sierra research

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Estimating the Cost of I/M Programs

prepared for:

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March 20, 2002

prepared by:

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Estimating the Cost of I/M Programs

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1. INTRODUCTION

During 1992, Sierra Research developed two I/M Cost Estimation spreadsheet models to estimate the cost of a variety of I/M program alternatives that were of interest to the California Air Resources Board (CARB) and the California I/M Review Committee. The models account for individual I/M program cost elements (e.g., direct labor, land, buildings, equipment, overhead, etc.) using a methodology that was patterned after manual I/M cost worksheets developed by EPA in the late 1970s.* Since the development of the 1992 version of the models, they have been updated and modified to support work that Sierra has performed for a variety of clients. The models have also been validated against the actual costs of several different I/M program designs and successfully predicted the significant cost increase that was associated with recent changes to the California I/M program (called "Smog Check") involving a conversion to loaded mode testing. Prior to the work described herein, the spreadsheet models were undocumented and no users manual was available.

Assistance in the area of I/M program cost estimation is one of the services that EPA provides to local, state, and international governments considering implementation of, or significant modifications to, I/M programs. Because Sierra's models appeared to be useful tools for estimating the costs of various I/M program designs, EPA issued, during 1999, Work Assignment 1-11 (under Contract No. 68-C7-0051) directing Sierra to prepare and deliver documented versions of the models for use by EPA and other interested parties. In 2000, EPA issued Work Assignment 2-04, directing Sierra to make certain revisions to the models to make them more flexible.

Scope of Work

The scope of work followed by Sierra under Work Assignment 1-11 consisted of five tasks:

1. Work Plan Preparation and Review of Existing Default Values;
2. Preparation of Narrative Description of Model Structure, Input Variables, and Default Values;
3. Internal Documentation and Code Review;
4. Preparation of Example Calculations; and
5. Reporting.

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* "Centralized I/M Program Cost Calculation Worksheet," U.S. Environmental Protection Agency, August 1979; and "Decentralized Private Garage I/M Program Cost Calculation Worksheet," U.S. Environmental Protection Agency, August 1979.

Task 1, Work Plan Preparation and Review of Existing Default Values - In addition to the preparation of the work plan, Task 1 involved a review of the many default values contained in the models. These include such values as the cost of bare land for inspection facilities, the cost of test equipment, salaries for various personnel categories, etc. Although all of these values can be modified by the user, the default values provide good starting points when the models are applied to urban areas in the U.S. As noted below, the documentation highlights those default values that are most likely to be affected by local conditions.

Task 2, Preparation of Narrative Description of Model Structure, Input Variables, and Default Values - Under this task, the structure of the models was summarized and the basic steps in the calculation process were explained in more detail. Work under this task also included developing warnings to the user about changing certain input variables or default values beyond certain limits. (The need for some of those warnings was subsequently eliminated under revisions made during the completion of Work Assignment 2-04.)

Task 3, Internal Documentation and Code Review - Internal documentation of the models primarily consisted of showing the basic formulas used at key locations in the spreadsheets. Headings embedded in the spreadsheets also explain the purpose of various sections of the model. The internal documentation will be useful to users who have already reviewed the separate documentation. During the performance of this task, the code was also reviewed and minor programming errors were corrected.

Task 4, Preparation of Example Calculations - To help users understand the operation of the models and the sensitivity of the output to key input variables and default values, several example calculations were described in detail. Two examples provide a comparison of a decentralized loaded mode program to a centralized program using the same test procedure. Other examples cover the effect of changes in the vehicle population and the length of the program.

Task 5, Reporting - This task covered the preparation of a draft final report. Sierra also submitted electronic versions of the documentation and spreadsheets on diskette. The report itself was in WordPerfect 8.0 format and the spreadsheets were in Lotus 123 format.

Under follow-on Work Assignment 2-04, there was a similar reporting task. All other work was covered under a task entitled "Model and Documentation Revisions." The revisions to the models and associated documentation made under that task were as follows:

1. Summary of Inspection Fees: There were two blocks of results contained in the version of the spreadsheet models prepared under Work Assignment 1-11. The first block showed the test fees associated with a program that requires motorists to pay for each test at the time it is performed. The second block showed the test fees associated with a program that requires motorists to pay only one fee that covers both the initial test and any retests that are subsequently required. Under Work Assignment 2-04, the

difference between these fee summaries were clarified in both the internal documentation and the written description of the model contained in this report.

2. Currency Adjustment: Sierra modified the models so that users can specify currency different from U.S. dollars. This was accomplished by adding a variable for the exchange rate from the local currency to U.S. Dollars and converting appropriate spreadsheet cells based on the specified conversion rate.

3. Labor Rate Multiplier: In order to adjust labor rates for various labor categories to local labor rates, the initial versions of the models require the user to make many changes in various protected cells in the spreadsheet. While a labor rate multiplier allowed the user to adjust, in effect, the overall or average rate, it did not allow for a change in the relationship between, for example, the program administrator and a test technician. To provide greater flexibility, two different labor rate multipliers were incorporated—one for the employees working in inspection facilities, and the other for administrative personnel.

4. Inflation Adjustment: Sierra added a factor to adjust all of the non-labor cost assumptions in the models (e.g., construction, equipment, etc.) for either inflation or local factors.

5. Comments: Sierra modified the descriptions of program operation contained in this report and the internal documentation within the spreadsheet models to provide more detailed information on the following inputs:

   a. *Percent of Vehicles Exempt*: The standard exemption rates are based on the typical U.S. fleet. Given the international application of this model, a more general explanation, using a U.S. example, was incorporated.

   b. *Annual Interest Rate*: Sierra clarified the statement "Use Prime Rate" to indicate that it is the expected cost of financing loans during the program period, with the U.S. Prime Rate being a recommended value for U.S. programs.

   c. *Lane Loading Percentage*: Sierra further defined this term and provided additional guidance regarding how to estimate this value.

   d. *Hourly Lane Throughput (Max.)*: To address ambiguities regarding the definition of this term, Sierra added a whole new section to the centralized program spreadsheet to internally calculate this value from program characteristics (e.g., test type, number of lane positions, etc.).

   e. *Property Tax Rate per Full Value (Contractor program)*: Sierra revised this description to clarify that it is the property tax rate based on the market value of land and facilities rather than a rate that applies to some arbitrarily discounted value (as is used in some jurisdictions).

f. *Average Number of Inspectors per Lane*: Based on information obtained from centralized I/M program operators, the average number of inspectors per lane is one less than the number of lane positions. This results from the partial staffing that is common during the slack periods associated with a lane loading percentage of 50%. The accuracy of this estimate was confirmed based on additional consultation with program operators and the spreadsheet was modified to eliminate the need for the user to enter this value.

g. *Lane Equipment*: Sierra reviewed the lane equipment cost estimates and adjusted them as required. Sierra also expanded the documentation to clarify precisely what equipment is included in the cost estimate. Sierra also added an estimate for VMAS flow measurement equipment to the transient loaded testing alternative.

h. *Site Preparation Costs*: Sierra provided a clearer explanation of specific items included in this input and specifically addressed whether utility connections are included.

i. *Lane Efficiency Factor*: Sierra provided more explanation of this term, which accounts for the net effect of equipment failures and test aborts, and clarified that it is not related to Land Loading Percentage.

j. *Initial/Recurring Program Design and Engineering Cost*: Sierra revised the documentation to clarify that the program design and engineering cost is a percentage of the total investment in land, buildings, and equipment.

k. *Excel Versions*: Sierra prepared Microsoft Excel versions of both spreadsheets to be provided along with the Lotus 123 versions.

Organization of the Report

Following this introductory section, Section 2 of the report describes the basic structure, input variables, and default values for the centralized program version of the model. Section 3 describes the differences between the structure, input variables, and default values for the decentralized (private garage) program version of the model. Section 4 presents the results of example calculations.

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2. CENTRALIZED PROGRAM MODEL

The basic method used in the computer spreadsheet for centralized (high-volume, test-only) I/M program cost estimation accounts for all costs "from the ground up." Capital costs (e.g., equipment purchases) are amortized and converted to annual costs after accounting for the money needed to make the capital investments. Annualized capital costs are added to recurring costs (e.g., wages) to determine the total annual cost. After accounting for an assumed profit margin, the annual cost is divided by the average annual number of I/M tests projected for the contract period to produce a cost-per-test estimate.

Figure 1 shows what the spreadsheet looks like on-screen with user inputs for a hypothetical program involving an automobile population of 2 million, exemptions for vehicles up to five years of age, and biennial testing. The spreadsheet contains a "Summary of Inspection Fees & Facilities" and five other sections. The first page of Figure 1 contains the fee summary, the number of inspection stations and lanes required, and the section of the spreadsheet listing various program parameters, many of which (e.g., automobile population) are unique to a particular program area. In addition to the parameters that are unique to a particular program area, there are a number of other parameters listed in Section I that the user has the option of modifying to reflect area-specific information (e.g., construction costs). Although it is possible for the user to edit the default values contained in other sections, the default values are considered representative and should be modified only when locally available data are clearly more accurate. *To minimize the risk of inappropriate changes in default values, the only "unprotected" cells in the spreadsheets are those where program-specific changes are expected (e.g., vehicle population, program length, etc.).* However, changes to the assumptions built into the spreadsheets can be made by unchecking the "Lock contents of protected cells" box on the "Sheet Properties" window.

The second page of Figure 1 shows the calculations made to determine the number of inspection lanes required for the specified vehicle population and test procedure. At the top of this page is the section used to calculate the maximum lane throughput associated with the selected combination of test procedures and the number of lane positions. The maximum throughput value is then used to calculate the number of inspection lanes required in conjunction with the values for average annual vehicle population (AAP), the percent of initial tests conducted at centralized facilities (INIT), the projected failure rate or "stringency" (STR), the estimated number of extra (out-of-cycle or voluntary) tests (XTR), and the percent of retests conducted at centralized facilities (RTST).

Beginning on the third page of Figure 1, Section II of the spreadsheet addresses the start-up or "initial" costs to a program operator associated with land acquisition, facility construction, hiring, and training. Beginning on the fifth page of Figure 1, Section III covers recurring program operator costs, such as employee wages and benefits. Beginning on page six of Figure 1, Section IV of the spreadsheet contains the

Figure 1

Centralized I/M Cost Model

Centralized_IM_EPA.123
Prepared by Sierra Research, Inc., November 2000

0. SUMMARY OF INSPECTION FEES & FACILITIES

Fees Shown in US Dollars

		Contractor Fee/Test	State CVS Cost/Test	Total State Costs/Test	Total/Test
Motorists pay for each test, whether initial or re-test.	With CVS Cell	14.02	0.45	1.52	15.54
	No CVS Cell	14.02	n.a.	1.07	15.09
		Fee/Init Test	CVS Cost/Init	State Costs/Init	Total/Initial Test
Motorists pay only for initial test. No charge for retests.	With CVS Cell	17.11	0.55	1.85	18.96
	No CVS Cell	17.11	n.a.	1.40	18.51

