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Transportation Systems Center, Cambridge, Mass

Prepared for

National Highway Traffic Safety Administration, Washington, D C Office of Research and Development

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AUTOMOTIVE FLEET FUEL CONSUMPTION MODEL: FUEL.FOR

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FINAL REPORT

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16. Abstract

A computer program has been developed which calculates potential fuel conservation benefits stemming from increases in automotive fuel economy. Inputs include:

(1) a schedule of new car registrations by model year, both historic and projected;

(2) a schedule of miles traveled annually by a car as a function of its age;

(3) a schedule of vehicle survival probability as a function of age;

(4) a description of average fuel economy, by model year, of the existing fleet;

(5) a hypothetical baseline schedule of new car fuel economy by model year; and

(6) a hypothetical improved schedule of new car fuel economy by model year.

Outputs include:

(1) annual fuel savings;

(2) cumulative fuel savings; and

(3) discounted cumulative cash savings.

Impacts upon aggregate consumer outlay for fuel, upon lifetime operating cost (per auto), and upon federal and state excise tax revenues are also calculated.

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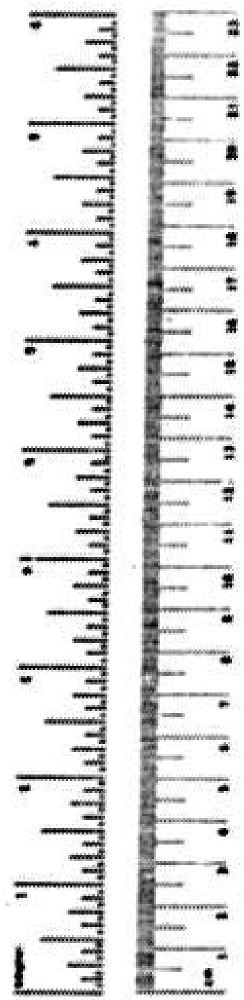
PREFACE

The Transportation Systems Center of the U. S. Department of Transportation performs studies for the Department related to the usage and possible conservation of fuel by the transportation sector. The computer model described in this report is a tool for determining the fuel conservation benefits arising from various hypothetical schedules of new car fuel economy standards.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		AREA		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MASS (weight)		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		VOLUME		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		AREA		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MASS (weight)		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		VOLUME		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

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1. INTRODUCTION

FUEL* is a Fortran program designed to assist the Office of Fuel Economy of the National Highway Transportation Safety Authority (NHTSA) in its selection of fuel economy standards for domestically manufactured passenger cars. The model calculates potential fuel conservation benefits resulting from increases in fuel economy. Benefits are reported in terms of three fundamental quantifiers:

(1) annual fuel savings (billions of gallons);
(2) cumulative fuel savings (billions of barrels); and
(3) discounted cumulative cash savings (billions of dollars).

Impacts upon aggregate consumer outlay for fuel, lifetime operating cost (per auto), and Federal and state excise tax revenues are also calculated.

*A listing of FUEL is given in Figure 8.

2. MODEL DESCRIPTION

The first portion of this section deals with only that part of the model which calculates the three fundamental quantifiers. Program logic, inputs, and outputs of the specialized, derivative features are described subsequently.

2.1 BASIC MODEL DESCRIPTION

2.1.1 Inputs

FUEL accepts six essential user-specified data files containing:

(1) a schedule of new car registrations by model year, both historic and projected into the future;

(2) a schedule of miles traveled annually by a car as a function of its age;

(3) a schedule of vehicle survivability as a function of age;

(4) a description of average new car fuel economy, by model year, of the existing fleet;

(5) a hypothetical "baseline" schedule of new car fuel economy by model year; and

(6) a hypothetical improved schedule of new car fuel economy by model year.

The user may build and use data files reflecting any set of assumptions regarding existing fleet characteristics, vehicle miles, vehicle survivability, future new car registrations, and future car fuel economy. However, in all work done to date for the Office of Fuel Economy, new car registrations, vehicle miles, vehicle survivability, and existing fleet fuel economy have been portrayed by files REGO2.DAT, MILE1.DAT, SURV1.DAT, and OLDFE.DAT, respecly. Contents of these files are shown in Tables 1 through 4.*

*The actual computer format and file structure of these and other data files used by FUEL is discussed in the User's Guide.

TABLE 1. NEW CAR REGISTRATIONS BY MODEL YEAR - REG02.DAT

Model Year	Registrations, millions	Model Year	Registrations, millions
1961	5.48	1984	10.01
1962	6.60	1985	10.21
1963	7.17	1986	10.41
1964	7.58	1987	10.62
1965	8.74	1988	10.83
1966	8.35	1989	11.05
1967	7.58	1990	11.27
1968	8.42	1991	11.50
1969	8.46	1992	11.73
1970	7.20	1993	11.96
1971	8.46	1994	12.20
1972	9.06	1995	12.44
1973	9.74	1996	12.69
1974	7.41	1997	12.95
1975	7.20	1998	13.20
1976	8.54	1999	13.47
1977	8.71	2000	13.74
1978	8.89	2001	14.01
1979	9.06	2002	14.29
1980	9.25	2003	14.58
1981	9.43	2004	14.87
1982	9.62	2005	15.17
1983	9.81		

TABLE 2. ANNUAL VEHICLE MILES VS. AGE - MILE1.DAT

Vehicle Age, years	Annual Mileage, 10^3 miles
1	18.0
2	15.1
3	13.4
4	12.2
5	11.3
6	10.5
7	9.9
8	9.3
9	8.8
10	8.4
11	8.0
12	7.6
13	7.3
14	7.0
15	6.7

TABLE 3. SURVIVAL PROBABILITY VS. AGE - SURV1.DAT

Vehicle Age, years	Survival Probability
1	0.998
2	.993
3	.982
4	.962
5	.929
6	.873
7	.784
8	.661
9	.519
10	.384
11	.273
12	.191
13	.134
14	.095
15	.067
16	0.000

TABLE 4. EXISTING FLEET FUEL ECONOMY BY MODEL YEAR - OLDFE.DAT

Model Year	Average Fuel Economy, mpg
1961	15.0
1962	15.0
1963	15.0
1964	15.0
1965	15.0
1966	14.9
1967	14.9
1968	14.3
1969	14.1
1970	14.1
1971	13.7
1972	13.5
1973	13.0
1974	12.9
1975	14.8

In the absence of user action to the contrary, these files are automatically selected by FUEL.

Data files have been constructed to portray many different new car fuel economy schedules of interest to the Office of Fuel Economy. Two such files are shown in Table 5 as examples. Most of the work for the Office of Fuel Economy has used the file named BASE.DAT as a "baseline" new car fuel economy schedule. This schedule portrays a gradual increase of new car fuel economy from 16.9 mpg in 1976 to 20 mpg by 1980, with no further improvement. The other data file, RSDA.DAT, portrays the same fuel economy schedule to 1980, but includes additional improvements up to 27.5 mpg by 1985, remaining at 27.5 thereafter.*

Certain parameters used by FUEL may be assigned values by the user. Among these are the number of calendar years for which impacts are to be examined (NYR), the initial calendar year (IYR), the discount rate (DIS), and the year to which cash savings are to be discounted (DYR). All work done to date for the Office of Fuel Economy has used the default values for these parameters. The significance of these parameters, their default values, and the means for changing their values are presented in the glossary and user sections.

2.1.2 Logic

FUF' calculates fuel consumption for all cars of each model year on a year-by-year basis according to the following formula:

$$FC_{ij} = \frac{(REG_k)\ (VM_j)\ (SURV_j)}{(FE_k)} \qquad (1)$$

*RSDA is an acronym for Rulemaking Support Document, schedule A. This is one of five schedules specified for study by the Office of Fuel Economy (RSDA through RSDE). Many other fuel economy schedules have been examined and their impacts reported (see "Data and Analysis for 1981-1984 Passenger Automobile Fuel Economy Standards, Summary Report," Part A. pp. 15-32). Effects of these various schedules are reported in Attachment 2 of a memorandum dated April 29, 1977, from Acting Chief, Energy Program Division, TSC, to A.C. Malliaris, Energy Research Division, NHTSA, N43-13.

