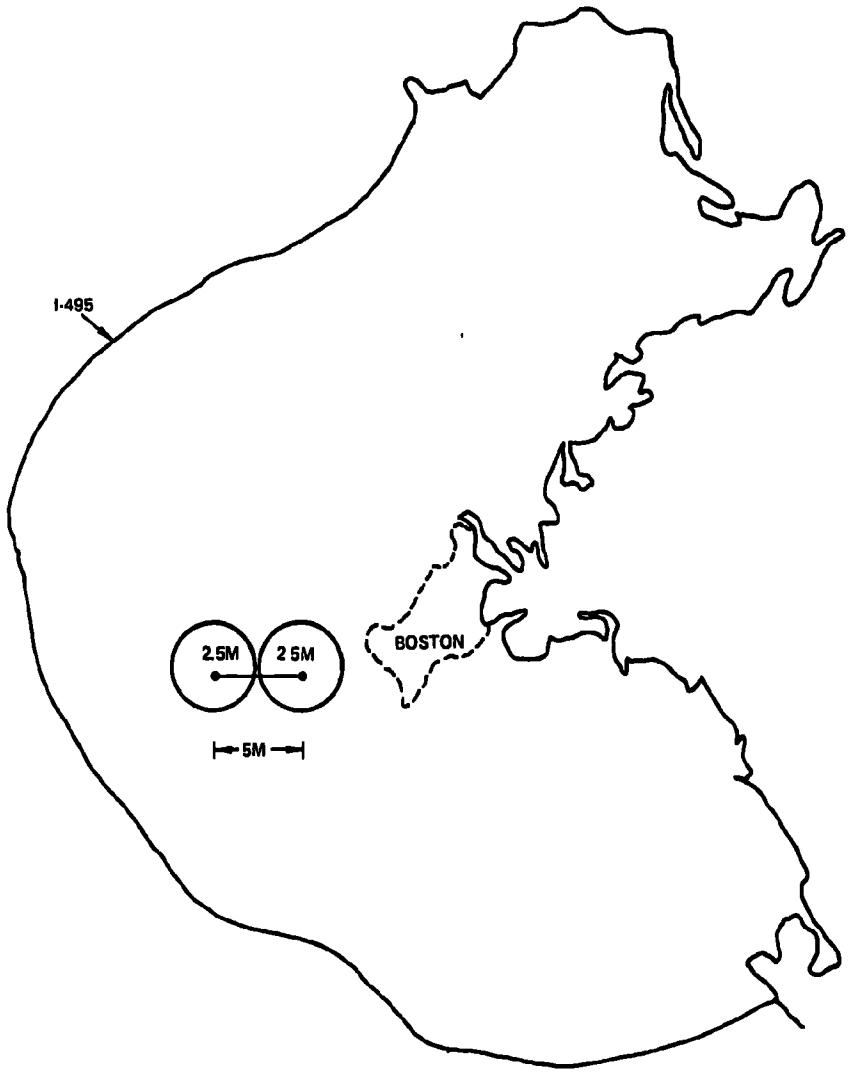

FIGURE V-5

Illustration of Method for Estimating Minimum Number of Inspection Stations Within I-495

- Number of Inspections. To accommodate future growth in the vehicle population, the total inspection volume was calculated to be approximately five million vehicles in 1986.

- Inspection Time. Ten minutes are presently required for conducting safety inspections. This inspection time will be supplemented by an additional 5 minutes to conduct an emissions test. The total time required to perform a combined safety and emissions test was therefore assumed to be 15 minutes.

- Daily Inspections Per Garage. Given a 15 minute inspection time, a certified garage could inspect 4 vehicles per hour or 32 vehicles per eight-hour day, if no other work were performed. In fact, the garage will be actively engaged in the auto repair business. A rough estimate of the amount of time which each garage may devote to the inspections is from 35 to 40 percent of the working day. Therefore, each garage was assumed to be capable of inspecting an average of 12 vehicles per day.

- Total Inspection Days. The final assumption necessary to calculate the minimum number of stations was the number of inspection days per year. Each garage was assumed to be open for business a minimum of 260 days per year, based on typical labor calendars.

The minimum number of certified garages needed for the program was calculated as follows:

$$\text{Minimum Number of Garages} = AM \div AG$$

Where:

AM = Annual number of vehicles subject to inspection in Massachusetts in 1986 (i.e., 5,000,000)

AG = Annual number of vehicles inspected at each garage, equal to:

$$VD \times TD$$

where VD is the number of vehicles inspected daily at each garage (i.e., 12) and TD is the total number of garage operating days per year (i.e., 260).

As a minimum, 1603 private certified inspection garages were found to be needed to provide combined safety and emissions inspections in Massachusetts.

5. MANUAL DATA HANDLING AND ANALYSIS

The calculation of life cycle costs for the inspection program base case assumed that program data would be collected, stored and analyzed using electronic data processing equipment. Costs for a computer programmer, several data entry operators and charges for computer time were therefore included in the cost estimates. If instead of using electronic data processing (EDP) equipment the data is analyzed manually, the EDP costs would be replaced by manual data processing costs, principally additional data clerks. This change in the program would not significantly impact the cost per vehicle, however, since both methods result in a cost of $3.50 per vehicle. It is expected that there may be fewer errors and greater efficiency, however, if electronic equipment is used.