Facilities

Number of Lanes	37
Number of Stations	10

I. PROGRAM PARAMETERS

A. Primary User Inputs

1.	Local Currency/US Dollar	LC/USD =	1	Enter amount of local currency equivalent to one US dollar.	
2.	Present Auto Population	POP =	2,000,000		
3.	Annual Auto Population Growth Rate (%)	GRT =	2.0%		
4.	Percent of Vehicles Exempt	EXEMPT =	44%	For '81 and later US fleet, use 20% for current yr + 2; 36% for current + 3; 44% for current +4	
5.	Inspection Frequency (Annual = 1, Biennial = 2)	FREQ =	2	Average years between inspections for non-exempt vehicles	
6.	Annual Inflation Rate (%)	INF =	1.5%	Use annual change in Consumer Price Index	
7.	Annual Interest Rate (%)	INT =	7.5%	Cost of financing loans; Use current prime rate for US programs.	
8.	Program Length (years)	PRL =	7	5-7 years minimum needed for cost/effective amortization	
9.	Annual Operating Hours	HRS =	2,340	Exceeding 2400 may not be cost/effective	
10.	Lane Loading Percentage (100% = all lanes always busy)	LLP =	50%	50% typical; long lines expected above 66%.	
11.	Lane Efficiency Factor	EFF =	85%	85% max for experienced contractors	
12.	Stringency Factor (%)	STR =	20.0%	New programs may require start-up standards to avoid excessive failure rates initially	
13.	Property Tax Rate per Full Value (contractor program)	PRT =	2.00%	Area specific, 2% typical in US	
14.	Number of Lane Positions	#POS =	3.0	1, 2, or 3; 1 position lanes inefficient except for simplest tests	
15.	Exhaust Test Type	ExTest =	asm1	IDLE, TSI, ASM1, ASM2, IM240, IM147, BAR31, NONE	
16.	Loaded Preconditioning?	Precond =	no	"Yes" or "No"	
17.	Fast Pass Algorithm?	Fast Pass =	yes	"Yes" or "No"	
18.	Dyno Type	Dyno =	ss	Steady-State (SS), Transient (TRANS), NONE	
19.	Exhaust Test Equipment	ExMeas =	ndir	CVS, VMAS, NDIR, CUSTOM, NONE	
20.	Evaporative Test Type	Evap =	cap	NONE, CAP, PRES, FULL	
21.	Time for Other Visual/Functional Checks	Func =	0	Enter Time in Seconds, Use 40 seconds for OBDII check	
22.	Maximum Lanes per Facility =	MaxLanes =	4	Default = 4 to minimize driving distance without major cost impact	
23.	Minimum Number of Test Facilities =	MinStations =	1	Default = 1for minimum cost per test	
24.	Minimum Number of Total Lanes =	MinLanes =	1	Default = 1 for minimum cost	

B. Optional User Inputs

25.	Steady State Loaded Mode Equipment Cost	$SSLoaded =	97,000	Default=US$ 97,000.00	
26.	Transient CVS Equipment Cost	$CVS =	145,000	Default=US$ 145,000.00	
27.	Transient VMAS Equipment Cost	$VMAS =	105,000	Default=US$ 105,000.00	
28.	Idle Equipment Cost	$Idle =	57,000	Default=US$ 57,000.00	
29.	Custom, User-Specified Equipment Cost	$CUSTOM =	100,000	Default=US$ 100,000.00	
30.	Equipment cost per lane =	$/LANE =	97,000		
31.	Land Acquisition Cost per square foot	$LAND/ft2 =	10.00	Typical = US$ 10.00	Metropolitan area costs range from US$7-15 in industrial areas
32.	Construction Costs per square foot	$CONS/ft2 =	80.00	Default=US$ 80.00	US$80 Typical barring extraordinary costs
33.	Site Preparation Costs	$SITE =	100,000	Typical = US$ 100,000.00	US$50,000 - US$200,000, depends on local utility hookup costs
34.	Paving Costs per square foot	$PAVG/ft2 =	2.00	Typical = US$ 2.00	US$2.00 Typical
35.	Monthly Office Space Rental Cost per square foot	$RENT/ft2 =	1.20	Typical = US$ 1.20	US$1.20 Typical
36.	Training Cost per mechanic	$MCH =	50.00	Typical = US$ 50.00	Cost covers dissemination of program information and perhaps one seminar
37.	Mechanics Required per 1,000 autos	Mech/1,000 =	1	1.0 typical	
38.	Initial Public Information Costs	$IPI =	0.50	Default/veh = US$ 0.50	US$0.50 Typical
39.	Recurring Public Information Costs	$RPI =	0.10	Default/veh = US$ 0.10	US$0.10 Typical
40.	Annual Percent Additional Tests (%)	XTR =	2.0%	2% is reasonable minimum	
41.	Percent of Initial Tests at Centralized Facility (%)	INIT =	100.0%	100% for pure centralized program	
42.	Percent of Retests at Centralized Facility (%)	RTST =	100.0%	100% for pure centralized program	
43.	Initial Program Design and Engineering Cost	IDE =	10.0%	Default = 10% of land, building, and equipment costs	
44.	Recurring Program Design and Engineering Cost	RDE =	0.2%	Default = 0.2% of land, building, and equipment costs	
45.	Computer Processing Cost per test	$CPT =	0.05	Default = US$ 0.05	
46.	CVS Test Cell Annual Capacity =	CVSCAP =	1,600	Default = 1600 for hot start IM240s	
47.	Labor Rate Multiplier for Administration/Management (Since 1/1/99)		1	Default = 1.0	
48.	Labor Rate Multiplier for Test Facility Staff (Since 1/1/99)		1	Default = 1.0	
49.	Capital, Land, Construction, Training Cost Multiplier (Since 1/199)		1	Default = 1.0	

Figure 1

C. Facility Requirement Calculations

1. Throughput Calculations

Lane Activities:	Number of Lane Positions One	Two	Three
No Exhaust Test	0	0	0
Idle/precond	0	0	0
Idle	0	0	0
TSI, precond	0	0	0
TSI	0	0	0
ASM1, fast pass	80	80	80
ASM1	0	0	0
ASM2, fast pass	0	0	0
ASM2	0	0	0
IM240	0	0	0
IM240, fast pass	0	0	0
Transient, fast pass/precond	0	0	0
Other Transient w/o precond	0	0	0
Position Change	0	10	10
Off/On Dyno	90	90	90
Evap Testing	20	20	20
Other Functional Testing	0	0	0
Data Entry Position	105	0	0
Test Results	50	50	50
Peak Tests/Hour	10.43	15.65	20.00
Degree of Difficulty	1.3	1.3	1.3

2. Average Annual Population

$$AAP = POP(1-EXEMPT) \times \{SUM_{i=0}^{i=PRL-1} (1+GRT)^{i}\} / (PRL \times FREQ) = 594,743$$

3. Average Annual Tests Performed

TST = AAP x [INIT + (STR + XTR) x RTST] = 725,586

4. Maximum Test Rate

(From table above) Cars/hr = 20.00

5. Annual Lane Capacity

CAP = HRS x Cars/hr CAP = 46,800

6. Total Test Lanes Required

LAN = TST / (CAP x LLP x EFF) LAN = 37 Larger of LAN or MinLanes =37

Figure 1

II. INITIAL COSTS TO PROGRAM OPERATOR

A. Estimates of Facility Requirements

1. Inspection Facility Square Footage Requirements (enter data in sq ft)

LAND		LANES	OFFICE, ETC.		PAVING	
Basic per Facility	Additional per Lane	per Lane	Basic per Facility	Additional per Lane	Basic per Facility	Additional per Lane
20,000	10,890	1,000	1,000	0	5,000	3,200

2. Allocation of Lanes and Square Footage Requirements

LANE ALLOCATION			LAND		BUILDING					
					LANES		OFFICE, ETC.		PAVING	
Lanes per Facility	# Facilities This Size	Total Lanes	Each Facility	Total	Each Facility	Total	Each Facility	Total	Each Facility	Total
1	0	0					1,000	0		
TOTAL	10	37	LND =	602,930	LNS =	37,000	OFC =	10,000	PVG =	168,400
	(FAC)	(LAN)								

3. Inspection Facility Personnel Hiring and Training Requirements

Position	# of Positions	Facility Staffing Requirements Pers-Yrs @ 2340 hrs/yr		Annual Salary per employee @ 40 hrs/week	Overhead & Fringe 30%	Duration of Instruction per Trainee (hrs)	Direct Costs of Instruction per Trainee	Total Training Cost per Employee	Hiring Cost per Employee	Total Training & Hiring Cost per Employee
Station Manager	1	1.13	per facility	27,750	8,325	640	400	11,500	200	11,700
Asst. Station Manager	1	1.13	per facility	19,990	5,997	160	400	2,399	100	2,499
Inspection Technicians	2.50	2.81	per test lane	18,928	5,678	160	200	2,093	50	2,143
Customer Service Rep	0	0.00	per facility	23,200	6,960	80	200	1,360	50	1,410

B. Calculation of Facility Investment Costs

1. Construction and Land Acquisition Costs

a. Land Acquisition = LND x $LAND/ft2 = $LANDAQ = 6,029,300

b. Paving = PVG x $PAVG/ft2 = $PAVING = 336,800

c. Construction = (OFC + LNS) x $CONS/ft2 = $CONSTR = 3,760,000

d. TOTAL Building = $PAVING + $CONSTR = $BUILDING = 4,096,800

2. Inspection Facility Personnel Hiring and Training Costs

a. Station Managers:
11700 x 1.13 / facil x FAC = 131,625

b. Assistant Station Managers:
2499 x 1.13 / facil x FAC = 28,114

c. Inspection Technicians:
2143 x 2.81 / lane x LAN = 222,985 (staffed lanes)

d. Customer Service Representatives:
___ x ___ / facil x FAC =

e. TOTAL Inspection Facility Personnel Hiring & Training = FIELDPERS = 382,724

3. Facility Preparation and Equipment Costs

Per (Category)	Site Preparation Number	Each	Total	Test Equipment Each	Total	Office & Other Equipmt. Each	Total	Data Proc. Equipmt. Each	Total	TOTAL
Facility	10	100,000	1,000,000			20,000	200,000	0		1,200,000
Test Lane	37			97,000	3,589,000			0		3,589,000
Satellite Offices	1	N/A				20,000	20,000	0		20,000
Central Office	1	N/A				40,000	40,000	100,000	100,000	140,000
TOTAL			1,000,000		3,589,000		260,000		100,000	$EQUIP = 4,949,000
			($PREP)							

Figure 1

C. Start-Up Administrative Costs

1. Start-Up Personnel Costs

Position Area	Number per Central Office	Number per Satellite Office	Total Number of Employees	Average No. of Startup Hours per Employee	Total Person Years	Annual Salary @ 40 hrs/week per Employee	Overhead & Fringe 50%	Total Salary and Benefits
Program Administrator	1	0	1	3,120	1.5	67,500	33,750	151,875
Area Administrators	0	1	1	2,080	1.0	62,500	31,250	93,750
Technical Officers	3	1	4	1,040	2.0	52,500	26,250	157,500
Data Analysis/Statistical Staff	2	0	2	693	0.7	37,500	18,750	37,482
Clerical and Secretarial Staff	4	1	5	693	1.7	22,500	11,250	56,223
TOTAL			13					496,830 ($CSBP)

2. Start-Up Training and Hiring Costs

Position Area	Total Number of Employees	Annual Salary and Benefits per Employee	Duration of Instruction (hrs) (Per Employee)	Direct Cost of Instruction (Per Employee)	Total Training Costs (All Employees)	Hiring Costs (Per Employee)	Total Training Plus Hiring (All Employees)
Program Administrator	1	101,250	40	2,000	3,947	10,000	13,947
Area Administrators	1	93,750	40	2,000	3,803	5,000	8,803
Technical Officers	4	78,750	80	3,000	24,115	1,000	28,115
Data Analysis/Statistical Staff	2	56,250	40	2,000	6,163	500	7,163
Clerical and Secretarial Staff	5	33,750	40	400	5,245	400	7,245
TOTAL	13				43,274		65,274 ($CHIRE)

3. Calculation of Start-Up Administrative Costs

a. Start-Up Personnel = $CSBP = 496,830

b. Initial Public Information
$IPI or $IPI/vehicle x POP = 1,000,000

c. Initial Program Design, Eng. & Eval.
%IDE x ($LANDAQ + $BUILDING + $EQUIP)
or $IDE/veh. x POP = 1,507,510

d. Administrative Personnel Hiring and Training = $CHIRE = 65,274

e. TOTAL Start-Up Administrative Costs = 3,069,614

D. Total Initial Costs to Program Operator

1. Land Acquisition = $LANDAQ = 6,029,300.00
2. Total Building = $BUILDING = 4,096,800.00
3. Field Personnel Training & Hiring = $FIELDPERS = 382,723.88
4. Facility Preparation & Equipment = $EQUIP = 4,949,000.00
5. Land Purchase & Re-Sale Fee = 6.0% x $LANDAQ = $LNDFEE = 723,516.00
6. TOTAL Start-Up Administrative Costs = $ADMIN = 3,069,613.97
7. SUBTOTAL = $FIELDPERS + $EQUIP + $ADMIN = $STARTUP = 9,124,853.84