TABLE 5. FUEL ECONOMY SCHEDULES - BASE.DAT AND RSDA.DAT

Model Year	Fuel Economy BASE	Fuel Economy RSDA
1976	16.9 mpg	16.9 mpg
1977	17.8 mpg	17.8 mpg
1978	18.0 mpg	18.0 mpg
1979	19.0 mpg	19.0 mpg
1980	20.0 mpg	20.0 mpg
1981	20.0 mpg	21.5 mpg
1982	20.0 mpg	23.0 mpg
1983	20.0 mpg	24.5 mpg
1984	20.0 mpg	26.0 mpg
1985	20.0 mpg	27.5 mpg
1986	20.0 mpg	27.5 mpg
1987	20.0 mpg	27.5 mpg
1988	20.0 mpg	27.5 mpg
1989	20.0 mpg	27.5 mpg
1990	20.0 mpg	27.5 mpg
1991	20.0 mpg	27.5 mpg
1992	20.0 mpg	27.5 mpg
1993	20.0 mpg	27.5 mpg
1994	20.0 mpg	27.5 mpg
1995	20.0 mpg	27.5 mpg
1996	20.0 mpg	27.5 mpg
1997	20.0 mpg	27.5 mpg
1998	20.0 mpg	27.5 mpg
1999	20.0 mpg	27.5 mpg
2000	20.0 mpg	27.5 mpg

where:

i = calendar year index;

j = vehicle age index;

k = model year index = $i-j+1$;

FC_{ij} = fuel consumption by all vehicles of age j during year i;

REG_k = new car registrations (sales) of model year k;

VM_j = yearly travel of cars of age j;

$SURV_j$ = likelihood of a car surviving to age j; and

FE_k = average new car fuel economy of model year k.

Index j ranges from one to fifteen, reflecting the assumption that only cars ranging in age from new ($j=1$) to fifteen years ($j=15$) are in service. Fuel consumption of the entire fleet during year i is determined by summing the fuel consumption of each age category:

$$SFC_i = \sum_{j=1}^{15} FC_{ij} . \qquad (2)$$

Table 6 provides a set of example calculations for the baseline schedule (BASE) in year 1980. For example, 9.25 million cars are sold in 1980 having an average fuel economy of 20 mpg. Since these cars are only one year old ($j=1$), they are each assumed to travel 18 thousand miles. Their aggregate fuel consumption during 1980 is, therefore,

$$(9.25\times10^6 \text{ cars}) \times (18.0\times10^3 \text{ miles/car}) \times 0.998 \div (20.0 \text{ miles/gallon}) = 8.31 \times 10^9 \text{ gallons.}$$

This calculation is done for each age group going back fifteen years to model year 1966. The results are summed to get fleet fuel consumption in 1980 for the baseline schedule: 54.74 billion gallons.

For 1981, a new table is constructed similar to Table 7, but with the VM_j and $SURV_j$ arrays shifted forward one year. Again, fuel consumption by model year is calculated and the

TABLE 6. FLEET FUEL CONSUMPTION FOR CASE BASE IN CALENDAR YEAR 1980 (I=5)

MODEL YEAR, K	REG(k) 10^6CARS	FEB(k)* MPG	VM(J) 10^3MI/CAR	SURV(J)	FCB(I,J)* 10^9 GALLONS
1981	9.43	20.0	-	-	-
80	9.25	20.0	15.0	0.998	8.31
79	9.06	19.0	15.1	.993	7.15
78	8.89	18.0	13.4	.982	6.50
77	8.71	17.8	12.2	.962	5.74
76	8.54	16.9	11.3	.929	5.30
75	7.20	14.8	10.5	.873	4.46
74	7.41	12.9	9.9	.784	4.46
73	9.74	13.0	9.3	.661	4.61
72	9.06	13.5	8.8	.519	3.07
71	8.54	13.7	8.4	.384	1.99
70	7.22	14.1	8.0	.273	1.12
69	8.46	14.1	7.6	.191	0.87
68	8.42	14.3	7.3	.134	0.58
67	7.58	14.9	7.0	.095	0.34
66	8.35	14.9	6.7	.067	0.25
65	8.74	15.0	—	—	—
				TOTAL = 54.74	

*FE_k and FC_{ij} have the letter B appended to distinguish these Baseline schedule arrays from the corresponding New (improved) schedule arrays.

TABLE 7. FLEET FUEL CONSUMPTION FOR CASE BASE IN CALENDAR YEAR 1981 (I=6)

MODEL YEAR, K	REG(k) 10^6 CARS	FEB(k)* MPG	VM(J) 10^3MI/CAR	SURV(J)	FCB(I,J)* 10^9 GALLONS
1982	9.62	20.0	–	–	–
81	9.43	20.0	18.0	0.998	8.47
80	9.25	20.0	15.1	.993	6.93
79	9.06	19.0	13.4	.982	6.27
78	8.89	18.0	12.2	.962	5.80
77	8.71	17.8	11.3	.929	5.14
76	8.54	16.9	10.5	.873	4.63
75	7.20	14.8	9.9	.784	3.78
74	7.41	12.9	9.3	.661	3.53
73	9.74	13.0	8.8	.519	3.42
72	9.06	13.5	8.4	.384	2.16
71	8.54	13.7	8.0	.273	1.35
70	7.22	14.1	7.6	.191	0.74
69	8.46	14.1	7.3	.134	0.59
68	8.42	14.3	7.0	.095	0.39
67	7.58	14.9	6.7	0.067	0.23
1966	8.35	14.9	–	–	–
				TOTAL = 53.44	

*FE_k and FC_{ij} have the letter B appended to distinguish these Baseline schedule arrays from the corresponding New (improved) schedule arrays.

results are summed. Total fuel consumption in 1981 for the baseline schedule is 53.44 billion gallons.

In the same manner, FUEL also calculates fleet fuel consumption according to the improved schedule. Through 1980, the two schedules, BASE and RSDA, are identical, so, the fuel consumption figures are the same. In 1981, however, the schedules begin to diverge. Table 8 shows the development of fuel consumption figures for the improved schedule in 1981. Fuel consumption is the same for each model year as in Table 7 except for model year 1981 cars. Here, the increase in fuel economy from 20 to 21.5 mpg has led to a reduction in fuel consumption from 8.47 to 7.88 billion gallons. Total fleet fuel consumption is similarly less.

FUEL performs these calculations for each calendar year, and a pair of matrices of fuel consumption figures, FC_{ij}, indexed by calendar year and vehicle age category, emerges. Figures 1 and 2 show such matrices for BASE.DAT and RSDA.DAT, respectively, each coupled with REG02.DAT, OLDFE.DAT, MILE1.DAT, and SURV1.DAT.

Element-by-element subtraction of the two fuel consumption matrices yields a third matrix which portrays year-by-year fuel savings. Figure 3 shows such a "delta" matrix for schedules BASE and RSDA.

The right-most column of the "delta" matrix gives the first of the three fundamental quantifiers of fuel conservation benefits: yearly fuel savings. From this set of values, the other two fundamental quantifiers are calculated.