* * * *

In summary, this chapter presented the results of sensitivity analyses which were conducted to determine the degree to which variations in major cost assumptions impact the inspection cost per vehicle. To recap, the factor which was found to most impact the cost per vehicle was inflation rate. The factors which were found to moderately impact the per vehicle inspection cost were the number of licensed garages and the number of years the program continues in operation. Variations in the interest rate and the method used for data processing (manual or automated) were found to have no significant impact on the inspection cost per vehicle.

APPENDIX A

SUMMARY OF BUILDING AND LAND COST DATA

1. SUMMARY OF BUILDING COST DATA

The estimation of building costs for the six State challenge garages was conducted in two steps.

- Estimation of building requirements
- Estimation of building cost

The process for deriving these estimates is described in the sections below.

(1) Estimation of Building Requirements

The use of challenge garages in inspection/maintenance programs is a new concept. Only two other I/M programs in the United States provide this service. For this reason, there is very little experience to guide us in designing such a facility. The only type of centralized inspection facility for which data is available is the high capacity types used in New Jersey, Phoenix, Portland and Chicago. These facilities are designed for performing up to 1500 inspections per day. Since a challenge garage would only reinspect those vehicles whose owners suspect a faulty initial inspection, the facility capacity requirements will not be as great. Challenge garages may be much smaller than the high capacity facilities. Experience in Rhode Island and Nevada, the only states with a challenge garage, indicates that the capacity requirements are not great.

In designing the challenge garage for estimating the building requirements, the following criteria were considered:

- drive-through lanes
- one station per lane (inspection position)
- two lanes per facility
- 14 x 5 meters per lane
- office and storage space
- good quality masonry construction

Figure A-1 is a preliminary sketch of the proposed challenge garage. The layout and size of the facility closely resemble a service station.

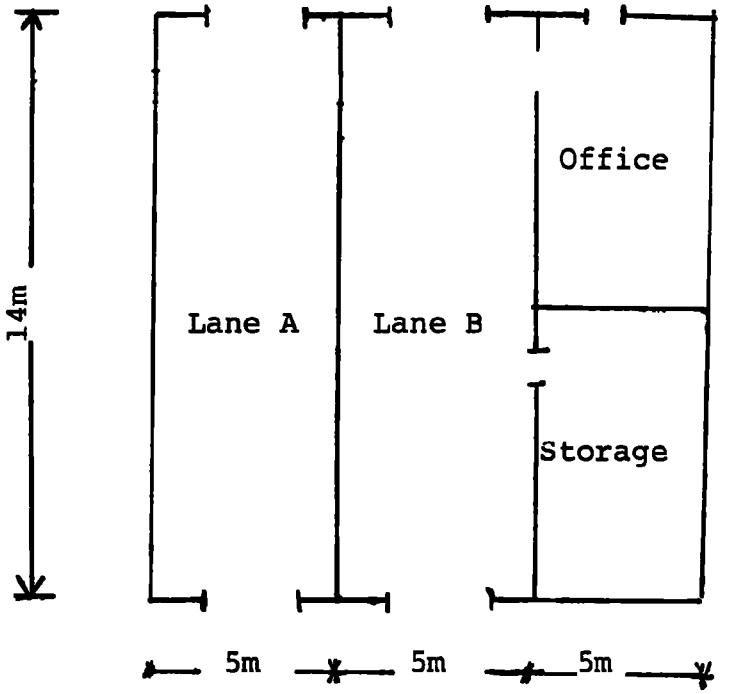

FIGURE A-1
Challenge Garage Sketch

The high capacity inspection facilities require a land area to building ratio in the range of 10:1 to 5:1. Since capacity is not a problem here, the lower end of the range was used in estimating land requirements.

(2) Estimation of Building Cost

Building costs were estimated using conventional engineering estimation techniques. Data for building costs were obtained from a cost calculator developed by Marshall Valuation Service. Multipliers were applied to convert the costs to reflect local conditions. The calculations below describe how the building costs were derived.

1. Base Cost:

Office and Two Bays	$285 per square meter (26.50 per square foot)

2 Hoists (@ $2500 ea) $5000

Paving = 13 cm concrete (5 inches) $12 per square meter ($1.10 per square foot)
Asphalt $4.30 per square meter ($.40 per square foot)

2. Composite Cost

Office and Two Bays (14x15) x $285 $59,850
Hoists 5,000
$64,850

Conversion to 1978 Dollars (1.05^2 x 64,850)
= $71,850

Conversion to Massachusetts costs (1.05 x 71,850) = $75,440

BUILDING COST PER SQUARE METER $\left(\frac{75,440}{210}\right)$ = $359

Paving (14x15)x(5-1)x$16.30 = $13,700
Conversion to 1978 Dollars
(1.05^2 x $13,700) $15,100

Conversion to Massachusetts cost (1.05x$15,100) = $15,800

PAVING COST PER SQUARE METER $\left(\frac{15,800}{840}\right)$ = $19

2. SUMMARY OF LAND COST DATA

In order to estimate what the approximate costs would be to build auto emmission testing challenge facilities in the four cities studied, current land costs were collected for each metropolitan area according to general locational criteria. The sources of information for each city are shown in Table A-1. These sources were asked to represent market conditions as of August 1978.