8. TOTAL Initial Costs = $LANDAQ + $BUILDING + $STARTUP = 19,250,953.84

Figure 1

III. RECURRING COSTS TO PROGRAM OPERATOR

A. Personnel Costs

1. Central Office Operating Staff

Position Area	Number	Annual Salary @ 40 hrs/week
Program Administrator	1	67,500
Technical Officers	3	52,500
Data Analysis/Statistical Staff	2	37,500
Clerical and Secretarial Staff	4	22,500
SUBTOTAL (salary x person years)		390,000
Overhead & Fringe	50.0%	195,000
TOTAL	$CSTAFF =	585,000

2. Each Satellite Offices Operating Staff

Position Area	Number Per Office	Annual Salary @ 40 hrs/week
Area Administrator	1	62,500
Technical Officers	1	52,500
Data Analysis/Statistical Staff	0	37,500
Clerical and Secretarial Staff	1	22,500
SUBTOTAL (salary x person years)		137,500
Overhead & Fringe	50.0%	68,750
Total per Satellite Office		206,250
TOTAL	$SSTAFF =	206,250

3. Inspection Facility Operating Staff

a. Station Managers:	$ salary	x #/facil	x FAC	312,187.50	
b. Assistant Station Managers:	$ salary	x #/facil	x FAC	224,887.50	
c. Inspection Technicians:	$ salary	x #/lane	x LAN	1,969,695.00	(staffed lanes only)
d. Customer Service Reps:	$ salary	x #/facil	x FAC		
e. SUBTOTAL			=	2,506,770.00	
f. Overhead and Fringe Benefits	30.0%		=	752,031	
g. TOTAL Inspection Facility Operating Staff	= $FSTAFF		=	3,258,801	

B. Miscellaneous Total Recurring Costs

1. Office Rental

#CSTAFF x $RENT/ft2 x 12 =	28,800	
#SSTAFF x $RENT/ft2 x 12 =	6,480	
TOTAL RENTAL COSTS =		35,280

2. Support Services to Facilities

Basic per facility =	12,000	
Additional per lane =		
TOTAL SUPPORT SERVICES		120,000

3. Operating Supplies

N2 Gas = US$30/250 Tests =	87,070	
Cal. Gases = US$240/2 mo./lane =	53,280	
Misc. Supplies = US$250/lane =	9,250	
$SUPP =		149,600

4. Travel 4,000 /facil x FAC = 40,000

5. Public Information = $RPI or $RPI/veh. x AAP = 59,474

6. Equipment Maintenance
   10% x ($EQUIP - $PREP) = 394,900

7. Annual Program Design, Eng. & Eval.
   %RDE x ($LANDAQ + $BUILDING + $EQUIP) = 30,150

8. Computer Processing of Tests = $CPT x TST = 36,279

9. Insurance Costs (where applicable)

	Rate as % Capital Cost	Insurance Cost	
"Buildings" rate =	0.3%	10,743	
"Office Contents" rate =	4.5%	11,700	
Liability Insurance =		65,303	US$0.09 per tested vehicle
"Test/Data Proc. Equip." rate =	0.4%	14,222	
TOTAL INSURANCE COSTS		101,967	

10. Personnel Costs
    $CSTAFF + $SSTAFF + $FSTAFF = 4,050,051

11. Property Taxes (contractor program only)
    PRT x ($BUILDING + $LANDAQ + $EQUIP) = 301,502

12. Hiring and Training Costs Due to Employee Turnover
    20% x ($FIELDPERS + $CHIRE) = 89,600

13. TOTAL Recurring Costs = $RECUR = 5,510,771

Figure 1

IV. ANNUALIZED COSTS TO PROGRAM OPERATOR

A. Average Recurring Costs ($RECURi) Accounting for Inflation

$$\$RECUR \times \left[\sum_{i=0}^{i=PRL-1} (1 + INF)^{i} \right] / PRL = 5{,}765{,}050$$

B. Amortization of Initial Costs

General Formulas

1. Value of Item Remaining at End of Program — VAE = $ITEM x (DEPR - PRL) / DEPR (where DEPR is depreciation period)
2. Present Discounted Value (PDV) of Item Remaining at End of Program (VAE) — PDV = VAE / (1 + INT)^PRL
3. Value of Principle to be Paid Off over Length of Program — PRIN = $ITEM - PDV
4. Annual Payment for Initial Loan for Item Plus Interest — $PMT = PRIN x INT (1 + INT)^PRL / (1 + INT)^PRL - 1

(Note: Interest Rate Already Accounts for Inflation)

Calculation for Initial Specific Cost Elements

					VAE	PDV	PRIN
1. Land Acquisition: Buy/Sell Discount Rate = (Relative VAE = (1 - Disc Rate) x $LANDAQ)	10.0%	$PMT-Land =	520,811		$5,426,370	3,270,771	2,758,529
2. Building: Depreciation period (yrs) =	20	$PMT-Bldg =	470,436		$2,662,920	1,605,088	2,491,712
3. Other Start-Up: Depreciation period (yrs) = (VAE = 0; PRIN = $STARTUP)	7	$PMT-Start =	1,722,775		$0	0	9,124,854
4. TOTAL Annual Payment Plus Interest For Initial Costs =		$PAYMENT =	2,714,022				

C. Total Annualized Costs to Program Operator

$RECUR i + $PAYMENT = $ANNUAL =		8,479,071.91
Contractor's Net Return	20.0%	1,695,814.38
TOTAL Annualized Contractor Program Costs = $CONTR =		10,174,886.30
Annualized Contractor Cost per Vehicle = $CONTR / TST =		14.02

Figure 1

V. PROGRAM COSTS TO STATE

A. Mass Emissions Testing Costs

1. Initial Test Cell Personnel

Position Area	Person Years	Cost/PY
Supervisor	0.3	37,500
Specialist 3	0.1	35,000
Specialist 2	0	32,000
Specialist 1	0.1	27,500
SUBTOTAL		17,500
Overhead & Fringe	95.0%	16,625
TOTAL	$MTSTIN=	34,125

2. Recurring Test Cell Personnel

Position Area		Person Years	Cost/PY
Supervisor		1	37,500
Specialist 3		1	35,000
Specialist 2		0	32,000
Specialist 1		1	27,500
SUBTOTAL	(#MPERS =)	3	100,000
Overhead & Fringe		95%	95,000
TOTAL		$MTSTAN =	195,000

3. Test Cell Start-Up Costs

a. Required Annual Mass Emission Tests

#MTSTS = Number of tests for statistically significant sample : 1,200

b. Required Number of Test Cells

#CELLS = MTSTS / CVSCAP 1

c. Facility Upgrades (dyno install, power, HVAC, etc.)

Single Test Cell Cost = $MBLDG = 200,000

$MBLDGS = $MBLDG x #CELLS = 200,000

d. Cost of Test Cell Equipment

Single Test Cell Cost = $MEQUIP = 200,000

$MEQUIPS = $MEQUIP x #CELLS = 200,000

e. Total Capital Cost

$MCAP = $MBLDGS + $MEQUIPS = 400,000

f. Initial Test Cell Personnel Cost = $MTSTIN = 34,125

g. Hiring and Training Cost for Test Cell Personnel

#MPERS x $2,000 /Employee 6,000

h. TOTAL Start-Up Test Cell Costs ($CELLIN) = 440,125

4. Test Cell Recurring Costs

a. Recurring Test Cell Pers. Cost = $MTSTAN = 195,000.00

b. Recurring Vehicle Recruitment Costs

Recruitment Cost/Vehicle = $RCTMT = 0.00

c. Recurring Maintenance Costs

% of Initial Test Cell Cost = %MMAINT = 10%

Annual Cost = $MMAINT x $MCAP = 40,000.00

d. TOTAL Recurring Test Cell Costs = 235,000.00

5. Amortization of Initial Test Cell Costs to State

$$\$CELLIN \times INT(1+INT)^{PRL} / ((1+INT)^{PRL} - 1) = \$CLPT = 83,096$$

Recurring Test Cell Costs to State Accounting for Inflation

$$\$CELLAN \times \left[\sum_{i=0}^{PRL-1} (1+INF)^{i}\right] / PRL = \$CLANN = 245,843$$

TOTAL Annualized Test Cell Costs to State

$$\$STPT + \$SANN = \$STATE = 328,939$$

6. Test Cell Portion Of Annual Fee to Motorists

a. Test Cell "Inspection Fee" = $TOTL / TST = $0.45

Figure 1

B. Initial Oversight Costs

1. Central Administrative Personnel

Position Area	Person Year:	Annual Salary @ 40 hrs/week	95% Overhead & Fringe	Duration of Instruction (hrs)	Direct Cost of Instruction	Total Training Costs	Hiring Costs	Total Training Plus Hiring
Program Administrator	1.0	67,500	64,125	40	600	3,131	10,000	13,131
Deputy Administrator		62,500		40	600	0	5,000	0
Auto Emissions Control Engineer		52,500		80	400	0	3,000	0
Emissions Testing Technician		27,500		80	400	0	200	0
Data Processing Specialist	1	52,500	49,875	40	200	2,169	200	2,369
Automotive Mechanic		35,000		80	400	0	200	0
Vehicle Inspection Specialist	2	42,000	79,800	80	400	7,100	200	7,500
Mechanic Certification Officer	1	37,500	35,625	80	400	3,213	200	3,413
Mechanic Certification Clerk	0	22,500		40	100	0	200	0
Secretary	0	25,000		40	50	0	200	0
Clerk/Typist	1	20,000	19,000	40	50	800	200	1,000
TOTAL	6.0	261,500	248,425			16,413	19,600	27,413
		($CAPIN)	($BENIN)					($FTRN)

2. Total Initial Costs to State

a. Central Administrative Personnel = $CAPIN + $BENIN = 509,925.00

b. Administrative Personnel Training & Hiring = $FTRN = 27,412.50

c. Initial Private Mechanic Training
Mech/1,000 x POP/(FREQ x 1,000) x $MCH = 50,000.00

d. Data Processing Equipment
$DEQUIP = 2,000 x #STAFF = 12,000.00

e. Initial Test Cell Costs = $CELLIN = 440,125.00

f. TOTAL Initial Costs to State = $STIN = 1,039,462.50

Figure 1

C. Recurring Costs

1. Central Administrative Personnel

Position Area		Person Years	Annual Salary @ 40 hrs/week	
Program Administrator		1.0	67,500	1 person year, regardless of program size
Deputy Administrator			62,500	
Auto Emissions Control Engineer			52,500	
Emissions Testing Technician			27,500	
Data Processing Specialist		1	52,500	1 person year, regardless of program size
Automotive Mechanic			35,000	
Vehicle Inspection Specialist		2	42,000	1 + 1 per million tests
Mechanic Certification Officer		1	37,500	1 + 0.2 per million tests
Mechanic Certification Clerk		0	22,500	0.2 per million tests
Secretary		0	25,000	0.2 per million tests
Clerk/Typist		1	20,000	1 + 0.05 per million tests
SUBTOTAL	(#STAFF) =	6	261,500	
Overhead & Fringe		95.0%	248,425	
TOTAL		$CAPAN =	509,925	

2. Total Recurring Costs to State

a. Central Administrative Personnel			= $CAPAN =		509,925
b. Annual Additional Mechanic Training 20% of Initial Mechanic Training Cost				=	10,000
c. Recurring Test Cell Costs			$CELLAN =		235,000
e. Travel	5000 +	300	x #STAFF =		6,800
g. Equip. Maintenance		10%	x $DEQUIP =		1,200
h. Contractual Services			=		100,000
i. Recurring Hiring and Training Costs			=		2,741
j. TOTAL Recurring Costs to State			= $STRC =		865,666

D. Annualized Costs to State

1. Amortization of Initial Costs to State

$$\$STIN \times INT\,(1+INT)^{PRL} / (1+INT)^{PRL} - 1 = \$STPT = 196,251$$

2. Recurring Costs to State Accounting for Inflation

$$\$STRC \times \left[\sum_{i=0}^{PRL-1} (1+INF)^{i} \right] / PRL = \$SANN = 905,610$$

3. TOTAL Annualized Program Costs to State

$$\$STPT + \$SANN = \$STATE = 1,101,861$$

$1.52 State Cost/test

calculations that convert the initial and recurring costs to an annualized basis. Beginning on page seven of Figure 1, Section V of the spreadsheet contains calculations addressing costs to the government agency overseeing the program. The calculations contained in this section are based on the assumption that the agency operates a CVS test facility for doing routine program evaluation testing; however, calculations are done with and without CVS testing cost included. The values calculated in Sections IV and V feed into the cost summary table at the top of the spreadsheet.