Accumulated fuel savings through calendar year i, AFS_i, are reported in terms of billions of barrels of petroleum and are calculated from:

$$AFS_i = AFS_{i-1} + \frac{SFCD_i}{GPB} \qquad (3)$$

TABLE 8. FLEET FUEL CONSUMPTION FOR CASE RSDA IN CALENDAR YEAR 1981 (I=6)

MODEL YEAR, K	REG(k) 10^6CARS	FEN(k)* MPG	VM(J) 10^3MI/CAR	SURV(J)	FCN(I,J)* 10^9 GALLONS
1982	9.62	23.0	–	—	–
81	9.43	21.5	18.0	0.998	7.88
80	9.25	20.0	15.1	.993	6.93
79	9.06	19.0	13.4	.982	6.27
78	8.89	18.0	12.2	.962	5.80
77	8.71	17.8	11.3	.929	5.14
76	8.54	16.9	10.5	.873	4.63
75	7.20	14.8	9.9	.784	3.78
74	7.41	12.9	9.3	.661	3.53
73	9.74	13.0	8.8	.519	3.42
72	9.06	13.5	8.4	.384	2.16
71	8.54	13.7	8.0	.273	1.35
70	7.22	14.1	7.6	.191	0.74
69	8.46	14.1	7.3	.134	0.59
68	8.42	14.3	7.0	.095	0.39
67	7.58	14.9	6.7	0.067	0.23
1966	8.35	14.9	–	–	–
				TOTAL = 52.85	

*FE_k and FC_{ij} have the letter N appended to distinguish these New (improved) schedule arrays from the corresponding Baseline schedule arrays.

BASE FUEL CONSUMPTION BY YEAR AND BY VEHICLE AGE, BILLIONS OF GALLONS

CASE BASE

YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
1976	9.68	7.89	7.86	8.79	7.88	5.66	3.97	2.68	2.69	1.84	1.32	0.85	0.60	0.32	0.80	60.80
1977	8.79	7.83	6.48	6.74	7.87	6.13	4.79	3.15	2.74	1.80	1.11	0.81	0.87	0.34	0.81	58.15
1978	8.87	7.34	6.68	6.71	6.83	6.87	5.31	3.88	2.34	1.84	1.89	0.74	0.88	0.30	0.83	60.83
1979	8.87	7.41	6.44	6.83	6.11	5.27	5.83	4.13	2.83	1.48	1.81	0.85	0.88	0.37	0.86	60.48
1980	8.31	7.19	6.88	6.74	6.28	4.46	4.66	4.61	3.87	1.99	1.12	0.87	0.88	0.34	0.29	66.74
1981	8.47	6.83	6.27	6.88	6.14	4.83	3.78	3.83	3.42	2.16	1.88	0.74	0.88	0.38	0.88	55.44
1982	8.44	7.87	6.88	6.68	6.18	4.49	3.92	3.88	3.82	2.82	1.87	0.88	0.88	0.88	0.86	58.84
1983	8.81	7.81	6.28	6.83	6.81	4.83	3.88	3.11	2.33	1.88	1.84	0.87	0.88	0.34	0.87	61.88
1984	8.88	7.38	6.33	6.83	6.86	4.37	3.83	3.81	2.81	1.87	1.88	0.88	0.81	0.88	0.83	61.78
1985	9.19	7.88	6.48	6.88	6.88	4.24	3.78	3.84	2.33	1.83	1.88	0.83	0.83	0.88	0.88	61.93
1986	9.38	7.68	6.89	6.78	6.88	4.32	3.88	3.83	2.86	1.86	1.18	0.71	0.86	0.88	0.88	62.38
1987	9.84	7.88	6.73	6.87	6.18	4.41	3.84	3.84	2.18	1.88	1.87	0.73	0.88	0.38	0.84	62.76
1988	9.73	7.86	6.88	6.89	6.88	4.88	3.73	3.88	2.11	1.84	1.88	0.71	0.88	0.38	0.86	62.43
1989	9.83	8.12	6.88	6.11	6.36	4.89	3.81	3.86	2.15	1.89	1.84	0.72	0.88	0.34	0.33	62.28
1990	10.18	8.88	7.13	6.33	6.84	4.48	3.88	3.83	2.88	1.88	1.81	0.69	0.88	0.33	0.83	66.36
1991	10.33	8.88	7.27	6.88	6.87	4.77	3.96	3.88	2.24	1.88	1.83	0.87	0.87	0.33	0.33	66.38
1992	10.54	8.82	7.41	6.88	6.88	4.87	4.84	3.14	2.89	1.88	1.85	0.88	0.88	0.32	0.33	66.88
1993	10.74	8.88	7.87	6.81	6.88	4.96	4.13	3.28	2.33	1.81	1.87	0.78	0.88	0.31	0.81	66.88
1994	10.96	8.87	7.72	6.78	6.82	5.86	4.28	3.36	2.38	1.88	1.89	0.71	0.87	0.31	0.81	66.84
1995	11.17	8.18	7.89	6.88	4.84	5.17	4.29	3.33	2.43	1.88	1.11	0.73	0.88	0.32	0.81	68.88
1996	11.48	8.83	8.88	7.82	6.16	5.27	4.37	3.48	2.47	1.71	1.14	0.74	0.89	0.33	0.82	68.86
1997	11.63	8.81	8.18	7.16	6.88	5.38	4.48	3.46	2.82	1.78	1.16	0.76	0.88	0.33	0.82	69.31
1998	11.84	8.81	8.38	7.28	6.48	5.48	4.88	3.83	2.87	1.78	1.18	0.77	0.81	0.34	0.32	68.87
1999	18.18	8.88	8.82	7.48	6.83	5.88	4.84	3.81	2.83	1.88	1.21	0.78	0.81	0.38	0.81	68.88
2000	12.34	18.18	8.48	7.88	6.86	5.78	4.73	3.88	2.88	1.88	1.23	0.88	0.81	0.38	0.88	88.18