TABLE A-1
Sources of Cost Information by City

Boston-Metropolitan Area	Boston Economic Development & Industrial Commission 617-725-3342
	Leggat, McCall & Werner, Inc. 617-423-7272
	Boston Redevelopment Authority 617-722-4300
Springfield	MacMillan & Son, Inc. 413-736-8338
Worcester	John Maher Real Estate Associates 617-832-5831
	Worcester Chamber of Commerce 617-753-2924
New Bedford*	New Bedford Industrial Development Commission 617-997-6501
	New Bedford Chamber of Commerce 617-999-5231

An effort was made to obtain cost data based on actual sites and buildings for sale in downtown, in-city and surburban locations. General criteria included:

- One-quarter to one acre of land
- Industrial or commercial zoning
- Access to major arterial roads
- Normal utility service at site

Each city is summarized as to findings in Table A-2 and described according to current market conditions in the following paragraphs. When reviewing the cost data, several factors should be understood:

- While it is likely that the test facilities could be built in either commercial or industrial zoned areas, commercial zoned sites are invariably higher in cost by $11-54 per square meter ($1-4 per square foot).

* New Bedford was selected as being representative of land costs in Southeastern Massachusetts.

TABLE A-2
Summary of Locational Cost Data by City

Location	Land Cost Per Square Meter	General Comments
(1) Springfield	$11.00 - $21.00	. North Side primarily industrial/commercial . Better residential to the South and East . Majority of the population east of the Connecticut River . Land acquisition costs fairly consistent throughout area
(2) Worcester	$5.00 - $16.00	. Major routes routes 290 and 9 provide easy access and circulation to metropolitan area . Primary suburban residential communities lie to the northwest, commercial/industrial concentrations to the east (Shrewsbury) and south (Auburn) . Several vacant service stations available in area
(3) Boston	$9.00 - $43.00	. Land costs vary substantially within metropolitan area due to strict growth controls adopted by selected communities . Wide variety of sites ranging from strip commercial, industrial parks and free-standing industrial sites . Convenience to major interstates and 128 intersections increases and equalizes cost differentials among communities
(4) New Bedford	$2.00 - $4.50	. Considerable industrial land available for reasonable rates from the Greater New Bedford Industrial Foundation . Land costs vary according to readiness for building and the extent of available utilities

- While Boston has industrial or commercial sites that have been made available through urban renewal, community development or EDA* projects, the land projects are frequently competitive with private sector offerings.

- Existing warehouse space varies tremendously from city to city in terms of cost, availability, location and suitability. Thus lease terms and costs were not explored in any detail.

- Land costs do not include fees, financing or other charges.

(1) Cost for Boston Metropolitan Area

The City of Boston forms the center of the fan-shaped metropolitan area which contains a population of approximately three million people. About 700,000 people live within the Boston city limits. Major transportation corridors feed into downtown Boston from the north, west and south urban municipalities located within the state highway, Route 128, which circles the high urbanized Boston area. The section of Route 128 between Dedham and Waltham has attracted major industrial and corporate development which has in turn drawn major regional commercial retail and office support facilities. Lower density and primarily residential communities have developed beyond Route 128. Many of these communities have adopted strong growth management policies which severely limit industrial or commercial development.

The City of Boston has several redevelopment projects underway, some of which could accommodate a challenge garage facility. However, the inner city locations might not necessarily provide the greatest convenience to the entire metropolitan area.

Given the physical configuration of the Boston metropolitan area briefly described above, land costs for industrial and commercial sites can vary significantly depending upon:

- Local community development controls

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* Economic Development Administration, U.S. Department of Commerce

- Proximity to major transportation corridors and particularly interchanges with Route 128
- Industrial or commercial office complexes versus strip and spot development sites
- Applicable building and design codes.

Land costs could range from $9.00 to $43.00 per square meter ($.80 to $4.00 per square foot) for areas within or adjacent to Route 128. The in-city sites which have been made available by public programs range from $9.00 to $21.00 per square meter ($.80 to $2.00 per square foot). Site costs within other areas outside of Boston reflect the general range accordingly:

- $11.00 per square meter ($1.00 per square foot) in the Dorchester area
- $21.00 per square meter ($2.00 per square foot) in the Brighton-Alston area
- $16.00 - $21.00 per square meter ($1.50 - $2.00 per square foot) in the Newton/ Waltham area
- $25.00 - $32.00 per square meter ($2.30 - 3.00 per square foot) in the Dedham area
- $38.00 - $43.00 per square meter (3.50 - $4.00 per square foot) for commercial-retail areas in the vicinity of Route 128.

(2) Cost for Springfield

The City of Springfield contains approximately 175,000 people and functions as the center of a metropolitan area comprising 600,000 population. Springfield is separated from West Springfield by the Connecticut River with the population distribution roughly 70 percent and 30 percent, east and west of the River, respectively. The Chicopee-Holyoke corridor which runs north of Springfield and is traversed by the Massachusetts Turnpike and Route 91, has a substantial amount of industrial and commercial development. The better residential areas tend to be to the south, east and west of the city.

Industrial zoned sites range in cost from $11 to $21 per square meter ($1.00 to $2.00 per square foot) with land on the north side frequently falling into the lower end of the range ($11.00 to $16.00 per square meter). A commercially zoned site will cost at least $21.00 to $38.00 per square meter. Springfield enjoys good access and circulation systems; therefore, several locations on the east and north sides, particularly, could be considered convenient within the metropolitan area.