Key formulas used throughout the spreadsheet are documented on the spreadsheet in text form. More detail on each section of spreadsheet is presented below.

Program Parameters and Default Values

Following the "Summary of Inspection Fees," the first section of the spreadsheet contains a listing of certain program parameters. The primary program-specific parameters affecting the cost per test are listed in Table 1. These are the most important "user inputs" required for a model run. They include the automobile population, the portion of that population that is exempt, the inspection frequency (e.g., annual or biennial), the period over which capital investments will be amortized (program length), the type of testing to be performed, and other relevant parameters.

Although all of the parameters listed in Table 1 can be modified to be program specific, default values are suggested in several areas. There are two reasons for the default values. In some cases a default value is used because program-specific data are not expected to have a significant impact on the ultimate cost per test. In other cases, a default value is used to provide some guidance. This is the case with respect to vehicle exemptions, inspection frequency, program length, annual operating hours, lane loading percentage, lanes per facility, minimum number of facilities, and stringency factor. The default values used in these areas are what are considered reasonable to achieve a good cost-effectiveness ratio and public acceptance. Significant deviations from the default values can create problems such as much higher costs per test or long waiting lines.

Additional comments regarding each of the 24 Primary User Inputs are set forth below.

1. Local Currency/US Dollar - This entry is the number of foreign currency units equal to one US dollar. For US programs, the value of this parameter is set at 1.0.

2. Present Auto Population - This entry is the population of vehicles in the I/M program area that are the type of vehicles (e.g., passenger cars, light-duty trucks) to be tested in the program, including those vehicles exempted because they are relatively new. This number excludes vehicles that are exempted because they are too old.

3. Annual Auto Pop. Growth Rate - Just as it sounds, this entry is the best local estimate of the growth rate of the type of vehicles subject to the program.

Table 1
Primary User Input Values for Centralized I/M Cost Model

Assumption	Default Value	Comments
Local Currency/US Dollar	1.0	Amount of Local Currency Equal to One US Dollar
Present Auto Population	None	Use Local Data
Annual Auto Pop. Growth Rate	None	Use Local Data
Percent New Vehicles Exempt	44%	Represents Current + 4 Model Years for 1981+ US Fleet
Inspection Frequency	2 (Biennial)	Most Cost-Effective
Annual Inflation Rate	None	Use Current CPI
Annual Interest Rate	None	Use Current Prime Rate
Program Length	7 years	Shorter Increases Cost/Test
Annual Operating Hours	2,340 (45 hr/week)	More Hrs/Wk May Increase Cost/Test
Lane Loading Percentage	50%	Higher = Longer Lines
Lane Efficiency Factor	85%	Maximum for Experienced Contractors
Stringency Factor (Failure Rate)	20%	Typical for Moderately Stringent Standards
Property Tax Rate	None	Use Local Rate
Number of Lane Positions	None	1, 2, or 3 (Optimum number depends on complexity of test)
Exhaust Test Type	None	Idle, TSI, ASM1, ASM2, IM240, IM147, BAR31, or None
Loaded Preconditioning?	None	Yes or No, Yes Recommended to Avoid False Failures
Fast Pass Algorithm?	None	Yes or No, Yes Recommended for Minimum Test Time
Dyno Type	None	Steady-State (SS), Transient (Trans), or None
Exhaust Test Equipment	None	CVS, VMAS, NDIR, CUSTOM, or NONE
Evaporative Test Type	None	None, Gas Cap Only ("Cap"), Cap and Pressure Test ("Press"), or "Full" (Purge and Pressure)
Time for Other Visual/Functional Checks	None	Use 40 Seconds for OBD Check
Maximum Lanes Per Facility	4	4-6 Lane Facilities are More Cost-Effective Than Smaller Facilities
Minimum Number of Test Facilities	1	Minimum of 1 Ensures Minimum Cost
Minimum Number of Lanes	1	Minimum of 1 Ensures Minimum Cost

4. Percent New Vehicles Exempt - This entry is the fraction of the vehicles otherwise subject to the program that are exempt because they are relatively new. Since there is relatively little benefit from inspecting new vehicles until they are more than five years old, programs will be more cost-effective if they exempt the current model year and four additional model years. For the 1981 and newer fleet of passenger cars and light trucks in the US, the current model year plus four additional model years is approximately 44% of the fleet. For the current plus three additional model years, the percentage drops to 36%. For the current plus two additional model years, the percentage drops to 20%.

5. Inspection Frequency - This entry is for the number of years between inspections: 1 for annual programs and 2 for biennial programs. Because properly performed I/M repairs last for more than one year and because of the relatively slow rate at which new defects occur in customer service, biennial programs are more cost-effective than programs with annual inspection frequency.

6. Annual Inflation Rate - The annual inflation rate, which in the US can be approximated by the annual change in the Consumer Price Index, is used in several calculations and needs to be adjusted to reflect current, local conditions.

7. Annual Interest Rate - This entry is for the cost of financing loans assumed to be used to raise the capital necessary to purchase land, construct facilities, and purchase test equipment. For US programs, the prime rate provides a reasonable estimate when more specific information is not available.

8. Program Length - This entry is the period of time over which start-up expenses and equipment costs can be amortized. The longer the period of time, the lower the cost per test.

9. Annual Operating Hours - In conjunction with other parameters, the annual operating hours for the test facilities affect the cost per test. Maximum convenience for the motorist is provided by relatively long operating hours; however, there must be a balance between the number of inspection lanes and the hours of operation to achieve a cost-effective program. Forty-five (45) hours per week has proven adequate in some programs; other programs successfully use over 50 hours per week.

10. Lane Loading Percentage - This entry is the annual average throughput for each lane as a percentage of the maximum theoretical throughput as adjusted by the "lane efficiency factor" (see below). This is the primary factor that must be balanced with the annual hours of operation. A lane loading percentage of 100% means there is always at least one vehicle in line, waiting to be tested. This results in the minimum program cost; however, unless motorist arrival times are uniformly distributed, a high lane loading percentage results in long lines. Experience in the US indicates that, to avoid long lines, the lane loading percentage should be no more than about 50%.

11. Lane Efficiency Factor - The lane efficiency factor is the average throughput that can be achieved in a test lane when there is a queue of vehicles waiting to be tested. The difference between the average throughput and the maximum theoretical throughput results from aborted tests due to vehicle or equipment failures and occasional difficulties

getting motorists to quickly respond to instructions. Experienced contractors can generally achieve an efficiency factor of about 85%.

12. Stringency Factor (Failure Rate) - This parameter is important because it affects the retest volume. Higher stringency factors generally increase program benefits by identifying more emissions-related defects. Excessively high stringency factors can cause "false failures," however, especially when vehicles are inadequately preconditioned. It also should be noted that the same emissions standards will cause a higher failure rate during the initial inspection cycle than in subsequent cycles. If less stringent "start up" standards are used during the initial inspection cycle, the failure rate during subsequent cycles will likely be about 20% using the most stringent standards that enable the false failure rate to be kept under 2%.

13. Property Tax Rate - The local property tax rate should determine this entry. If necessary, the local rate should be adjusted to reflect the annual tax as a percentage of the actual cost of the land, buildings, and equipment (as opposed to some discounted value).

14. Number of Lane Positions - Any I/M test can be conducted in a single position lane; however, land, buildings, and equipment may be more efficiently utilized if the required activities can be divided among two or three people working in two or three different positions in the lane. More vehicles can be tested per hour if, for example, data entry is performed in one position, the actual emissions test is performed in another position, and the test results are presented to the motorist in a third position. Whether multiple lane positions make sense depends on the complexity of the test. The more complex the test, the more lane positions needed to minimize the cost per test.

The "Throughput Calculations" section of the spreadsheet determines the number of vehicles per hour that can be tested as a function of the number of lane positions and the type of test. The time required for each element of each type of test used in this portion of the spreadsheet was obtained from experienced I/M contractors.

The table is structured to reduce the complexity of formulas that would otherwise be needed to calculate the throughput based on the combination of program parameters entered at the top of the spreadsheet. (The formula required to compute throughput in one cell is too long for spreadsheet use.)

Each of the three columns of the table is for the number of "positions" in each lane. Each row of the table represents a potential type of in-lane operation. The first 13 rows cover the various types of exhaust emission test procedures. Within each of these rows, the entry is zero unless that particular type of test is specified in the Primary User Inputs portion of the spreadsheet. For the type of test that is specified, the entry in each column of the row is the number of seconds required to perform the test. In the case of idle and/or 2500 rpm tests, the entry in the row includes emissions measurement time plus the time required to open the vehicle hood and attach the RPM hookup, insert the exhaust sample probe, detach the RPM hookup, and close the hood. In the case of loaded mode tests, the entry in the row is only for the number of seconds during which emissions are measured. Other required activities are covered later in the table in the row labeled "On/Off Dyno."

The fourteenth row of the table lists the estimated time required to change from one lane position to another.

The fifteenth row of the table is for the time required for the dynamometer test, excluding the emissions test itself. This includes opening the vehicle hood, moving a cooling fan into place, installing an exhaust collection device, getting the motorist out of the vehicle, entering the vehicle, exiting the vehicle, returning the motorist to the vehicle, moving the fan, closing the hood, and removing the exhaust collection device.

The next four rows of the table are for the time required for evaporative testing, other functional testing, data entry, and presentation of test results to the motorist. The formula embedded in the cells for the evaporative testing row calculates a time for the test as a function of the type of test selected in the program parameters portion of the spreadsheet (e.g., gas cap test only vs. gas cap plus pressure test). The time for other functional tests depends on what has been entered in the program parameters section. The time for data entry depends on whether a dynamometer is used for the exhaust emissions test or whether emissions are measured only under idle and/or 2500 rpm conditions. More time is associated with dynamometer testing because of the need to enter additional information regarding the type of vehicle being tested. Likewise, the amount of time required to report the results to the motorist depends on the complexity of the test.

The calculation of maximum throughput at the bottom of each row involves a relatively simple allocation of individual time entries among the available positions. For one-position lanes, the throughput calculation is based on a summation of all entries. For two-position lanes, the data entry is assumed to occur in position one, and the emissions testing and results reporting is assumed to occur in position two. The location of the evap and functional testing depends on which location results in the minimum time in the lane. For the three position case, the results reporting is assumed to occur in the final position, and the evaporative and functional testing is placed in position two or position three, depending on which position minimizes the time in the lane. The throughput calculation results are shown in the next-to-last row.

The final row of the table contains the estimated "degree of difficulty" associated with the selected test procedure. For loaded mode testing, the degree of difficulty is set at 1.3. For idle or two-speed idle tests, the degree of difficulty is set at 1.0. This value is subsequently used to adjust the labor rate for the inspectors working in the lane.