FIGURE 1. BASE FUEL CONSUMPTION BY YEAR AND BY VEHICLE AGE, BILLIONS OF GALLONS, CASE BASE

NEW FUEL CONSUMPTION BY YEAR AND BY VEHICLE AGE, BILLIONS OF GALLONS

CASE RSDA

YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
1976	8.08	7.89	7.56	8.79	7.08	5.66	3.97	8.69	2.69	1.64	1.22	0.88	0.69	0.32	0.80	66.80
1977	8.79	7.56	8.48	8.74	7.07	6.15	4.79	8.15	2.76	1.89	1.11	0.81	0.87	0.36	0.81	68.18
1978	8.87	7.34	8.48	8.71	6.83	6.87	5.21	2.88	2.86	1.84	1.29	0.74	0.85	0.39	0.23	68.83
1979	8.87	7.41	8.44	8.83	5.11	5.27	5.82	4.13	2.82	1.68	1.21	0.88	0.88	0.37	0.86	68.42
1980	8.21	7.15	8.88	8.74	5.80	4.46	4.46	4.81	3.87	1.99	1.12	0.87	0.88	0.84	0.89	68.74
1981	3.88	6.83	8.27	5.88	8.14	4.63	3.78	8.83	3.43	2.16	1.25	0.74	0.89	0.39	0.83	68.88
1982	3.81	6.88	8.89	8.89	5.18	4.49	3.82	2.99	2.62	2.42	1.47	0.98	0.88	0.48	0.86	68.92
1983	3.19	6.87	8.77	8.43	5.81	4.83	3.88	8.11	2.22	1.88	1.84	0.97	0.88	0.34	0.87	48.88
1984	6.82	6.88	8.58	8.18	4.84	4.37	3.83	3.81	2.31	1.87	1.28	1.89	0.84	0.41	0.83	48.16
1985	6.87	8.17	8.27	8.81	4.88	4.24	3.78	8.84	2.28	1.63	1.88	0.83	0.33	0.48	0.28	48.42
1986	6.88	8.87	8.87	4.78	4.19	4.82	3.89	3.83	2.86	1.88	1.18	0.71	0.86	0.88	0.28	44.87
1987	6.84	8.88	4.89	4.83	4.18	3.83	3.48	3.84	2.18	1.89	1.87	0.73	0.48	0.88	0.84	42.87
1988	7.87	8.89	4.98	4.36	4.84	3.87	3.25	3.78	2.11	1.84	1.88	0.71	0.49	0.83	0.86	42.37
1989	7.33	8.81	8.88	4.44	8.98	3.83	3.11	3.87	2.88	1.89	1.84	0.72	0.88	0.84	0.82	42.84
1990	7.34	8.82	8.18	4.83	8.87	3.48	2.99	3.66	1.91	1.81	1.81	0.69	0.68	0.33	0.83	41.99
1991	3.81	8.14	5.29	4.62	4.88	3.47	2.88	2.27	1.83	1.38	0.98	0.67	0.67	0.33	0.32	42.18
1992	3.66	8.87	5.39	4.72	4.13	3.84	2.94	2.38	1.76	1.89	0.91	0.64	0.66	0.32	0.32	42.83
1993	3.81	8.48	5.88	4.81	4.88	3.81	2.88	2.33	1.78	1.84	0.87	0.61	0.63	0.31	0.81	42.84
1994	3.89	8.62	5.41	4.81	4.28	3.89	2.86	2.27	1.72	1.28	0.84	0.88	0.61	0.29	0.81	42.88
1995	8.13	8.69	5.72	8.81	4.29	3.76	3.12	2.42	1.74	1.22	0.81	0.84	0.89	0.28	0.88	42.41
1996	8.29	8.88	5.84	8.18	4.48	3.83	3.18	2.47	1.88	1.28	0.83	0.84	0.88	0.27	0.19	42.22
1997	8.48	8.92	5.98	8.31	4.87	3.91	3.25	2.53	1.84	1.27	0.84	0.88	0.86	0.26	0.18	42.88
1998	8.48	7.84	6.87	8.31	4.86	3.89	3.31	2.87	1.87	1.28	0.86	0.84	0.87	0.25	0.17	42.87
1999	8.88	7.38	6.38	8.42	4.78	4.87	3.38	2.63	1.91	1.82	0.88	0.87	0.88	0.28	0.17	42.98
2000	8.98	7.84	6.32	8.83	4.84	4.19	3.44	2.67	1.95	1.89	0.89	0.88	0.89	0.26	0.17	43.84

FIGURE 2. NEW FUEL CONSUMPTION BY YEAR AND BY VEHICLE AGE, BILLIONS OF GALLONS, CASE RSDA

DELTA FUEL CONSUMPTION BY YEAR AND VEHICLE AGE, BILLIONS OF GALLONS

BETWEEN CASES BASE AND RSDA

YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
1976	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1977	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1979	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	0.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	1.13	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.62
1983	1.68	0.94	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.05
1984	0.07	1.35	0.83	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.64
1985	0.00	1.03	1.19	0.74	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.30
1986	2.05	2.09	1.58	1.06	0.66	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.18
1987	2.60	2.13	1.63	1.16	0.81	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.59
1988	2.66	2.17	1.67	1.63	1.21	0.83	0.49	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.06
1989	2.71	2.21	1.91	1.67	1.26	1.06	0.70	0.39	0.19	0.00	0.00	0.00	0.00	0.00	0.00	13.35
1990	2.76	2.26	1.94	1.70	1.29	1.20	0.90	0.55	0.29	0.11	0.00	0.00	0.00	0.00	0.00	14.27
1991	2.82	2.30	1.98	1.73	1.34	1.30	1.06	0.71	0.41	0.20	0.07	0.00	0.00	0.00	0.00	14.16
1992	2.87	2.35	2.03	1.77	1.38	1.33	1.15	0.86	0.53	0.29	0.14	0.00	0.00	0.00	0.00	14.00
1993	2.90	2.40	2.06	1.80	1.40	1.36	1.12	0.87	0.64	0.37	0.20	0.09	0.00	0.00	0.00	14.06
1994	2.93	2.45	2.10	1.84	1.41	1.39	1.18	0.89	0.68	0.45	0.25	0.13	0.00	0.00	0.00	14.07
1995	2.98	2.49	2.15	1.88	1.44	1.41	1.17	0.91	0.66	0.46	0.28	0.17	0.09	0.04	0.01	14.43
1996	3.11	2.64	2.19	1.91	1.46	1.44	1.19	0.93	0.67	0.47	0.31	0.20	0.11	0.06	0.03	14.86
1997	3.17	2.69	2.23	1.96	1.51	1.47	1.22	0.94	0.69	0.48	0.32	0.21	0.14	0.08	0.04	15.33
1998	3.23	2.85	2.28	1.99	1.56	1.49	1.24	0.96	0.70	0.49	0.33	0.21	0.14	0.09	0.05	15.60
1999	3.30	2.90	2.33	2.03	1.60	1.52	1.27	0.98	0.72	0.50	0.33	0.21	0.14	0.09	0.06	15.96
2000	3.37	2.89	2.37	2.07	1.62	1.55	1.29	1.00	0.73	0.51	0.34	0.22	0.14	0.10	0.06	16.33

FIGURE 3. DELTA FUEL CONSUMPTION BY YEAR AND BY VEHICLE AGE, BILLIONS OF GALLONS, BETWEEN CASES BASE AND RSDA

where:

$SFCD_i$ = total fuel consumption delta between the baseline and improved schedule cases in year i; and

GPB = number of gallons of motor fuel assumed equivalent to one barrel of crude oil, default = 42.

Discounted accumulated cash savings through calendar year i, $DACS_i$, arising from reduced purchases of crude oil, are obtained from:

$$DACS_i = DACS_{i-1} + \frac{(SFCD_i) \times (DPB)}{(GPB)} \times (1+DIS)^{-(i+IYR-DYR)} \quad (4)$$

where:

DPB = price assumed for crude oil, default = $13/bbl;

DIS = fractional discount rate, typically 0.10 (10%);

IYR = initial year of case study, typically 1975; and

DYR = year to which cash savings are to be discounted, typically 1980.

2.1.3 Outputs

The principal output of FUEL is a table which summarizes aggregate fuel conservation effects of a shift from one fuel economy schedule to another. Figure 4 shows such a table for the case where BASE and RSDA are the baseline and improved fuel economy schedules, respectively.

The first three columns of the table give the calendar year for which savings are computed, the baseline new car fuel economy for that year, and the improved new car fuel economy for that year. The next column lists the total fleet economy as it evolves under the improved fuel economy schedule.

The next three columns show fleet fuel consumption for the baseline and improved schedule cases, and the difference between them. Values are simply the yearly totals of the three fuel consumption matrices discussed earlier.

The "Delta Fuel Consumption" column presents the first of the three fundamental quantifiers, given in billions of gallons. The other two quantifiers are listed on a year-by-year basis in

SUMMARY OF FUEL CONSERVATION BENEFITS

EFFECTED BY SHIFT FROM FE SCHEDULE BASE TO SCHEDULE BBBA
CASH SAVINGS DISCOUNTED AT 10.0 PERCENT TO 1980
GALLONS PER BARREL : 42.00 DOLLARS PER BARREL : 13.00