(3) Cost for Worcester

The Worcester metropolitan area contains approximately 365,000 people and is located midway between Boston and Springfield. About 175,000 people live within the Worcester city limits. Several major transportation routes serve Worcester; Route 9 connects Worcester and Boston, while Route 290 bisects the City of Worcester and intersects with the Massachusetts Turnpike just south of Worcester at Auburn.

While downtown prime commercial land commands $108 - $129 per square meter ($10 - $12 per square foot) other in-city land zoned for industrial use is available for about $8100 per hectare--$5.00 per square meter ($20,000 per acre or $.46 per square foot). Suburban industrial zoned acreage, well-located with respect to the major transportation routes ranges in price from $10,000 to $18,000 per hectare or $6.00 to $11.00 per square meter ($25,000 to $45,000 per acre or $.57 to $1.03 per square foot).

(4) Cost For New Bedford

The New Bedford metropolitan area contains approximately 191,000 people and includes the neighboring towns of Dartmouth, Rochester, Westport, Acushnet, Fairhaven, Freetown, Marion, Mattapoisett and Wareham. New Bedford is in the southeast section of Massachusetts, just East of Newport, Rhode Island and West of Cape Cod. The city of New Bedford has a population of 100,000.

The major transportation route through New Bedford is I-195. Traffic from Boston into New Bedford is on Route 140, while Routes 18 and 105 provide truck and

freight connections from Brockton, a major warehousing district to the North. Route 6 connects Wareham and the New Bedford area with Cape Cod.

Considerable industrial land in the New Bedford area is owned by a private non-profit foundation, the Greater New Bedford Industrial Foundation. This foundation sells land at competitive rates in order to attract industry to the area. Most of the land is organized into industrial parks ranging in size from 1,000 to 300,000 acres. Land may be obtained from this foundation for as low as $5,000 per acre.

Generally the costs of land in New Bedford depend on its readiness for building and the extent of available utilities. Industrial/commercial land with full utilities and leveled for construction may cost as much as $19,600 per acre. Property which is partially served by utilities ranges in costs from $10,000 to 12,000 per acre or $.23 to $.27 per square foot. Some commercial/industrial property on the waterfront which is part of a harbor development project is available for lease at $6,000 per acre or $.14 per square foot.

APPENDIX B

CAPITAL INVESTMENTS SUMMARY

TABLE B-1
Salvage Values

At the end of the life cycle (5 years),		
Building value*	=	$595,000
Land value*	=	$135,000
Equipment value	=	0

* Factors used to compute building decay and land appreciation were obtained from Comparative Cost Analysis for Decisions to Lease or Purchase General Purpose Real Property, OMB circular A-104.

TABLE B-2

Summary of Capital Investments
(1978 Dollars)

	STATE	PRIVATE GARAGE
Challenge Garage		
- Lanes	2 per facility at 65 square meters each, at $359 per square meter	-
- Offices	1 per facility at 65 square meters, at $359 per square meter	
- Paving	780 square meters per facility at $19 per square meter	-
- Program Storage and Laboratory Facility	130 square meters at one challenge garage at $359 per square meter	-
Land	5:1 ratio of land to building area: 5 x 195 = 975 square meters at $26 in Boston, $16 in Springfield and $11 in Worcester and $3 in New Bedford ($ per square meter)	-
	650 square meters additional land for program storage and laboratory facility at $11 per square meter	-
Equipment		
- Analyzer	4 per challenge garage at $2,200 each	1 per garage at $2,000 ea.
- Computer	4 data entry devices at $1,000 each	-
- Mobile Units	5 at $14,200 including analyzer ($2,200) generator ($2,000), hand tools ($500) and custom van ($9,500).	

APPENDIX C

SUMMARY OF START-UP COSTS

TABLE C-1
Estimated Start-up Labor Costs For
Massachusetts Private Garage-Operated Inspection Program
(1978 Dollars)

Position	Salary	Number	Cost
Director	$24,000	1	$ 24,000
Field Enforcement Manager	21,000	1	21,000
Statistician	15,500	1	15,500
Public Information Officer*	-	-	-
Training Officer*	-	-	-
Garage Licensing Supervisor	13,900	1	13,900
Maintenance Technician	14,000	1	14,000
Computer Programmer	16,500	1	16,500
Secretary	9,200	1	9,200
Data Clerks	8,500	2	17,000
Fringe Benefits (30%)			39,300
	TOTAL		$170,400

* Costs are included in public information and training startup costs.

TABLE C-2
Start-up Training Costs
(1978 Dollars)

State Inspectors (paid by State of Massachusetts)		
2-week course for State inspectors:		
1 Training Officer (6 months preparation)	Salary	$ 7,300
	Benefits	2,190
48 Inspectors (2-weeks pay during course)	Salary	$21,600
	Benefits	6,480
5 Supervisors (2-weeks pay during course)	Salary	$ 2,560
	Benefits	770
Course Materials and Other Expenses		$ 3,000
	TOTAL	$43,900
Garage Mechanics (paid by mechanics/garage)		
32 hour course (similar to Colorado State University course)		
1 Training Officer (6 months preparation)	Salary	$ 7,300
	Benefits	2,200
4200 Mechanics (4 days pay during course)	Salary	$649,800
Course Materials and Other Expenses		$ 3,000
	TOTAL	$662,300

TABLE C-3

Summary of Start-Up Costs
(1978 Dollars)