15. Exhaust Test Type - This entry is used to indicate the type of exhaust emissions test to be used. The options are for idle and two-speed idle (TSI) testing, single mode Acceleration Simulation Mode testing (ASM1), dual mode ASM testing (ASM2), IM240 testing, IM147 testing, the very short BAR31 transient test, and "None". The entry made here affects the test time and equipment cost calculations made later in the spreadsheet.

16. Loaded Preconditioning? - A yes or no entry for loaded preconditioning affects the test time for certain test procedures. Although it increases the test time, preconditioning is recommended to avoid false failures.

17. Fast Pass Algorithm? - A yes or no entry for the use of a fast pass algorithm also affects the test time. With a fast pass algorithm, test time can be shortened with no significant loss in program benefits.

18. Dyno Type - This entry is subsequently used to determine the equipment cost associated with the program. Logic incorporated in the spreadsheet produces error messages if the type of dyno selected is inconsistent with the type of exhaust emissions test selected, e.g., transient dynos must be specified for transient tests like the IM240.

19. Exhaust Test Equipment - As with the dyno type entry, this entry affects the equipment costs and is checked for consistency with the type of test selected. Transient tests require either constant volume sampling (CVS) equipment or the less expensive "VMAS" equipment that uses NDIR analyzers to measure pollutants in the raw exhaust stream while using dual oxygen sensors and flow meters to determine exhaust volume.

20. Evaporative Test Type - This entry specifies what type of test, if any, of the evaporative emissions control system is to be performed. The options range from a simple pressure test of the gas cap, to a pressure test of the cap and the rest of the system, to a full purge and pressure test.

21. Time for Other Visual/Functional Checks - This entry is to cover the time (in seconds) required for any additional inspection procedures besides the exhaust test and the evaporative system check. It is recommended that a value of 40 seconds be entered for OBD system checks, which includes the time needed to connect/disconnect the OBD connector and download the data from the vehicle.

22. Maximum Lanes Per Facility - This entry is used to specify the maximum number of test lanes at each test facility. In conjunction with the minimum number of test facilities and the minimum number of total lanes, this parameter can affect the overall cost per test. Multi-lane facilities are more cost-effective than single-lane facilities; however, multi-lane facilities increase the spacing between facilities, thereby increasing the time required for motorists to drive to the nearest facility. For large urban areas, 4-6 lanes per facility is usually a good compromise.

23. Minimum Number of Test Facilities - As noted above, this parameter involves a tradeoff between facility spacing and cost per test. Specifying a minimum of one facility ensures the minimum program cost per test. A value of one will allow the number of facilities to be based on the specified maximum number of lanes per facility and the total projected test volume (or the specified minimum number of lanes).

24. Minimum Number of Lanes - This is another parameter that involves a tradeoff between motorist convenience and program cost. For minimum cost, the minimum number of lanes should be set at one. A value of one will allow the number of lanes to be based on the specified minimum number of facilities and the total projected test volume.

In addition to the parameters listed in Table 1, there are several other parameters contained in the first section of the spreadsheet ("Optional User Inputs") that are not

intended to be routinely modified by program users. These parameters are listed in Table 2. They include equipment cost estimates, construction costs, public information costs, and program design and engineering costs. At the bottom of this list are three adjustment factors to account for program-specific differences in labor rates and other costs.

Equipment Costs - The first several entries under the "Optional User Inputs" portion of the spreadsheet cover Steady-State Equipment Cost, Transient CVS Equipment Cost, Transient VMAS Equipment Cost, Idle Equipment Cost, and "Custom" Equipment Cost. The "Custom" cost category is intended to deal with unique situations without requiring the user to modify a default value for one of the standard equipment configurations. Based on the type of test selected under the "Primary User Inputs," one of the cost estimates is transferred to the entry labeled "Equipment Cost Per Lane." (This is a protected cell not intended to ever be overwritten.)

Basic Facility Costs - The next four lines of the Optional User Inputs cover Land Acquisition Cost Per Square Foot, Construction Costs Per Square Foot, Site Preparation Costs, and Paving Costs Per Square Foot. The default values are typical of US urban areas; however, regional differences can be substantial for land costs. In addition, site preparation costs can be highly variable. They are often affected by whether public roadway improvements are required. The default value of US$100,000 per site assumes no extraordinary costs, such as public roadway improvements. It also assumes electric power and sewer hookups are available without extraordinary expenses. However, the cost of bringing power, water, and sewer to the site from adjacent streets and properties is included.

The entry for "Monthly Office Space Rental Cost Per Square Foot" covers the cost of facilities for administrative personnel.

Training Cost Per Mechanic - This entry covers the cost of educating mechanics about the requirements of the program. The $50 default value is only sufficient to cover the cost of preparing and mailing informational materials and conducting seminars prior to program startup for interested mechanics. If the program is to cover the costs of a more meaningful training program, the cost for this item can increase substantially.

Mechanics Per 1,000 Autos - In conjunction with the above item, the number of mechanics per 1,000 vehicles subject to the program determines the total mechanic training cost.

Public Information Costs - Initial and recurring public information costs are intended to covered by this entry. Initial public information costs are significant because public confusion about program requirements is a common problem that threatens the viability of I/M programs.

Table 2
Secondary User Input Values for Centralized I/M Cost Model

Assumption	Default Value	Comments
Steady-State Equipment Cost	US$97,000	Vendor Cost Estimate
Transient CVS Equipment Cost	US$145,000	Vendor Cost Estimate
Transient VMAS Equipment Cost	US$105,000	Vendor Cost Estimate
Idle Equipment Cost	US$57,000	Vendor Cost Estimate
Custom Equipment Cost	None	User Specified
Equipment Cost Per Lane	None	Calculated Value
Land Acquisition Cost Per Square Foot	US$10	Typical US costs range from $7-15/sq.ft.
Construction Costs/Square Foot	$80/ft^2	Local Rates May Vary
Site Preparation Costs	$100,000	Local Costs Vary
Paving Costs/Square Foot	$2.00/ft^2	Local Rates May Vary
Office Space Rental/Square Foot	$1.20/mo./ft^2	Local Rates May Vary
Training Cost Per Mechanic	$50	Covers Information Mailing Plus One Seminar
Mechanics Per 1,000 Autos	1.0	Typical
Initial Public Information Costs	$0.50/veh 1st yr	Recommendation Based on Historical Experience
Recurring Public Information Costs	$0.10/veh/yr	Recommendation Based on Historical Experience
Annual % Additional Tests	2.0%	Out-of-Cycle/ Voluntary/ Multiple Retests/ Unnecessary Test Estimate
Percent of Initial Tests at Centralized Facility	100%	100% for Pure Centralized Program
Percent of Retests at Centralized Facility	100%	100% for Pure Centralized Program
Initial Program Design & Engineering Costs	10%	10% of Land & Equipment Costs
Recurring Program Design & Engineering Costs	0.2%	0.2% of Land & Equipment Costs
Computer Processing Costs/Test	US$0.05	
CVS Test Cell Annual Capacity	1,600	Hot Start IM240 Tests
Labor Rate Multiplier for Admin/Management	1.0	Baseline is 1/1/99
Labor Rate Multiplier for Test Facility Staff	1.0	Baseline is 1/1/99
Capital, Land, Construction, Training Cost Multiplier	1.0	Baseline is 1/1/99

Volume of Tests at Centralized Facilities - "Annual % Additional Tests" is an entry intended to cover out-of-cycle tests (e.g., due to a change of ownership inspection requirement), voluntary tests, multiple retests (for vehicles that fail their initial retests), or otherwise unnecessary tests that might be conducted at centralized facilities. Although the suggested default value of 2% is relatively small, ignoring this factor can result in an undersized network. The entries for "Percent of Initial Tests at Centralized Facility" and "Percent of Retests at Centralized Facility" will be 100% unless the centralized testing network is part of a "hybrid" program design under which some testing is conducted at private garages.

Program Design & Engineering Costs - Initial and recurring program design and engineering costs are expressed as a percentage of land, facilities, and equipment costs. Although some economies of scale would be anticipated, empirical data indicate that design and engineering costs are proportional to the total capital investment.

Computer Processing Costs/Test - This relatively small item is broken out because program-specific computer processing costs can be significantly larger depending on whether repair data are collected and used to identify underperforming facilities.

CVS Test Cell Annual Capacity - When a CVS test facility is used for routine program evaluation, the cost per test depends on whether the testing involves quick, simple hot start tests, like the IM240, or more time-consuming cold start tests using the full Federal Test Procedure. The default estimate for annual test cell capacity assumes IM240 testing.

Labor and Capital Cost Adjustments - Three different adjustment factors can be entered to account for local conditions and/or inflation: "Labor Rate Multiplier for Administration/Management," "Labor Rate Multiplier for Test Facility Staff," and "Capital, Land, Construction, Training Cost Multiplier." To account for inflation only, the same value would be entered for each factor. As indicated in the parenthetical comments on the spreadsheet, the baseline from which the adjustments should be made is January 1999, which is the date applicable to the default values in the spreadsheet.

Sections II-V of the spreadsheet involve calculations that utilize these additional parameter values in addition to the "User Input" parameter values entered by the user in Section I of the spreadsheet. However, there are many default values throughout Sections II-V that can be altered by users of the program in cases where a more detailed analysis is being conducted. Table 3 provides a fairly comprehensive listing of the type of information contained in Sections II-V that can be modified, if necessary.

Salary rates used in Sections II-V are one area where program-specific values might be substituted for the default values used in the spreadsheet. However, to simplify salary adjustments, the last rows in the "Optional User Inputs" section of the spreadsheet provide labor cost multipliers that adjust all labor rates in the remainder of the spreadsheet.

Table 3
Embedded Default Values for Centralized I/M Cost Model

Assumption	Default Value	Source
Facility Square Footage Requirements	(see spreadsheet)	I/M Contractors
Test Facility Staffing Requirements	(see spreadsheet)	I/M Contractors
Contractor Personnel Salaries	$7-9/hr inspectors to $13/hr station mgr	I/M Contractors
Contractor Hiring and Training Costs	(see spreadsheet)	I/M Contractors
Office Equipment Costs	(see spreadsheet)	Sierra
Data Processing Equipment Costs	(see spreadsheet)	I/M Contractors, Sierra
Start-Up Administrative Personnel Requirements for Contractor	(see spreadsheet)	I/M Contractors
Satellite Office Requirements	(see spreadsheet)	I/M Contractors
On-going Administrative Personnel Requirements for Contractor	(see spreadsheet)	I/M Contractors
Personnel Overhead Rates	(see spreadsheet)	I/M Contractors, Sierra
Support Services Costs/Facility (Utilities, Janitorial, Etc.)	(see spreadsheet)	Sierra
Travel Costs/Facility	(see spreadsheet)	I/M Contractors
Equipment Maintenance Costs	10% of original cost of purchase	I/M Contractors
Insurance Costs	(see spreadsheet)	Insurance Broker
Contractor's Net Return	20%	I/M Contractors
State-Operated Mass Emissions Test Cell Throughput and Cost	(see spreadsheet)	Sierra
State Administrative Personnel Requirements and Costs	(see spreadsheet)	Sierra Recommendation
State Hiring and Training Costs	(see spreadsheet)	Sierra
State Data Processing Equipment Costs	(see spreadsheet)	Sierra
State Travel Costs	(see spreadsheet)	Sierra
State Contractual Services Costs	(see spreadsheet)	Sierra
State Personnel Salaries	(see spreadsheet)	Based on California Wage Rates

*Information provided by the I/M contractors was reviewed for reasonableness and used to adjust cost model inputs developed by Sierra in previous studies.

Initial Costs to Program Operator

Section II of the spreadsheet contains the calculations of start-up costs for the program operator. This area of the spreadsheet contains estimates of the land area required for inspection facilities, the square footage of buildings and paving, personnel hiring and training, and the costs for public information and mechanic education. Details are provided on the third and fourth pages of Figure 1.