YEAR	BASE FUEL ECON MPG	NEW FUEL ECON MPG	FLEET FUEL ECON MPG	BASE FUEL CONS BG	NEW FUEL CONS BG	DELTA FUEL CONS BG	ACCUM FUEL SAVED BB	ACCUM CASH SAVED BB	FLEET SIZE MILL	TOTAL VMT BILL
1976	16.90	16.90	16.36	60.10	60.80	0.00	0.00	0.00	33.7	868.
1977	17.80	17.80	16.76	59.18	59.18	0.00	0.00	0.00	33.4	873.
1978	18.00	18.00	19.28	57.93	57.93	0.00	0.00	0.00	84.1	880.
1979	19.00	19.00	19.07	56.48	56.48	0.00	0.00	0.00	84.9	890.
1980	20.00	20.00	18.89	54.74	54.74	0.00	0.00	0.00	98.7	900.
1981	20.00	21.50	17.44	53.44	53.05	0.39	0.01	0.17	96.8	922.
1982	20.00	23.00	18.46	52.54	50.92	1.62	0.09	0.98	88.1	940.
1983	20.00	24.50	19.59	51.99	49.00	2.99	0.12	1.28	97.5	958.
1984	20.00	26.00	20.72	51.79	47.16	4.64	0.83	2.36	81.1	977.
1985	20.00	27.50	21.96	51.98	48.42	6.56	0.89	3.81	82.7	997.
1986	20.00	27.50	28.09	52.28	44.07	8.18	0.88	4.93	84.4	1017.
1987	20.00	27.50	26.09	52.76	43.07	9.69	0.81	6.47	86.1	1038.
1988	20.00	27.50	24.97	53.43	42.37	11.08	1.00	8.07	87.7	1060.
1989	20.00	27.50	29.69	54.29	42.06	12.30	1.27	9.68	89.6	1080.
1990	20.00	27.50	26.29	55.26	41.99	13.37	1.69	11.26	91.4	1102.
1991	20.00	27.50	26.67	56.30	42.16	14.14	2.02	12.50	93.3	1126.
1992	20.00	27.50	26.97	57.38	42.03	14.85	2.30	14.26	95.3	1142.
1993	20.00	27.50	27.19	58.59	43.04	15.46	2.74	15.68	97.1	1170.
1994	20.00	27.50	27.31	59.66	43.68	15.97	3.12	16.95	99.0	1190.
1995	20.00	27.50	27.49	60.85	44.41	16.43	3.53	18.17	101.0	1217.
1996	20.00	27.50	27.65	62.06	45.03	16.85	3.93	19.30	103.0	1241.
1997	20.00	27.50	27.68	63.31	46.08	17.23	4.33	20.38	105.1	1266.
1998	20.00	27.50	27.69	64.57	46.97	17.60	4.79	21.56	107.1	1291.
1999	20.00	27.50	27.85	65.86	47.78	17.96	5.17	22.56	109.3	1317.
2000	20.00	27.50	27.89	67.18	48.86	18.32	5.61	23.69	111.8	1344.

FIGURE 4. SUMMARY OF FUEL CONSERVATION BENEFITS

the next two columns. Accumulated fuel savings are reported in billions of barrels. Discounted accumulated cash savings are reported in billions of dollars (typically 1980 dollars).

Two final columns report the total fleet size (millions of cars) and total vehicle miles (billions).

2.2 SPECIAL FEATURES

FUEL contains several special features which calculate impacts upon aggregate consumer outlay for fuel, upon lifetime operating savings per auto, and upon federal and state excise tax revenues. Program logic and outputs of each feature are described below.

2.2.1 Consumer Outlay Impacts

Aggregate consumer outlay impact is defined as the difference in total retail expenditures for motor fuel between the baseline and improved fuel economy schedule cases. National impacts are described in terms of year-by-year cash saving (billions of dollars) and in terms of discounted accumulated cash saving (typically, billions of dollars discounted at 10 percent to 1980).

Cash savings in year i, CS_i, is obtained from:

$$CF_i = P \times SFCD_i \qquad (5)$$

where:

P = price of motor fuel, dollars per gallon; and

$SFCD_i$ = total fleet fuel consumption delta between the baseline and improved schedule cases in year i, billions of gallons.

Discounted accumulated consumer cash saving through year i, DAS_i, is obtained from:

$$DAS_i = DAS_{i-1} + \left[P \times SFCD_i \times (1 + DIS)^{-(i+IYR-DYR)} \right] . \qquad (6)$$

Savings are calculated for each of six assumed motor fuel prices ranging from 65 cents per gallon (CPG) to 2 dollars per gallon. An example of the output is shown in Figure 5.

CONSUMER OUTLAY IMPACTS OF FUEL ECONOMY IMPROVEMENT FROM CASE BASE TO CASE RSDA

	YEARLY SAVINGS, BILLIONS OF DOLLARS						DISCOUNTED ACCUMULATED SAVINGS, BILLIONS OF DOLLARS					
YEAR	68 CPG	95 CPG	125 CPG	150 CPG	175 CPG	200 CPG	68 CPG	95 CPG	125 CPG	150 CPG	175 CPG	200 CPG
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1979	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1983	0.28	0.36	0.74	0.89	1.09	1.18	0.00	0.01	0.67	0.81	0.94	1.07
1984	1.05	1.36	2.03	2.43	2.84	3.24	1.23	1.70	2.89	3.01	3.20	3.75
1985	1.96	2.84	3.74	4.49	5.26	5.98	2.68	3.88	5.16	6.19	7.32	8.28
1986	3.01	4.41	5.88	6.96	8.18	9.27	4.74	6.81	9.11	10.84	12.76	14.87
1987	4.28	6.18	8.13	9.79	11.38	13.00	7.06	10.78	14.16	16.99	19.82	22.66
1988	5.31	7.77	10.28	12.26	14.21	16.28	10.26	15.15	19.93	24.01	27.90	31.88
1989	6.36	9.21	12.13	14.46	16.98	19.29	13.66	19.97	26.16	31.38	36.68	41.83
1990	7.19	10.38	13.63	16.08	19.14	22.11	16.98	24.77	32.69	39.11	46.03	53.18
1991	7.96	11.64	15.31	18.27	21.43	24.68	20.18	29.78	39.08	46.98	55.72	63.94
1992	8.63	12.61	16.69	19.91	23.23	26.64	23.08	34.07	45.08	54.08	64.07	73.79
1993	9.19	13.43	17.67	21.20	24.74	28.27	25.87	38.27	51.07	62.01	73.34	83.68
1994	9.66	14.11	18.67	22.28	25.99	29.71	28.86	42.77	57.08	68.11	80.63	93.14
1995	10.08	14.68	19.32	23.18	27.08	30.91	31.66	46.98	63.19	75.03	88.66	101.10
1996	10.38	15.18	19.97	23.96	27.96	31.98	34.09	50.84	68.64	82.13	96.83	109.91
1997	10.68	15.61	20.54	24.65	28.76	32.87	36.18	54.38	73.36	88.03	103.71	117.98
1998	10.95	16.00	21.06	25.27	29.48	33.69	40.03	59.04	77.94	93.83	109.13	126.71
1999	11.20	16.37	21.54	25.85	30.16	34.46	43.10	63.60	83.01	99.66	116.09	131.93
2000	11.44	16.72	22.00	26.40	30.80	35.20	44.81	66.68	86.16	103.66	120.63	137.06
2001	11.66	17.04	22.43	26.94	31.43	35.93	46.71	68.87	89.03	107.08	124.77	142.74
2002	11.81	17.41	22.90	27.48	32.04	36.64	48.48	70.86	92.04	111.09	129.03	149.18

FIGURE 5. CONSUMER OUTLAY IMPACTS OF FUEL ECONOMY IMPROVEMENT FROM CASE BASE TO CASE RSDA

2.2.2 Lifetime Operating Savings

Lifetime operating savings per car are reported for each model year in terms of quantity of fuel saved and in terms of total discounted cash savings for each of six motor fuel prices.

Per-auto fuel conservation benefit for cars of a given model year is defined as the summation of year-by-year fuel savings of all such cars,* divided by the number of new car registrations for that model year. Lifetime fuel saving for cars of model year k, LFS_k, is obtained from:

$$LFS_k = \frac{1}{(REG_k)} \times \sum_{j=1}^{NOP} FCD_{ij} \qquad (7)$$

where:

k = model year index;

j = vehicle age index;

i = calendar year index (i = k+j-i);

REG_k = new car registrations (sales) of model year k;

FCD_{ij} = fuel consumption delta between the baseline and improved schedule cases during year i for all cars of age j; and

NOP = assumed maximum lifetime of a car, usually 15 years.