	STATE	PRIVATE GARAGE
Labor	(See Table C-1)	-
Training	$43,900 for two week course for 53 inspectors and supervisors	$662,300 for 4 day course for 4200 mechanics (one per garage)
Public Information	29¢ per vehicle for 4.0* million light duty vehicles in 1981	-
Program Design	$100,000	-

* Based on information received from Arizona I/M program

APPENDIX D

SUMMARY OF OPERATING COSTS

TABLE D-1
Estimated Operating Labor Costs For
Massachusetts Private Garage Inspection Program
(1978 Dollars)

Position	Salary	Number	Cost
Director	$24,000	1	$ 24,000
Field Inspection/ Enforcement Mgr.	21,000	1	21,000
Statistician	15,500	1	15,500
Public Information Officer*		1	
Training Officer	16,500	1	16,500
Field Enforcement Supervisors	16,500	5	80,000
Maintenance Technician	14,000	1	14,000
Computer Programmer	16,500	1	16,500
Field Enforcement Officers**	13,500	70	910,000
Data Entry Clerks	9,300	3	27,900
Secretary	9,200	1	9,200
Data Clerks***	8,500	3	25,500
Fringe Benefits (30%)			221,348
TOTAL		84	$1,508,000

* Costs are included in public information operating costs.

** Officers who will inspect garages which have applied for certification, perform routine checks for certified garages, respond to complaints about individuals stations, provide inspections at the challenge garages and perform other routine surveillance activities.

*** Will also support garage licensing and data analysis activities.

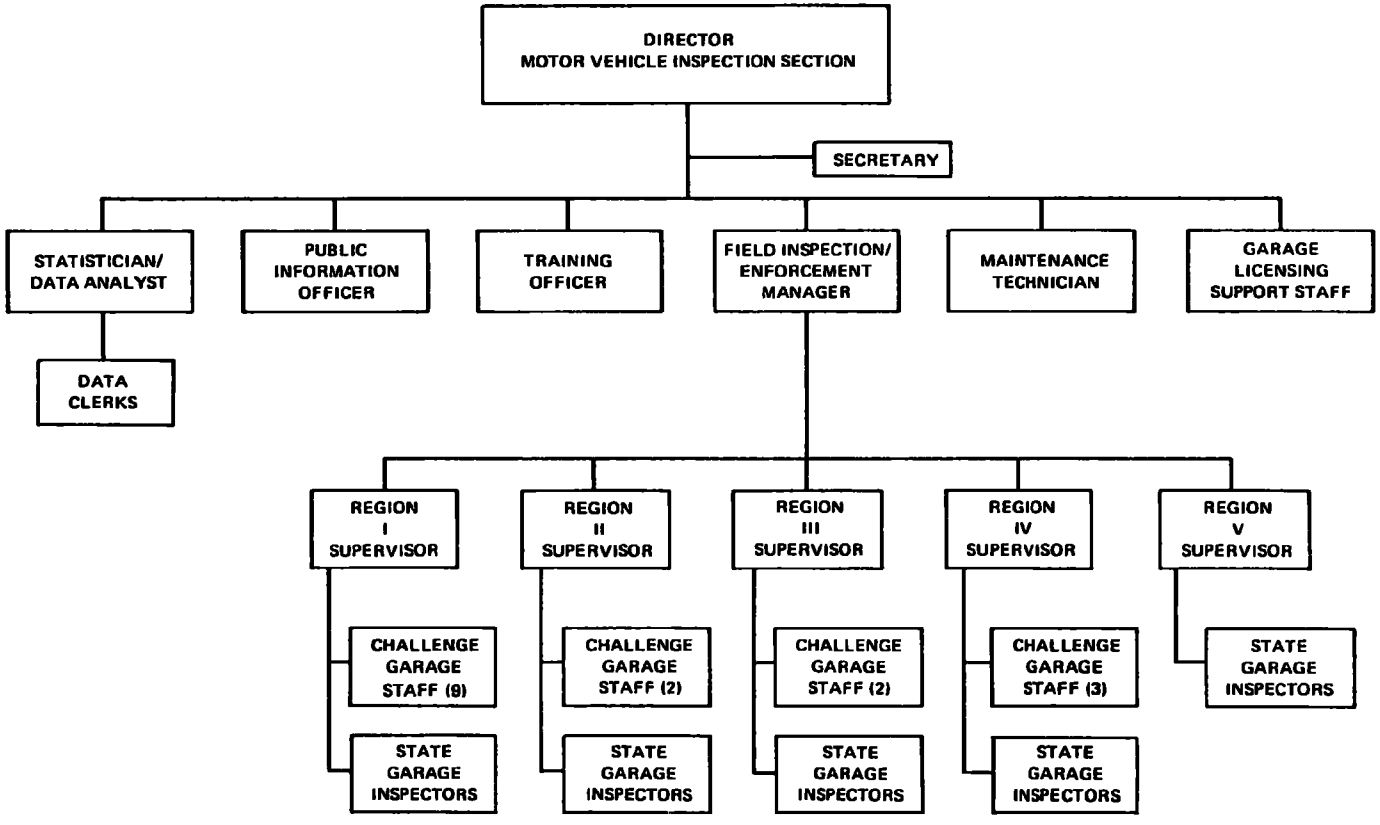

FIGURE D-1

Example of Organization Plan
for Massachusetts Motor Vehicle Inspection Program

TABLE D-2
Garage Life-Cycle Operating Cost
For Emissions Inspection

Assumptions:

Labor Rate - $15 per hour (includes overhead)