Recurring Costs to Program Operator

Section III of the spreadsheet contains the calculations for recurring costs to the program operator. These costs are dominated by personnel costs. Equipment maintenance, supplies (e.g., span gases), insurance, and property taxes are also a significant factor. Details of the assumptions and calculation procedures are shown on the fifth page of Figure 1.

Annualized Costs to Program Operator

Section IV of the spreadsheet is shown on the sixth page of Figure 1. It covers the annualized cost to the program operator. The calculations in this section include the amortization of the start-up costs from Section II. The residual value of land and buildings at the end of the program is specifically accounted for. When combined with the annual recurring costs from Section III, the total annual cost is determined. Cost per test is then calculated following the application of an assumed profit of 20%.

Although users can modify this profit assumption, history indicates that I/M program operation has a relatively high risk factor and lower profit assumptions are difficult to justify. The 20% default value is considered to reflect a reasonable rate of return for a program that does not involve excessive risk to the contractor. I/M contractors contacted during the preparation of this report, however, emphasized that they considered a rate of return of 30% or even higher reasonable for programs involving high risk. This would include new programs with significant uncertainty in projected revenues (e.g., due to non-guaranteed test volumes), penalty clauses that are likely to be invoked, and other contract provisions that I/M contractors would consider risky.

Program Costs to State

Beginning on page seven of Figure 1, the first subsection of "Program Costs to State" addresses mass emissions testing costs. The capital investment and operating costs for running a test cell equipped with IM240 capability are covered. Land acquisition cost for the test facility is <u>not</u> included, as it is assumed that CVS testing capability is added to one of the I/M testing facilities. However, $200,000 is allocated to facility upgrades, which could include additional floor space under the roof, a dynamometer pit, additional electrical power, compressed air, heating and air conditioning for climate control, etc.

Another $200,000 is allocated to purchase of the IM240 system itself, including an electric dynamometer. The way this section of the spreadsheet is configured, an annual mass emissions test volume of 1,200 is hard-coded (although easily modified by the user). At this annual testing volume, only one test cell is required, regardless of program size. A total of three employees are estimated to be necessary to operate the cell and recruit vehicles from the I/M lanes.

Additional state costs covered in this section are primarily related to the operation of a Program Administration Office. Regardless of program size, each Program Administration Office is assumed to have a Program Administrator, a Data Processing Specialist, and at least one Vehicle Inspection Specialist, one Mechanic Certification Officer, and one Clerk/Typist. Additional staffing is added in proportion to program size. Office space and equipment for the Program Administration Office is covered by a 95% rate for overhead and fringe. Start-up costs include expenses for recruiting and training Program Administration Office staff. Recurring costs include a modest travel budget and some contractor support services.

###

3. DECENTRALIZED PROGRAM MODEL

The structure of the decentralized program spreadsheet is similar to that used for the centralized program spreadsheet. Figure 2 shows what the spreadsheet looks like on-screen with user inputs for a hypothetical program that is similar to the program assumptions reflected in the centralized program described in the previous section (e.g., an automobile population of two million, exemptions for vehicles up to five years of age, and biennial testing).

The main difference between this and the centralized program spreadsheet is that a new section (Section II) is added addressing "Cost to Private Garages." In this section, there is no consideration of capital costs for buildings and land. This reflects the fact that decentralized programs generally involve utilization of existing facilities. In addition, this section of the spreadsheet uses the average hourly "shop rate" rather than actual employee salaries. This rate incorporates a charge to recover rents or capital invested in land and buildings. However, the shop rate is not assumed to cover the cost of emission analyzers and other equipment specifically required for the I/M program, nor the cost of mechanics training required for program participation. These program-specific capital costs are computed using the same type of methodology used in the centralized program spreadsheet, i.e., amortized over the inspection volume. In addition, recurring costs are added for an extended warranty on the emissions testing equipment and miscellaneous supplies (span gases, analyzer maintenance, etc.).

Six additional program parameters are required for the decentralized spreadsheet:

1. Inspection bays per 1,000 autos;
2. Garage costs per hour;
3. Minutes per inspection;
4. Number of mechanics/inspectors per bay;
5. Equipment costs per inspection bay; and
6. Referee test volume as a percent of initial tests.

In addition, several of the parameters contained in the centralized program spreadsheet are renamed and have different values for the decentralized program spreadsheet. In all cases, these changes reflect the fact that the "centralized" style test facilities are now referee facilities. To see the specific changes, the program parameters listed on the first page of Figure 2 can be compared to the parameters listed on the first page of Figure 1.

Figure 2

Decentralized I/M Cost Model

Decentralized_IM_EPA.123
Prepared by Sierra Research, Inc., November 2000

Note: Fees Shown in US Dollars

0. SUMMARY OF INSPECTION FEES

	Garage Fee/Test	State CVS Cost/Test	Total State Costs/Test	Total/Test
With CVS Cell	39.59	0.63	4.66	44.25
No CVS Cell	39.59	n.a.	4.03	43.62
	Fee/Init Test	**CVS Cost/Init**	**State Costs/Init**	**Total/Init**
With CVS Cell	48.30	0.63	5.68	53.98
No CVS Cell	48.30	n.a.	5.05	53.36

I. PROGRAM PARAMETERS

A. Primary User Inputs

1.	**Local Currency/US Dollar**	**LC/USD =**	**1**	Enter amount of local currency equivalent to one US dollar.
1.	**Present Auto Population**	**POP =**	**2,000,000**	
2.	**Annual Auto Population Growth Rate (%)**	**GRT =**	**2.0%**	
3.	**Percent of Vehicles Exempt**	**EXEMPT =**	**44%**	For '81 and later US fleet, use 20% for current yr + 2; 36% for current + 3; 44% for current +4
4.	**Inspection Frequency (Annual = 1, Biennial = 2)**	**FREQ =**	**2**	Average years between inspections for non-exempt vehicles
5.	**Annual Inflation Rate (%)**	**INF =**	**1.5%**	Use annual change in Consumer Price Index
6.	**Annual Interest Rate (%)**	**INT =**	**7.5%**	Cost of financing loans; Use current prime rate for US programs.
7.	**Program Length (years)**	**PRL =**	**7**	5-7 years minimum needed for cost/effective amortization
8.	**Inspection Bays per 1,000 Autos**	**BAY/1000 =**	**0.70**	More bays increase cost per test
9.	**Garage Costs Per Hour ("Shop Rate")**	**$MPH =**	60.00	Default=US$ 60
10.	**Minutes Per Inspection**	**GTI =**	**30**	Use 30 minutes for loaded mode test or TSI test with extensive visual/functional inspections
11.	**Referee Test Volume as % of Initial Tests**	**PCHT =**	**1%**	Default = 1%
12.	**Annual Operating Hours for Referee Lane**	**HRS =**	**2,340**	Exceeding 2400 may not be cost/effective
13.	**Lane Loading Percentage at Referee**	**LLP =**	**75%**	75% OK for Referee lanes
14.	**Hourly Lane Throughput (Max.) at Referee**	**Cars/hr =**	**6**	Referee = 6
15.	**Stringency Factor (%)**	**STR =**	**20.0%**	New programs may require start-up standards to avoid excessive failure rates initially
16.	**Training Cost per mechanic**	**$MCH =**	400.00	Minimum US$ 400
17.	**Number of Mechanics/Inspectors Per Bay**	**MCH =**	**1.50**	Number of mechanics to be trained per bay, usually only 1-2
18.	**Property Tax Rate per Full Value (contractor program)**	**PRT =**	**2.00%**	Area specific
19.	**Average Number of Inspectors per Referee Lane =**		**1.00**	1.0 for Referee; 1.5 for simple 2 position lane; 2.5 for 3 position lane
20.	**Equipment Costs Per Inspection Bay =**	**$/BAY =**	45,000.00	US$ 45000 US$45,000 for SS loaded; $20,000 for idle
21.	**Equipment Cost Per Referee Lane =**	**$/LANE =**	80,000.00	US$ 80000 US$80,000 for SS loaded; $40,000 for idle
22.	**Maximum Lanes per Referee Facility =**		**1**	Default = 2 to limit driving distance without major cost impact
23.	**Minimum Number of Test Facilities =**		**1**	Default = 1for minimum cost per test

B. Optional User Inputs

24.	Land Acquisition Cost per square foot	$LAND/ft2 =	10.00	Typical = US$ 10
25.	Construction Costs per square foot	$CONS/ft2 =	80.00	Default = US$ 80
26.	Site Preparation Costs	$SITE =	100,000.00	Typical = US$ 100000
27.	Monthly Office Space Rental Cost per square foot	$RENT/ft2 =	1.20	Typical = US$ 1.2
28.	Paving Costs per square foot	$PAVG/ft2 =	2.00	Typical = US$ 2
29.	Initial Public Information Costs	$IPI =	0.50	Default/veh = US$ 0.5
30.	Recurring Public Information Costs	$RPI =	0.10	Default/veh = US$ 0.1
31.	Referee Lane Efficiency Factor	EFF =	85%	85% max for experienced contractors
32.	Annual Percent Additional Tests (%)	XTR =	2.0%	2% is reasonable minimum
33.	Percent of Initial Tests at Centralized Facility (%)	INIT =	1.0%	From referee test volume above
34.	Percent of Retests at Centralized Facility (%)	RTST =	0.0%	0% for decentralized program
35.	Mechanics Required per 1,000 autos	Mech/1,000 =	1	1.0 typical
36.	Initial Program Design and Engineering Cost	IDE =	10.0%	Default = 10%
37.	Recurring Program Design and Engineering Cost	RDE =	0.2%	Default = 0.2%
38.	Computer Processing Cost per test	$CPT =	0.05	Default = US$ 0.05
39.	CVS Test Cell Annual Capacity =		1,600	Default = 1600 for hot start IM240s
40.	Capital, Land, Construction, Training Cost Multiplier (Since 1/199)		1	Default = 1.0
41.	Labor Rate Multiplier for Administration/Management (Since 1/1/99)		1	Default = 1.0
42.	Labor Rate Multiplier for Private Garages Since 1/1/99		1	Default = 1.0

Figure 2

C. Parameter Calculations

1. Average Annual Population

$$AAP = POP(1\text{-}EXEMPT) \times \left[\sum_{i=0}^{i=PRL-1} (1+GRT)^i\right] / (PRL \times FREQ) = 594{,}743$$

2. Average Annual Tests Performed

Decentralized Tests = AAP x (1 + STR + XTR) =	725,586
Referee Tests = AAP x [INIT + (STR + XTR) x RTST] =	5,947

3. Total Inspection Bays Required

AAP/1000 x BAY/1000 =	BYRQ =	416

4. Annual Referee Lane Capacity

CAP = HRS x Cars/hr	CAP =	14,040

5. Total Referee Lanes Required

LAN = TST / (CAP x LLP x EFF)	LAN =	1

II. COSTS TO PRIVATE GARAGES

A. Initial Investment Costs

1. Per Inspection Bay

Analyzer and Equipment	45,000
Mechanic Training ($MIT)	5,000
Mechanics/Bay (MCH)	1.50
Total per Bay = $PGI =	52,500

2. Program Wide

$PGI x BYRQ = $PWI =	21,840,000

B. Annually Recurring Costs

1. Per Inspection Bay

Extended Warranty	2,502	5.56% of $/BAY
Calibration Gases/Supplies	1,500	
Total per Bay = $PGA =	4,002	

2. Per Test

Inspector's Time & Overhead	
GTI x $MPH = $PIA =	30.00
N2 Gas = $30/250 Tests =	0.12
Total per Test = $PTA =	30.12

3. Program Wide

($PGA x BYRQ) + ($PTA x TST) = $PWA =	23,519,484

C. Annualized Total Costs to Private Garages

1. Amortization of Initial Costs

$$\$PWI \times INT(1+INT)^{PRL} / (1+INT)^{PRL} - 1 = 4{,}123{,}399$$

2. Annual Costs with Inflation

$$\$PWA \times \left[\sum_{i=0}^{i=PRL-1} (1+INF)^i\right] / PRL = 24{,}604{,}721$$