What this formula actually provides is the summation along a diagonal of the delta matrix shown in Figure 3. For instance, under the improved fuel economy schedule, RSDA 1982 cars get 23 mpg instead of the baseline 20 mpg. As a result, they collectively consume 1.13 billion fewer gallons of motor fuel during their first year of operation, 0.94 billion fewer gallons during their second year of operation, 0.83 billion fewer gallons during the third year, and so on through the fifteenth year, for a total of 6.58 billion gallons. This number is divided by the number of

*Over the period during which the cars are operated, typically fifteen years.

new car registrations in 1982, 9.62 million, to get the average per auto fuel conservation benefit for 1982 cars: 684 gallons.

Per auto lifetime discounted cash saving for model year k, LDS_k, is obtained from:

$$LDS_k = \frac{P}{(REG_k)} \times \sum_{j=1}^{NOP} [FCD_{ij} \times (1+DIS)^{-(i+IYR-DYR)}] . \quad (8)$$

The calculation is made for six motor fuel prices ranging from 65 cents per gallon to 2 dollars per gallon.

Figure 6 summarizes lifetime operating savings. Note that savings for cars are reported only through 1986. Later model years are excluded, because the "delta" matrix of Figure 3 does not provide the necessary fuel saving information: the diagonals for 1987 and later years are truncated at the year 2000.

2.2.3 Tax Revenue Impacts

Tax revenue impact is defined as the difference in motor fuel excise tax revenues collected under the baseline and the improved fuel economy schedule cases. Impacts at the federal and state levels are reported in terms of year-by-year difference (billions of dollars) and in terms of discounted accumulated difference (billions of dollars, typically discounted at 10 percent to 1980).

The federal tax revenue delta for calendar year i, FTD_i, is obtained from:

$$FTD_i = (FTR_i) \times (SFCD_i) \quad (9)$$

where:

FTR_i = federal tax rate in year i, dollars per gallon.

Discounted accumulated federal tax delta through year i, $DAFTD_i$, is obtained from:

$$DAFTD_i = (DAFTD_i\text{-}1) + (FTR_i) \times (SFCD_i) \times (1.0+DIS)^{-(i+IYR-DYR)} . \quad (10)$$

LIFETIME OPERATING COST SAVINGS (PER AUTO) BY MODEL YEAR, $ THOUSANDS

EFFECTED BY SHIFT FROM FE SCHEDULE BASE TO SCHEDULE ABOA
15 YEAR OPERATING LIFETIME ASSUMED
SAVINGS DISCOUNTED AT 10.0 PERCENT TO 1980

MODEL YEAR	FUEL SAVED GGAL	60 CPG	90 CPG	120 CPG	150 CPG	175 CPG	200 CPG
1976	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1977	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1978	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1979	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1980	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1981	0.206	0.189	0.198	0.206	0.367	0.426	0.469
1982	0.404	0.370	0.390	0.404	0.720	0.836	0.919
1983	0.594	0.544	0.573	0.595	1.059	1.232	1.355
1984	1.311	0.998	0.999	0.769	0.913	1.064	1.216
1985	1.491	0.920	0.881	0.817	0.900	1.143	1.307
1986	1.491	0.886	0.964	0.748	0.891	1.039	1.189

FIGURE 6. LIFETIME OPERATING COST SAVINGS (PER AUTO) BY MODEL YEAR

The federal tax rate is a function of the calendar year. The user may specify a data file which reflects the federal tax schedule of interest. In the absence of user action, the program automatically selects the file ATAX.DAT, representing a continuation of the 4 cent per gallon excise tax.

State tax revenue impacts are calculated in a similar manner. However, unlike the federal tax rate, the state tax rate, STR, is a single value, not a function of calendar year. The user may select any value for the state tax rate. The default value is 8 cents per gallon.

Figure 7 illustrates the table generated by the program. The two hypothetical fuel economy schedules are, as before, BASE and RSDA. The federal tax schedule is DTAX, representing a 4 CPG tax through 1980 followed by annual 5 CPG increments to 24 CPG by 1984. The state excise tax is the default 8 CPG.

TAX REVENUE IMPACTS OF FUEL ECONOMY IMPROVEMENT

EFFECTED BY SHIFT FROM FE SCHEDULE BASE TO SCHEDULE BBDA
FEDERAL TAX SCHEDULE : 87AX
STATE TAX RATE : 0.00 CPG

YEAR	FED TAX RATE CPG	BASE FED TAX $BILL	NEW FED TAX $BILL	DELTA FED TAX $BILL	DISC ACCUM F.T. $BILL	BASE STATE TAX $BILL	NEW STATE TAX $BILL	DELTA STATE TAX $BILL	DISC ACCUM S.T. $BILL
1976	0.04	3,439	3,439	0.000	0.000	0.040	0.040	0.000	0.000
1977	0.06	2,366	2,366	0.000	0.000	0.728	0.728	0.000	0.000
1978	0.06	2,317	2,317	0.000	0.000	0.696	0.696	0.000	0.000
1979	0.06	2,287	2,287	0.000	0.000	0.814	0.814	0.000	0.000
1980	0.04	3,190	3,190	0.000	0.000	0.879	0.879	0.000	0.000
1981	0.09	6,889	6,796	0.093	0.068	0.278	0.830	0.047	0.043
1982	0.14	9,206	7,129	0.227	0.286	0.802	0.674	0.128	0.150
1983	0.19	9,879	9,310	0.068	0.603	0.190	0.950	0.239	0.330
1984	0.24	12,430	11,317	1.113	1.433	0.148	0.778	0.371	0.582
1985	0.24	13,460	10,900	1.560	2.302	0.188	0.693	0.000	0.906
1986	0.24	13,939	10,877	1.965	3.499	0.180	0.930	0.696	1.279
1987	0.24	13,663	10,337	2.327	4.693	0.231	0.660	0.776	1.673
1988	0.24	13,023	10,170	2.853	5.981	0.274	0.898	0.806	2.086
1989	0.24	13,039	10,099	2.940	7.177	0.263	0.863	0.000	2.601
1990	0.24	13,263	10,078	3.188	8.486	0.681	0.869	1.068	3.011
1991	0.24	13,911	10,119	3.792	9.998	0.864	0.873	1.131	3.307
1992	0.24	13,771	10,307	3.565	10.730	0.800	0.668	1.108	3.606
1993	0.24	14,060	10,330	3.709	11.805	0.800	0.643	1.156	3.964
1994	0.24	14,310	10,406	3.894	12.814	0.773	0.698	1.270	4.386
1995	0.24	14,004	10,060	3.944	13.789	0.868	0.893	1.315	4.898
1996	0.24	14,695	10,052	4.643	14.889	0.800	0.613	1.340	5.000
1997	0.24	15,194	11,060	4.134	15.987	0.000	0.000	1.379	5.361
1998	0.24	15,607	11,272	4.334	16.216	0.186	0.298	1.488	5.816
1999	0.24	15,867	11,496	4.311	16.981	0.269	0.838	1.437	6.749
2000	0.24	16,133	11,726	4.307	17.978	0.874	0.909	1.446	6.987

FIGURE 7. TAX REVENUE IMPACTS OF FUEL ECONOMY IMPROVEMENT

3. USER'S GUIDE

The program FUEL and its supporting data files are available through the computer facility at the Transportation Systems Center in Cambridge, Massachusetts. The procedure for using FUEL through the TSC facility is described in following paragraphs. Use of other computer facilities might require modifications to the system-specific elements of the program and the procedure.