Emissions Inspection Time - 5 minutes

Inspections and Reinspection - 27.5 million

Life Cycle Inflation Rate - 34%

Life Cycle Operating Cost:

$$\$15 \times \frac{5}{60} \times 27.5 \text{ million} \times 1.34 = 46{,}062{,}000$$

TABLE D-3

Calculation of Fuel Oil Requirements and Cost For a Massachusetts Challenge Garage

Average Outdoor Temperature	Hours at Outdoor Temperature	ΔT ($65^{\circ}F$)	Heat Load (10^3 Btu's)	Heat Loss (10^3 Btu's)	Annual Heat Loss (10^6 Btu's)	Night Set Back Factor	System Efficiency	Energy Requirements (10^6 Btu's)	Fuel Oil Use (gallons)	Cost
62	804	3	6.1	6.1	4.9	.82	.62	6.4	46	$ 23
57	781	8	16.2	10.1	7.9	.82	.64	10.1	72	36
52	766	13	26.3	20.2	15.5	.84	.68	19.1	136	68
47	757	18	36.4	30.2	22.9	.85	.68	28.6	204	102
42	828	23	46.5	40.3	33.4	.86	.69	41.6	297	148
37	848	28	56.6	50.4	42.7	.87	.69	53.8	384	192
32	674	33	66.7	60.5	40.8	.88	.70	51.3	366	183
27	429	38	76.9	70.6	30.3	.89	.70	38.5	275	138
22	256	43	86.9	80.7	20.7	.90	.71	26.2	187	93
17	151	48	97.1	90.9	13.7	.91	.71	17.6	126	63
12	74	53	107.2	101.0	7.5	.92	.72	9.6	69	35
7	35	58	117.3	111.1	3.9	.93	.72	5.0	36	18
2	4	63	127.4	121.2	.5	.94	.72	0.7	5	2
-3	9	68	137.5	131.3	1.3	.95	.72	1.7	12	6
									2214	$1107

Assumptions:

Building Configuration = 45'0" x 45'0" x 12'0" high
Door Area = 200 ft^2
Window Area = 50
Heating valve of Fuel = 140,000 BTU/gallon
Boston Fuel Oil Price = $.50/gal

TABLE D-4

Calculation of Electricity Requirements and Cost for a Massachusetts Challenge Garage

Lighting: Assuming 32 watts per square meter, the annual electricity usage is:

32 watts per square meter x 195 square meters x 2600 hours per year

= 16,224 KWH per year

Compressor: 920 watts x 2 hours per day x 260 days per year

= 478 KWH per year

TOTAL ELECTRICAL CONSUMPTION PER YEAR PER GARAGE

16,224 + 478 = 16,702 KWH

TOTAL COST PER YEAR PER GARAGE

16,702 x $0.05 per KWH = $835.

TABLE D-5
Summary of Operating Costs
(1978 Dollars)

	STATE	PRIVATE GARAGE
Labor	(See Table D-1)	(See Table D-1)
Public Information	10¢ per vehicle per* year	-
Other Operating Costs		
Utilities & Supplies	$58,000 per year for printing, computer charges, mobile units, and challenge garage utilities**	-
Maintenance & Repair	$13,000 per year for maintenance and repairs on mobile vans, challenge garages, and all emission analyzers	$61 per year per garage for calibration gas and analyzer maintenance***

* Based on Arizona I/M program

** Based on expenditures in existing Massachusetts inspection program and results derived from conventional engineering estimating procedures

*** Based on industry sources.

APPENDIX E

MASSACHUSETTS VEHICLE REGISTRATION

TABLE E-1
Calculation of 1977 Massachusetts
Light Duty Vehicle Registration

Assume 74% of all commercial vehicles are less than 10,000 lbs and that all buses are over 10,000 lbs.* Based on data supplied by the Massachusetts Registry of Motor Vehicles, 1977 light duty vehicles (L.D.V.) registration is:

Passenger Vehicles	3,110,612
Motorcycles	86,233
Commercial Vehicles	241,191
State & Municipal Vehicles	32,000
TOTAL L.D.V.'s	3,470,036

Assume that 2.5% of all vehicles are older than 15 years**

TOTAL L.D.V.'s (0-15 years old)	.975 x 3,470,036 = 3.4 million

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* Assumption based on national average of trucks owned, U.S. Bureau of the Census, Census of Transportation, 1972 Truck Inventory and Use Survey.

** Based on data supplied in MVMA Facts and Figures 1977.

TABLE E-2
Calculation of Massachusetts Registration Growth, 1968-1977

Year	Total Vehicles Registered
1968	2,365,517
1969	2,456,692
1970	2,616,751
1971	2,748,298
1972	2,899,450
1973	3,067,550
1974	3,211,790
1975	3,317,770
1976	3,448,885
1977	3,599,688

$$\frac{\text{1977 vehicles}}{\text{1968 vehicles}} = \frac{3,599,688}{2,365,517} = 1.52$$

Average Annual Growth: $(1.52)^{\frac{1}{10}} = 1.043$

or

4.3% per year.