3. Total Annualized Program Cost to Private Garages

= $TPPG =	28,728,120
Cost per test =	39.59
Cost/Initial Test =	48.30

Figure 2

III. INITIAL COSTS TO REFEREE PROGRAM OPERATOR

A. Estimates of Facility Requirements

1. Inspection Facility Square Footage Requirements (enter data in sq ft)

LAND		LANES	OFFICE, ETC.		PAVING	
Basic per Facility	Additional per Lane	per Lane	Basic per Facility	Additional per Lane	Basic per Facility	Additional per Lane
20,000	10,890	1,000	1,000	0	5,000	3,200

2. Allocation of Lanes and Square Footage Requirements

LANE ALLOCATION			LAND		BUILDING					
					LANES		OFFICE, ETC.		PAVING	
Lanes per Facility	# Facilities This Size	Total Lanes	Each Facility	Total	Each Facility	Total	Each Facility	Total	Each Facility	Total
1	1	1	30,890	30,890	1,000	1,000	1,000	1,000	8,200	8,200
0	0									
1	0						1,000	0		
TOTAL	1 (FAC)	1 (LAN)	LND =	30,890	LNS =	1,000	OFC =	1,000	PVG =	8,200

3. Inspection Facility Personnel Hiring and Training Requirements

Position	Facility Staffing Requirements # of Positions	Pers-Yrs @ 2340 hrs/yr		Annual Salary per employee @ 40 hrs/week	Overhead & Fringe 30%	Duration of Instruction per Trainee (hrs)	Direct Costs of Instruction per Trainee	Total Training Cost per Employee	Hiring Cost per Employee	Total Training & Hiring Cost per Employee
Station Manager	1	1.13	per facility	27,750	8,325	640	400	11,500	200	11,700
Asst. Station Manager	1	1.13	per facility	19,990	5,997	160	400	2,399	100	2,499
Inspection Technicians	1	1.13	per test lane	14,560	4,368	160	200	1,656	50	1,706
Customer Service Rep	0	0.00	per facility	23,200	6,960	80	200	1,360	50	1,410

B. Calculation of Facility Investment Costs

1. Construction and Land Acquisition Costs

a. Land Acquisition = LND x $LAND/ft2 = $LANDAQ = 308,900

b. Paving = PVG x $PAVG/ft2 = $PAVING = 16,400

c. Construction = (OFC + LNS) x $CONS/ft2 = $CONSTR = 160,000

d. TOTAL Building = $PAVING + $CONSTR = $BUILDING = 176,400

2. Inspection Facility Personnel Hiring and Training Costs

a. Station Managers:
$11700 x 1.13 / facil x FAC = 13,163

b. Assistant Station Managers:
$2499 x 1.13 / facil x FAC = 2,811

c. Inspection Technicians:
$1706 x 1.13 / lane x LAN = 1,919 (staffed lanes)

d. Customer Service Representatives:
$___ x ___ / facil x FAC =

e. TOTAL Inspection Facility Personnel Hiring & Training = FIELDPERS = 17,893

3. Facility Preparation and Equipment Costs

Per (Category)	Number	Site Preparation Each	Total	Test Equipment Each	Total	Office & Other Equipmt. Each	Total	Data Proc. Equipmt. Each	Total	TOTAL
Facility	1	100,000	100,000			20,000	20,000	0		120,000
Test Lane	1			80,000	80,000			0		80,000
Satellite Offices	0	N/A				20,000		0		
Central Office	1	N/A				40,000	40,000	100,000	100,000	140,000
TOTAL			100,000 ($PREP)		80,000		60,000		100,000	$EQUIP = 340,000

Figure 2

C. Start-Up Administrative Costs

1. Start-Up Personnel Costs

Position Area	Number per Central Office	Number per Satellite Office	Total Number of Employees	Average No. of Startup Hours per Employee	Total Person Years	Annual Salary @ 40 hrs/week per Employee	Overhead & Fringe 50%	Total Salary and Benefits
Program Administrator	1	0	1	3,120	1.5	67,500	33,750	151,875
Area Administrators	0	1	0	2,080	0.0	62,500	31,250	
Technical Officers	1	1	1	1,040	0.5	52,500	26,250	39,375
Data Analysis/Statistical Staff	1	0	1	693	0.3	37,500	18,750	18,741
Clerical and Secretarial Staff	2	1	2	693	0.7	22,500	11,250	22,489
TOTAL			5					232,480 ($CSBP)

2. Start-Up Training and Hiring Costs

Position Area	Total Number of Employees	Annual Salary and Benefits per Employee	Duration of Instruction (hrs) (Per Employee)	Direct Cost of Instruction (Per Employee)	Total Training Costs (All Employees)	Hiring Costs (Per Employee)	Total Training Plus Hiring (All Employees)
Program Administrator	1	101,250	40	2,000	3,947	10,000	13,947
Area Administrators	0	93,750	40	2,000	0	5,000	0
Technical Officers	1	78,750	80	3,000	6,029	1,000	7,029
Data Analysis/Statistical Staff	1	56,250	40	2,000	3,082	500	3,582
Clerical and Secretarial Staff	2	33,750	40	400	2,098	400	2,898
TOTAL	5				15,156		27,456 ($CHIRE)

3. Calculation of Start-Up Administrative Costs

a. Start-Up Personnel = $CSBP = 232,480.17

b. Initial Public Information
$IPI or $IPI/vehicle x POP = 1,000,000.00

c. Initial Program Design, Eng. & Eval.
%IDE x ($LANDAQ + $BUILDING + $EQUIP)
or $IDE/veh. x POP = 82,530.00

d. Administrative Personnel Hiring and Training = $CHIRE = 27,455.77

e. TOTAL Start-Up Administrative Costs = 1,342,465.94

D. Total Initial Costs to Program Operator

1. Land Acquisition = $LANDAQ = 308,900.00
2. Total Building = $BUILDING = 176,400.00
3. Field Personnel Training & Hiring = $FIELDPERS = 17,893.13
4. Facility Preparation & Equipment = $EQUIP = 340,000.00
5. Land Purchase & Re-Sale Fee = 6.0% x $LANDAQ = $LNDFEE = 37,068.00
6. TOTAL Start-Up Administrative Costs = $ADMIN = 1,342,465.94
7. SUBTOTAL = $FIELDPERS + $EQUIP + $ADMIN = $STARTUP = 1,737,427.06
8. TOTAL Initial Costs = $LANDAQ + $BUILDING + $STARTUP = 2,222,727.06

Figure 2

IV. RECURRING COSTS TO REFEREE PROGRAM OPERATOR

A. Personnel Costs

1. Central Office Operating Staff

Position Area	Number	Annual Salary @ 40 hrs/week
Program Administrator	1	67,500
Technical Officers	1	52,500
Data Analysis/Statistical Staff	1	37,500
Clerical and Secretarial Staff	2	22,500
SUBTOTAL (salary x person years)		202,500
Overhead & Fringe	50.0%	101,250
TOTAL	$CSTAFF =	303,750

2. Each Satellite Offices Operating Staff

Position Area	Number Per Office	Annual Salary @ 40 hrs/week
Area Administrator	1	62,500
Technical Officers	1	52,500
Data Analysis/Statistical Staff	0	37,500
Clerical and Secretarial Staff	1	22,500
SUBTOTAL (salary x person years)		137,500
Overhead & Fringe	50.0%	68,750
Total per Satellite Office		206,250
TOTAL	$SSTAFF =	

3. Inspection Facility Operating Staff

a. Station Managers:	$ salary x #/facil x FAC	31,218.75	
b. Assistant Station Managers:	$ salary x #/facil x FAC	22,488.75	
c. Inspection Technicians:	$ salary x #/lane x LAN	16,380.00	(staffed lanes only)
d. Customer Service Reps:	$ salary x #/facil x FAC		
e. SUBTOTAL	=	70,087.50	
f. Overhead and Fringe Benefits	30.0% =	21,026.25	
g. TOTAL Inspection Facility Operating Staff	$FSTAFF =	91,113.75	

B. Miscellaneous Total Recurring Costs

1. Office Rental
   #CSTAFF x $RENT/ft2 x 12 = 14,400
   #SSTAFF x $RENT/ft2 x 12 =
   TOTAL RENTAL COSTS = 14,400

2. Support Services to Facilities
   Basic per facility = 12,000
   Additional per lane =
   TOTAL SUPPORT SERVICES 12,000

3. Operating Supplies
   N2 Gas = $30/250 Tests = 714
   Cal. Gases = $240/2 mo./lane = 1,440
   Misc. Supplies = $250/lane = 250
   $SUPP = 2,404

4. Travel 4,000 /facil x FA 4,000

5. Public Information = $RPI or $RPI/veh. x AAP = 59,474

6. Equipment Maintenance
   10% x ($EQUIP - $PREP) 24,000

7. Annual Program Design, Eng. & Eval.
   %RDE x ($LANDAQ + $BUILDING + $EQUIP)
   or $RDE/veh. x AAP = 1,651

8. Computer Processing of Tests = $CPT x TST = 36,279

Figure 2

9 Insurance Costs (where applicable)

		Rate as % Capital Cost	Insurance Cost	
"Buildings" rate	=	0.3%	457	
"Office Contents" rate	=	4.5%	2,700	
Liability Insurance =			535	US$0.09 per tested vehicle
"Test/Data Proc. Equip." rate	=	0.4%	694	
	TOTAL INSURANCE COSTS		4,386	

10. Personnel Costs
$CSTAFF + $SSTAFF + $FSTAFF = 394,864

12. Property Taxes (contractor program only)
PRT x ($BUILDING + $LANDAQ + $EQUIP) = 16,506

13. Hiring and Training Costs Due to Employee Turnover
20% x ($FIELDPERS + $CHIRE) = 9,070

14. TOTAL Recurring Costs = $RECUR = 583,420

V. ANNUALIZED COSTS TO REFEREE PROGRAM OPERATOR

A. Average Recurring Costs ($RECURi) Accounting for Inflation

$$\$RECUR \times \left[\sum_{i=0}^{i=PRL-1} (1 + INF)^{i} \right] / PRL = 610,340$$

B. Amortization of Initial Costs

General Formulas

1. Value of Item Remaining at end of Program: VAE = $ITEM x (DEPR - PRL) / DEPR (where DEPR is depreciation period)
2. Present Discounted Value of Item Remaining at end of Program: PDV = VAE / (1 + INT)^PRL
3. Value of Principle to be Paid Off over Length of Program: PRIN = $ITEM - PDV
4. Annual Payment <ITEM> of Initial Loan <ITEM> Plus Interest: $PMT = PRIN x INT (1 + INT)^PRL / (1 + INT)^PRL - 1

(Note: Interest Rate Already Accounts for Inflation)

Calculation for Initial Specific Cost Elements

					VAE	PDV	PRIN
1	Land Acquisition: Buy/Sell Discount Rate = (Relative VAE = (1 - Disc Rate) x $LANDAQ)	10.0%	$PMT-Land =	26,683	$278,010	$167,572	$141,328
2.	Building: Depreciation period (yrs) =	20	$PMT-Bldg =	20,256	$114,660	$69,112	$107,288
3	Other Start-Up: Depreciation period (yrs) = (VAE = 0; PRIN = $STARTUP)	7	$PMT-Start =	328,027	$0	$0	$1,737,427
4	TOTAL Annual Payment Plus Interest For Initial Costs =		$PAYMENT =	374,966			

C. Total Annualized Costs to Program Operator

$RECUR i + $PAYMENT = $ANNUAL =		985,305.86
Contractor's Net Return	15.0%	147,795 88
TOTAL Annualized Contractor Program Costs = $CONTR =		1,133,101.74
Annualized Contractor Cost per Vehicle = $CONTR / TST =		190.52

Figure 2

VI. PROGRAM COSTS TO STATE

A. Mass Emissions Testing Costs

1. Initial Test Cell Personnel

Position Area	rson Years	Cost/PY
Supervisor	0.3	37,500
Specialist 3	0.1	35,000
Specialist 2	0	32,000
Specialist 1	0.1	27,500
SUBTOTAL		17,500
Overhead & Fringe	95.0%	16,625
TOTAL	$MTSTIN =	34,125

2. Recurring Test Cell Personnel

Position Area		Person Years	Cost
Supervisor		1	37,500
Specialist 3		1	35,000
Specialist 2		0	32,000
Specialist 1		1	27,500
SUBTOTAL	(#MPERS =)	3	100,000
Overhead & Fringe		95%	95,000
TOTAL		$MTSTAN =	195,000

3. Test Cell Start-Up Costs

a. Required Annual Mass Emission Tests

#MTSTS = Number of tests for statistically significant sample 1,200

b. Required Number of Test Cells

#CELLS = MTSTS / CVSCAP = 1

c. Facility Upgrades (dyno install, power, HVAC, etc.)