The reader is assumed to have a basic familiarity with the TSC computer facility. If not, the reader is referred to Getting Started With TOPS-10 Commands (DEC-10-OTSCA-A-D), and Getting Started With DECsystem10 (DEC-10-XGSDA-A-D), both available from Software Distribution Center, Digital Equipment Corporation (DEC), Maynard, Massachusetts 01754.

3.1 DESCRIPTION OF PROGRAM AND DATA FILES

3.1.1 Program File

Figure 8 gives a listing of the Fortran program FUEL. The program uses standard Fortran input/output, arithmetic, and format statements. A glossary of variable names is given at the end of the report. Readers unfamiliar with Fortran as used on the DEC10 system are referred to DECsystem10 Fortran Programmer's Reference Manual (AA-0944E-TB), available from DEC.

The program is arranged in ten short sections. Each section is set off by Fortran statement labels. For instance, statements bracketed by labels 300 and 302, inclusive, perform the basic calculations for the summary table and for the derivative features of the model (see Figure 8, sheet 2). Statements 400 and 404 delimit the section which prints out the summary table. Table 9 lists the purpose of each section.

3.1.2 Data Files

FUEL uses six essential data files ranging in size from fifteen to forty-five elements. Also, if the tax revenue impacts

```
      DIMENSION RES(10),YR(10),DURV(10),OPE(10),PEN(10),PEN(10),
     1          DYR(30),PEN(30,10),PEN(30,10),PEN(30,10),DPE(30),
     2          DPEN(30),DPED(30),PPE(30),APE(30),DADE(30),PE(30),PVNT(30)
      INTEGER DYR
      REAL LPE,LDPE,LDPE9,LDPE99,LDPE199,LDPE199,LDPE199,LDPE200,NTX
      NTX  = 25
      IYR  = 1979
      DYR  = 1980
      NOP  = 15
      DIR  = 0.10
      DPE  = 12.00
      DPE  = 13.00
      DTX  = 0.00
      NTX  = 0.0
      TDE  = 1.0
      TDL  = 0.0
      TDE  = 0.0
      TDI  = 0.0
      RESIN = 'RESERV'
      SLOPE = 'SLOPE'
      MILES = 'MILES'
      DURVL = 'DURVL'
      PEDAS = 'DADE'
      PENEW = 'NEDW'
      YAX   = 'AYAX'
      WRITE(9,98)
   98 FORMAT(1H1,2X,' INITIAL CASE ?'//)
   99 FORMAT(1X)
  100 READ(9,101) PAR,VAL
      IF(PAR.EQ.'ADD') GO TO 200
      IF(PAR.EQ.'DYE') GO TO 999
      IF(PAR.EQ.'PEN') READ(9,102) PENEW
      IF(PAR.EQ.'PPD') READ(9,102) PEDAS
      IF(PAR.EQ.'RES') READ(9,102) RESIN
      IF(PAR.EQ.'SPE') READ(9,102) SLOPE
      IF(PAR.EQ.'VMT') READ(9,102) MILES
      IF(PAR.EQ.'DUR') READ(9,102) DURVL
      IF(PAR.EQ.'TAX') READ(9,102) YAX
      IF(PAR.EQ.'NTX') NYR  = IFIX(VAL)
      IF(PAR.EQ.'IYR') IYR  = IFIX(VAL)
      IF(PAR.EQ.'DYR') DYR  = IFIX(VAL)
      IF(PAR.EQ.'NOP') NOP  = IFIX(VAL)
      IF(PAR.EQ.'SPD') SPD  = VAL
      IF(PAR.EQ.'DPD') DPD  = VAL
      IF(PAR.EQ.'DIR') DIR  = VAL
      IF(PAR.EQ.'NTX') NTX  = VAL
      IF(PAR.EQ.'TDD') TDD  = VAL
      IF(PAR.EQ.'TDL') TDL  = VAL
      IF(PAR.EQ.'TDA') TDA  = VAL
      IF(PAR.EQ.'TDI') TDI  = VAL
      IF(PAR.EQ.'DTX') DTX  = VAL
      GO TO 100
  101 FORMAT(A3,F)
  102 FORMAT(A6)
  999 CONTINUE
      OPEN(UNIT=1,DEVICE='DSK',FILE='RES10',ACCESS='SEQIN')
      READ(1,999)(RES(I),I=1,N)
      CLOSE(UNIT=1)
      OPEN(UNIT=1,DEVICE='DSK',FILE='DPE',ACCESS='SEQIN')
      READ(1,999) (DPE(I),I=1,19)
      CLOSE(UNIT=1)
```

FIGURE 8. LISTING OF FUEL..FOR (Sheet 1 of 4)

```
      DO 200 I=1,14
      PEB(I)=0.0
      PEN(I)=0.0
  200 CONTINUE
      OPEN(UNIT=1,DEVICE='DSK',FILE='FILE',ACCESS='SEQIN')
      READ(1,999) (VM(I),I=1,19)
      CLOSE(UNIT=1)
      OPEN(UNIT=1,DEVICE='DSK',FILE='DURVL',ACCESS='SEQIN')
      READ(1,999) (DURV(I),I=1,19)
      CLOSE(UNIT=1)
      OPEN(UNIT=1,DEVICE='DSK',FILE='PEBAR',ACCESS='SEQIN')
      READ(1,999) (PEB(I),I=1,N)
      CLOSE(UNIT=1)
      OPEN(UNIT=1,DEVICE='DSK',FILE='PENEW',ACCESS='SEQIN')
      READ(1,999) (PEN(I),I=1,N)
      CLOSE(UNIT=1)
  999 FORMAT(8F)
  300 APB(0) = 0.0
      PCT    = 100.*DIS
      DACB(0)= 0.0
      DO 302 I=1,NYR
      PVMT(I)  = 0.0
      PB(I)    = 0.0
      BPCB(I) = 0.0
      BPCN(I) = 0.0
      DO 301 J=1,14
      K=I+J-1
      PVMT(I)   = PVMT(I)+REB(K)*VM(J)*DURV(J)
      PB(I)     = PB(I)+REB(K)*DURV(J)
      PCB(I,J) = REB(K)*VM(J)*DURV(J)/PEB(K)
      PCN(I,J) = REB(K)*VM(J)*DURV(J)/PEN(K)
      PCD(I,J) = PCB(I,J)+PCN(I,J)
      BPCB(I)  = BPCB(I)+PCB(I,J)
  301 BPCN(I)  = BPCN(I)+PCN(I,J)
      PPE(I)  = PVMT(I)/BPCN(I)
      BPCD(I) = BPCB(I)+BPCN(I)
      APB(I)  = APB(I-1)+BPCD(I)/BPB
      DACB(I) = DACB(I-1)+BPCD(I)/BPB
     1                    *DPB*(1.+DIS)**(-PLOAT(I-1)*(YR-BYR))
  302 CONTINUE
  400 IF(TBB.LT.1.0) GO TO 800
      WRITE(6,401) PEBAR,PENEW,PCT,BYR,BPB,DPB
  401 FORMAT(1H1//3X' SUMMARY OF FUEL CONSERVATION BENEFITS'//
     1 6X' EFFECTED BY SHIFT FROM PE SCHEDULE 'A8' TO SCHEDULE 'A8/
     2 6X' CABN SAVINGS DISCOUNTED AT 'F4.1' PERCENT TO '19/
     3 6X' GALLONS PER BARREL |'F6.0,4X'DOLLARS PER BARREL |'F6.0//
     4 3X'YEAR'4X'BASE'4X'NEW'9X'FLEET'9X'BASE'4X'NEW'9X'DELTA'8X'ACCUM'
     9 3X'ACCUM'3X'FLEET'3X'TOTAL'/10X'FUEL'4X'FUEL'4X'FUEL'9X'FUEL'4
     $'FUEL'4X'FUEL'8X'FUEL'4X'CABN'4X'BIBE'4X'VMT'/
     $10X'CON'4X'CON'4X'ECON'9X'CONS'4X'CONS'4X'CONS'9X'SAVED'
     83X'SAVED'/10X'MPG'9X'MPG'9X'MPG'11X'GG'6X'GG'6X'GG'11X'GG'6X
     9'GG'9X'BILL'4X'BILL'//)
      DO 403 I=1,NYR
      K=I+1
      N=I+9
      WRITE(6,404) N,PEB(K),PEN(K),PPE(I),BPCB(I),BPCN(I),BPBB(I),
     1             APB(I),DACB(I),PB(I),PVMT(I)
  403 IF((I.EQ.(N/10)*10-1).OR.(I.EQ.N)) WRITE(6,99)
  404 FORMAT(3X,I4,3F8.0,8X,3F8.0,8X,3F8.3,F8.1,F8.0)
  800 IF(NTB.EQ.0) GO TO 900
      WRITE(6,801) PEBAR
```