TABLE E-3
Summary of Vehicle Population

1977 Registered Light Duty Vehicle (Less than 15 years old) (LDV's)*	3.4 million
Average Annual Growth (1968 - 1977)*	4.3 percent
Projected 1981 LDV's **	4.0 million
Projected Life Cycle Vehicles (1982 - 1986) ***	22.9 million
Projected Life Cycle Inspection ****	27.5 million

* Source: Commonwealth of Massachusetts, Registry of Motor Vehicles

** $(1.043)^4$ x 3.4 million

*** $\sum_{i=5}^{9} (1.043^i \times 3.4 \text{ million})$

**** Assumes a retest rate of 20 percent

APPENDIX F

SUMMARY OF TOTAL LIFE CYCLE COSTS, INFLATION ASSUMPTIONS, AND INSPECTION FEE CALCULATION

TABLE F-1
Five Year Life Cycle Cost Element Summary
(1982 - 1986 Dollars)

	COST ELEMENTS	
CAPITAL	Building	$ 855,000
	Land	166,000
	Equipment - State	190,000
	- Private Garages	14,887,000
START-UP	Labor - State	261,000
	Program Design	153,000
	Public Information	1,777,000
	Training - State	67,000
	- Private Garages	1,068,000
OPERATING	Labor - State	10,353,000
	- Private Garages	46,062,000
	Public Information	3,070,000
	Other Operating Costs - State	458,000
	- Garages	1,486,000

TABLE F-2
Assumed Inflation Index

Year	Index
1978	1.00
1979	1.05
1980	1.10
1981	1.16
1982	1.21
1983	1.28
1984	1.34
1985	1.41
1986	1.48

Assumptions Pertaining to Inflation

- All capital investments and start-up costs will be incurred in 1981.
- All operating costs are subject to a common inflation rate throughout the life cycle. The average index applied to operating costs is:

$$\frac{1.21 + 1.28 + 1.34 + 1.41 + 1.48}{5} = 1.34$$

TABLE F-3
Inspection Fee Calculation

Life Cycle Investment Cost = ICC =

$$\left[(\text{Building} + \text{Land} + \text{Equipment}) \times 1.16 \times 5 \times \frac{i(1+i)^5}{(1+i)^5 - 1} \right] - \left[\begin{array}{l} \text{Building and Land} \\ \text{Salvage Value} \end{array} \right]$$

Life Cycle Start-up Cost = SUC =

$$(\text{Labor} + \text{Training} + \text{Public Information} + \text{Program Design}) \times 1.16 \times 5 \times \frac{i(1+i)^5}{(1+i)^5 - 1}$$

Life Cycle Operating Cost = OCC =

$$(\text{Labor} + \text{Public Information} + \text{Other Operating Costs}) \times 1.34$$

AVERAGE ANNUAL COST (INSPECTION FEE) =

$$\frac{\text{ICC} + \text{SUC} + \text{OCC}}{22.9 \text{ million vehicles}}$$

APPENDIX G

SENSITIVITY ANALYSIS CALCULATIONS

1. INTEREST RATE

If the State interest rate is 8% (instead of 10%), then:

Life Cycle Investment Cost	- State	$ 441,000
	- Garage	$ 14,887,000
Life Cycle Start-up Cost	- State	$ 2,190,000
	- Garage	$ 1,068,000
Life Cycle Operating Cost	- State	$ 13,888,000
	- Garage	$ 47,548,000
Total Life Cycle Cost	- State	$ 16,519,000
	- Garage	$ 63,503,000

Average Annual Cost per vehicle

- State	$ .72
- Garage	$ 2.77
- TOTAL	$ 3.49

If the State interest rate is 12% (instead of 10%), then:

Life Cycle Investment Cost	- State	$ 542,000
	- Garage	$ 14,887,000
Life Cycle Start-up Cost	- State	$ 2,378,000
	- Garage	$ 1,068,000
Life Cycle Operating Cost	- State	$ 13,888,000
	- Garage	$ 47,548,000
Total Life Cycle Cost	- State	$ 16,808,000
	- Garage	$ 63,503,000

Average Annual Cost per Vehicle

- State	$ .73
- Garage	$ 2.77
- TOTAL	$ 3.50

2. INFLATION RATE

If the inflation rate is 10% per year (instead of 5%), then

Life Cycle Investment Cost	- State	$ 656,000
	- Garage	17,105,000
Life Cycle Start-up Cost	- State	2,590,000
	- Garage	1,163,000
Life Cycle Operating Cost	- State	18,521,000
	- Garage	63,507,000
Total Life Cycle Cost	- State	21,767,000
	- Garage	81,775,000

Average Annual Cost per Vehicle

- State	$ .95
- Garage	$ 3.57
- TOTAL	$ 4.52

If the inflation rate is 3% per year (instead of 5%), then:

Life Cycle Investment Cost	- State	$ 405,000
	- Garage	$ 13,989,000
Life Cycle Start-up Cost	- State	$ 2,122,000
	- Garage	$ 1,003,000
Life Cycle Operating Cost	- State	$ 12,474,000
	- Garage	$ 42,714,000
Total Life Cycle Cost	- State	$ 15,001,000
	- Garage	$ 57,706,000

Average Annual Cost per Vehicle

- State	$ .66
- Garage	$ 2.52
- TOTAL	$ 3.28

3. PROGRAM LIFE CYCLE

If life cycle is three years (instead of 5 years), then:

Life Cycle Investment Cost	- State	$ 377,000
	- Garage	$ 13,495,000
Life Cycle Start-up Cost	- State	$ 2,070,000
	- Garage	$ 968,000
Life Cycle Operating Cost	- State	$ 7,235,000
	- Garage	$ 24,774,000
Total Life Cycle Cost	- State	$ 9,682,000
	- Garage	$ 39,237,000