Single Test Cell Cost = $MBLDG = 200,000.00

$MBLDGS = $MBLDG x #CELLS = 200,000.00

d. Cost of Test Cell Equipment

Single Test Cell Cost = $MEQUIP = 200,000.00

$MEQUIPS = $MEQUIP x #CELLS = 200,000.00

e. Total Capital Cost

$MCAP = $MBLDGS + $MEQUIPS = 400,000.00

f. Initial Test Cell Personnel Cost = $MTSTIN = 34,125.00

g. Hiring and Training Cost for Test Cell Personnel

#MPERS x $2,000 /Employee 6,000.00

h. TOTAL Start-Up Test Cell Costs ($CELLIN) = 440,125.00

4. Test Cell Recurring Costs

a. Recurring Test Cell Pers. Cost = $MTSTAN = 195,000.00

b. Recurring Vehicle Recruitment Costs

Recruitment Cost/Vehicle = $RCTMT = 100.00

Annual Cost = $RCTMT X #MTSTS = 120,000.00

c. Recurring Maintenance Costs

% of Initial Test Cell Cost = %MMAINT = 0.10

Annual Cost = $MMAINT x $MCAP = 40,000.00

d. TOTAL Recurring Test Cell Costs = 355,000.00

5. Amortization of Initial Test Cell Costs to State

$$\$CELLIN \times INT(1+INT)^{PRL} / \left[(1+INT)^{PRL} - 1\right] = \$CLPT = 83,095.74$$

Recurring Test Cell Costs to State Accounting for Inflation

$$\$CELLAN \times \left[\sum_{i=0}^{PRL-1} (1+INF)^{i}\right] / PRL = \$CLANN = 371,380.42$$

TOTAL Annualized Test Cell Costs to State

$$\$STPT + \$SANN = \$STATE = 454,476.16$$

6. Test Cell Portion Of Annual Fee to Motorists

a. Test Cell "Inspection Fee" = $TOTL / TST = 0.63

Figure 2

B. Initial Oversight Costs

1. Central Administrative Personnel

Position Area		rson Years	Annual Salary @ 40 hrs/week	95% Overhead & Fringe	Duration of Instruction (hrs)	Direct Cost of Instruction	Total Training Costs	Hiring Costs	Total Training Plus Hiring
Program Administrator	(see below for	1.0	75,000	71,250	40	600	3,413	10,000	13,413
Deputy Administrator	person-year	0	62,500		40	600	0	5,000	0
Auto Emissions Control Engineer	formulas)		52,500		80	400	0	3,000	0
Emissions Testing Technician			27,500		80	400	0	200	0
Data Processing Specialist		1	52,500	49,875	40	200	2,169	200	2,369
Automotive Mechanic		2	35,000	66,500	80	400	9,075	200	9,675
Vehicle Inspection Specialist		3	42,000	119,700	80	400	17,750	200	18,750
Mechanic Certification Officer		1	37,500	35,625	80	400	3,213	200	3,413
Mechanic Certification Clerk		1	22,500	21,375	40	100	944	200	1,144
Secretary		0	25,000		40	50	0	200	0
Clerk/Typist		1	20,000	19,000	40	50	800	200	1,000
TOTAL		10.0	403,500 ($CAPIN)	383,325 ($BENIN)			37,363	19,600	49,763 ($FTRN)

2. Total Initial Costs to State

a. Central Administrative Personnel = $CAPIN + $BENIN = 786,825.00

b. Administrative Personnel Training & Hiring = $FTRN = 49,762.50

c. Initial Private Mechanic Training
Mech/1,000 x POP/(FREQ x 1,000) x $MCH = 400,000.00

d. Data Processing Equipment $DEQUIP = $2,000 x #STAFF = 26,000.00

e. Initial Test Cell Costs = $CELLIN = 440,125.00

f. Program Design Cost (contract) 500,000.00

g. Initial Undercover Vehicle Fleet $10,000 x 10/1000 bays = 41,600.00

h. TOTAL Initial Costs to State = $STIN = 2,244,312.50

C. Recurring Costs

1. Central Administrative Personnel

Position Area		rson Years	Annual Salary @ 40 hrs/week	
Program Administrator		1.0	75,000	1 regardless of program size
Deputy Administrator		0	62,500	0.5/1 million tests
Auto Emissions Control Engineer			52,500	
Emissions Testing Technician			27,500	
Data Processing Specialist		1	52,500	1 + 1/2 million tests
Automotive Mechanic		3	35,000	1 + 5/1,000 Bays
Vehicle Inspection Specialist		5	42,000	1 + 10/1,000 Bays
Mechanic Certification Officer		1	37,500	1 + 1/1,000 Bays
Mechanic Certification Clerk		1	22,500	1 + 1/1,000 Bays
Secretary		0	25,000	0.2/1 million tests
Clerk/Typist		1	20,000	1 + 0.25/1 million tests
SUBTOTAL	(#STAFF) =	13	522,500	
Overhead & Fringe		95.0%	496,375	
TOTAL		$CAPAN =	1,018,875	

Figure 2

2. Total Recurring Costs to State

a. Central Administrative Personnel		= $CAPAN =		1,018,875
b. Annual Additional Mechanic Training 20% of Initial Mechanic Training Cost		=		80,000.00
c. Recurring Test Cell Costs = $CELLAN		=		355,000.00
e. Travel =	$5,000 +	$300 x #STAFF =		8,900.00
g. D.P. Equip. Maintenance =		10% x $DEQUIP =		2,600.00
h. Contract Services		=		250,000.00
i. Recurring Hiring and Training Costs		=		4,976.25
j. Recurring Undercover Car Costs =	$5000 x 10/1000 bays =			20,800.00
k. TOTAL Recurring Costs to State		= $STRC =		1,741,151.25

D. Annualized Costs to State

1. Amortization of Initial Costs to State

$$\$STIN \times INT(1+INT)^{PRL} / (1+INT)^{PRL} : 1 = \$STPT = 423,727$$

2. Recurring Costs to State Accounting for Inflation

$$\$STRC \times \left[\sum_{i=0}^{PRL-1} (1+INF)^{i} \right] / PRL = \$SANN = 1,821,491$$

3. TOTAL Annualized Program Costs to State

$\$STPT + \$SANN$ = $STATE = 2,245,218

3.09 State Cost/Test for Program Eval and Enforcement
1.56 Costs/Test for Referee Contract
4.66 Total Costs/Test Referee + Other State Costs

The costs associated with referee testing capability are addressed using a calculation methodology very similar to that used for centralized test facility operating costs in the centralized program spreadsheet. CVS testing costs are also calculated in a very similar manner; however, vehicle recruitment costs have to be added because of the lack of centralized lanes from which randomly selected vehicles can be easily recruited for testing. Other program costs to the state are also handled in a manner similar to that contained in the centralized program spreadsheet; however, significantly greater staffing is assumed to deal with the greater enforcement needs of decentralized programs. The main increase in staffing is associated with the resources necessary to average two inspections per licensed garage each year. One or both of these inspections could involve undercover car runs. Details of the staffing formulas are shown on the eighth page of Figure 2. The basic assumption behind the formula for "Vehicle Inspection Specialists" is that two-person teams will be able to do two undercover runs per day. One mechanic is assumed to be required to support each 2-person team in the field.

Another element of costs contained in the decentralized spreadsheet involves a fleet of undercover vehicles. Initial costs are based on purchasing two $10,000 vehicles per team of field personnel. Recurring costs for the operation, maintenance, and annual replacement of the vehicles with comparable models are estimated at $5,000 per vehicle. No separate costs are assigned to a facility at which the undercover vehicles will be housed and maintained. The overhead charge for the personnel associated with these vehicles is considered sufficient to cover the cost of the necessary garage space.

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4. EXAMPLE CALCULATIONS

In Figures 1 and 2, costs were presented for a centralized program and a decentralized program for a hypothetical area with a vehicle population of 2 million, a 2.0% annual vehicle population growth rate, exemptions for 44% of the vehicles, biennial ASM testing frequency, a 1.5% inflation rate, a 7.5% interest rate, and a 7-year program length. The results are summarized below in Table 4.

Table 4
Summary of Inspection Cost/Test for Hypothetical Programs

	Inspection Fee	CVS Testing	Oversight and Enforcement	Total Cost
Decentralized	$39.59	$0.63	$4.03	$44.25
Centralized	$14.02	$0.45	$1.07	$15.54

As shown in Table 4, the total cost per test for the decentralized program was almost three times higher than the centralized program. The most significant factor was the higher inspection fee needed to cover the fundamentally less efficient inspection process done in a private garage as opposed to a highly automated, drive-through inspection lane. Also contributing to the cost increase for decentralized testing is the higher oversight and enforcement cost associated with so many more locations where inspections are being performed and the fact that the inspections in private garages are more easily falsified (necessitating greater enforcement resources).

As shown in Table 5, the spreadsheet models indicate that the economy of scale is a significant factor for both centralized and decentralized I/M programs. This is because there is a minimum number of people needed to design and manage both the public and private sector activities. However, centralized programs are projected to have significantly lower costs per test, regardless of the vehicle population. With a relatively small program (e.g., 250,000 vehicle population) decentralized testing is twice as expensive. With relatively large programs (e.g., ≥2 million), decentralized testing is about three times more expensive.

Table 5
Cost Per Test vs. Vehicle Population
(44% Exempt, Biennial ASM Testing, 7 Year Program Length)

Vehicle Population	Centralized	Decentralized	Decentralized/ Centralized
250,000	$34.82	$66.79	1.92
500,000	$23.71	$54.04	2.28
1,000,000	$18.56	$47.46	2.56
2,000,000	$15.54	$44.25	2.85
4,000,000	$13.96	$43.13	3.09
8,000,000	$13.49	$42.32	3.14

Table 6 illustrates the relationship between program length and cost per test. The longer the length of the program, the greater the time over which capital investments and start-up costs can be amortized. As a result, costs per tests are substantially lower for programs that are five to seven years in length compared to shorter programs.

Table 6
Cost Per Test vs. Program Length
(44% Exempt, Biennial ASM Testing, 4 Million Vehicle Population)

Program Length	Centralized	Decentralized
1 Year	$28.26	$72.75
2 Years	$19.84	$54.82
3 Years	$17.07	$49.02
4 Years	$15.58	$46.24
5 Years	$14.79	$44.68
6 Years	$14.43	$43.73
7 Years	$13.96	$43.13

Although the combinations of program parameters that can be evaluated with the models are essentially unlimited, there are certain combinations that should be avoided.

Parameter combinations to avoid include those for which there is no evidence of practicality. For example, increasing the minimum number of centralized test facilities beyond a certain level will result in large cost increases. For decentralized programs, reducing the enforcement resources in the body of the spreadsheet would result in a relatively ineffective program.

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