Average Annual Cost per Vehicle

- State	$ .74
- Garage	$ 2.99
- TOTAL	$ 3.63

If life cycle is 10 years (instead of 5 years), then:

Life Cycle Investment Cost	- State	$ 905,000
	- Garage	$ 37,971,000
Life Cycle Start-up Cost	- State	$ 2,784,000
	- Garage	$ 1,359,000
Life Cycle Operating Cost	- State	$ 31,494,000
	- Garage	$107,875,000
Total Life Cycle Cost	- State	$ 35,183,000
	- Garage	$147,205,000

Average Annual Cost per Vehicle

- State	$ .69
- Garage	$ 2.88
- TOTAL	$ 3.57

4. NUMBER OF CERTIFIED GARAGES

If 3000 garages are certified (instead of 4200), then:

Life Cycle Investment Cost	- State	$ 481,000
	- Garage	$ 10,634,000
Life Cycle Start-up Cost	- State	$ 2,258,000
	- Garage	$ 769,000
Life Cycle Operating Cost	- State	$ 13,888,000
	- Garage	$ 47,072,000
Total Life Cycle Cost	- State	$ 16,627,000
	- Garage	$ 58,475,000

Annual Average Cost per Vehicle

- State	$ .73
- Garage	$ 2.55
- TOTAL	$ 3.28

If 5000 garages are certified (instead of 4200), then:

Life Cycle Investment Cost	- State	$ 481,000
	- Garage	$ 17,723,000
Life Cycle Start-up Cost	- State	$ 2,258,000
	- Garage	$ 1,267,000
Life Cycle Operating Cost	- State	$ 13,888,000
	- Garage	$ 47,746,000
Total Life Cycle Cost	- State	$ 16,627,000
	- Garage	$ 66,736,000

Average Annual Cost per Vehicle

- State	$ .73
- Garage	$ 2.91
- TOTAL	$ 3.64

5. MANUAL DATA HANDLING AND ANALYSIS

If state labor requirements are increased by 6 data clerks and the computer programmer, 3 data entry clerks, computer equipment and charges are deleted, then:

Life Cycle Investment Cost	- State	$ 472,000
	- Garage	$ 14,887,000
Life Cycle Start-up Cost	- State	$ 2,288,000
	- Garage	$ 1,068,000
Life Cycle Operating Cost	- State	$ 13,867,000
	- Garage	$ 47,548,000
Total Life Cycle Cost	- State	$ 16,627,000
	- Garage	$ 63,504,000

Average Annual Cost per Vehicle

- State	$ .73
- Garage	$ 2.77
- TOTAL	$ 3.50

APPENDIX H

GLOSSARY

GLOSSARY

AMBIENT AIR: The surrounding or outside air.

CALIBRATION GASES: A blend of HC and CO gases using nitrogen as a carrier gas.

CAPITAL INVESTMENT: Initial expenditures for goods necessary for the operation of a program (e.g., building, land and equipment).

CERTIFIED MECHANIC: An individual licensed by the State to inspect motor vehicle engine emissions related components and pollution control devices for compliance with specified emissions standards.

CERTIFIED STATION: A private facility licensed by the State to inspect motor vehicle engine emissions related components and pollution control devices for compliance with specified emissions standards.

EMISSION INSPECTION/MAINTENANCE PROGRAM: An inspection and maintenance program in which each vehicle is subjected at specified intervals to a test of its emissions under specified conditions. The emission levels are compared with a standard established for the vehicle class. If the emissions are higher than the standards, the vehicle is failed and must be adjusted or repaired to bring its emissions into compliance with the standards.

EXHAUST GAS ANALYZER: An instrument for sensing the amount of air contaminants in the exhaust emissions of a motor vehicle.

EXHAUST EMISSIONS: The products of combustion emitted into the ambient air from any opening downstream of the exhaust ports of a motor vehicle engine.

HEAVY-DUTY VEHICLE: Any motor vehicle designed for highway use which has a gross vehicle weight of more than 10,000 pounds.

IDLE TEST: An emission inspection program which measures the exhaust emission from a motor vehicle operating at idle (no motion of the rear wheels.) A vehicle with an

automatic transmission may be in drive gear with brakes applied or in neutral gear.

INSPECTION FEE: Annual payment for inspecting a vehicle.

INSPECTOR: An individual who inspects motor vehicles and pollution control devices for compliance with applicable regulations.

LIFE CYCLE COSTS: Total of all costs incurred by a program during a predetermined period (life cycle).

LIGHT-DUTY VEHICLE: A motor vehicle designed for highway use of less than 10,000 pounds gross vehicle weight. Further distinctions are sometimes made between light-duty automobiles and light-duty trucks such as pickup trucks.

MODEL YEAR OF ENGINE: The production period of new vehicle or new vehicle engines designated by the calendar year in which such period ends.

OPERATING COSTS: Annual costs incurred during the operation of a program.

START-UP COSTS: Initial expenditures for services necessary for laying the foundation of a program (e.g., initial labor costs, initial training, initial public information and program design).

VEHICLE EMISSIONS STANDARD: A specific emission limit allowed for the class of vehicles. The standard is normally expressed in terms of maximum allowable concentrations of pollutants (e.g., parts per million). However, a standard could also be expressed in terms of mass emissions per unit of time or distance traveled (e.g., grams per mile).