FIGURE 8. LISTING OF FUEL.FOR (Sheet 2 of 4)

```
      WRITE(9,900)
901   FORMAT('1',7X,'BASE FUEL CONSUMPTION BY YEAR AND BY VEHICLE AGE,'
     1         12X'BILLIONS OF GALLONS'//8X'CASE 'A8/)
      DO 908 I=1,NVR
      N=I+1YR
      WRITE(9,903) N,(FCB(I,J),J=1,10),BFCB(I)
902   IF((FLOAT(N)/8.).EQ.IFIX(N/8.)) WRITE(9,90)
903   FORMAT(8X,I4,10F8.0,F8.2)
      WRITE(9,904) FENEW
904   FORMAT('1',7X,'NEW  FUEL CONSUMPTION BY YEAR AND BY VEHICLE AGE,'
     1         12X'BILLIONS OF GALLONS'//8X' CASE 'A8/)
      WRITE(9,900)
      DO 908 I=1,NVR
      N=I+1YR
      WRITE(9,903) N,(FCN(I,J),J=1,10),BFCN(I)
905   IF((FLOAT(N)/8.).EQ.IFIX(N/8.)) WRITE(9,90)
      WRITE(9,906) FEDAB,FENEW
906   FORMAT('1',7X,'DELTA FUEL CONSUMPTION BY YEAR AND VEHICLE AGE,'
     1         12X'BILLIONS OF GALLONS'//7X' BETWEEN CASES 'A9' AND 'A9/)
      WRITE(9,900)
      DO 907 I=1,NVR
      N=I+1YR
      WRITE(9,903) N,(FCD(I,J),J=1,10),BFCD(I)
907   IF((FLOAT(N)/8.).EQ.IFIX(N/8.)) WRITE(9,90)
909   FORMAT('0',7X'YEAR',3X' 1'4X' 2'4X' 3'4X' 4'4X' 5'4X' 6'4X' 7'4X' 8'
     1 4X' 9'3X' 10'3X' 11'3X' 12'3X' 13'3X' 14'3X' 15'4X'TOTAL'//)
908   IF(TOL.EQ.0.0) GO TO 900
      WRITE(9,601) FEDAB,FENEW
601   FORMAT('1'//8X'CONSUMER OUTLAY IMPACTS OF FUEL ECONOMY IMPROVEME
     1NT FROM CASE 'A9' TO CASE 'A9'//14X'YEARLY SAVINGS, BILLIONS OF DO
     2LLARS'12X'DISCOUNTED ACCUMULATED SAVINGS, BILLIONS OF DOLLARS'//
     3 3X'YEAR'6X'A9'4X'99'8X'189'8X'198'8X'179'8X'888'10X'A9'4X'99'8X
     4'189'8X'198'8X'179'8X'888'/11X'CPG'8X'CPG'8X'CPG'8X'CPG'8X'CPG'
     5 8X'CPG'8X'CPG'8X'CPG'8X'CPG'8X'CPG'8X'CPG'8X'CPG'/)
      DO 602 I=1,NVR
      N=I+1YR
      SAL   = BFCD(I)
      DSCNT = DACB(I)*SPB/DPB
      CB00A = 0.0A*SAL
      CB009 = 0.09*SAL
      CB129 = 1.29*SAL
      CB198 = 1.98*SAL
      CB179 = 1.79*SAL
      CB888 = 2.08*SAL
      DAB0A8 = 0.A8*DSCNT
      DAB009 = 0.99*DSCNT
      DAB198 = 1.98*DSCNT
      DAB198 = 1.98*DSCNT
      DAB178 = 1.78*DSCNT
      DAB888 = 2.08*DSCNT
      WRITE(9,603) N,CB0A8,CB009,CB189,CB198,CB178,CB888,
     1                DAB0A8,DAB009,DAB189,DAB198,DAB178,DAB888
602   IF((FLOAT(N)/8.).EQ.IFIX(N/8.)) WRITE(9,90)
603   FORMAT(8X,I4,6F8.0,4X,6F8.0)
900   IF(TOL.EQ.0.0) GO TO 800
      WRITE(9,701) FEDAB,FENEW,NOD,PCT,DVR
701   FORMAT('1'//4X'LIFETIME OPERATING COST SAVINGS (PER AUTO) BY'1X
     1'MODEL YEAR, 8 THOUSANDS'//8X'EXPECTED BY SHIFT FROM PC BOWSOULE '
     2A8' TO BOWSOULE 'A9/8X,I2' YEAR OPERATING LIFETIME ASSUMED'/
     3 8X'SAVINGS DISCOUNTED AT 'F4.1' PERCENT TO '14//
     4 8X'MODEL'4X'FUEL '4X' 88'4X' 98'4X'188'4X'198'4X'178'4X'888'/
```

FIGURE 8. LISTING OF FUEL.FOR (Sheet 3 of 4)

```
 9?X'YEAR '6X'SAVED'4X'CPS'4X'CPS'4X'CPS'4X'CPS'4X'CPS'4X'CPS'/
 6(6X'GAL '//)
      DO 703 N=1,NYR,NOP+1
      N=ITNOK
      LFS  = 0.0
      LDFS = 0.0
      DO 702 J=1,NNP
      I=N+J-1
      LFS  = LFS+FCD(I,J)/RES(N+1)
 702  LDFS = LDFS+FCD(I,J)/RES(N+1)*(1.0+DIS)**(-FLOAT(I+IYR-DYR))
      LDS060 = 0.060*LDFS
      LDS090 = 0.090*LDFS
      LDS120 = 1.200*LDFS
      LDS150 = 1.500*LDFS
      LDS175 = 1.750*LDFS
      LDS200 = 2.000*LDFS
      WRITE(5,704) N,LFS,LDS060,LDS090,LDS120,LDS150,LDS175,LDS200
 703  IF(FLOAT(N)/5..EQ.IFIX(N/5.)) WRITE(5,90)
 704  FORMAT(1X,I4,F10.3,1X,6F7.3)
 800  IF(TDS.EQ.0.0) GO TO 997
      OPEN(UNIT=1,DEVICE='DSK',FILE=TAX,ACCESS='SEQIN')
      READ(1,990) (FTR(I),I=1,NYR)
      CLOSE(UNIT=1)
      S = 100.*STR
      WRITE(5,801) FEDAS,FENEW,TAX,S
 801  FORMAT(1H1//6X' TAX REVENUE IMPACTS OF FUEL ECONOMY IMPROVEMENT'
     1//6X' EFFECTED BY SHIFT FROM FE SCHEDULE 'A5' TO SCHEDULE 'A5/
     2  6X' FEDERAL TAX SCHEDULE : 'A5/
     3  6X' STATE TAX RATE : 'F5.2' CPG'//
     4 7X'YEAR'4X'FE'7X'BASE'6X'NEW'7X'DELTA'9X'DISC'
     5(1X'BASE'4X'NEW'7X'DELTA'9X'DISC'/10X'TAX'7X'FED'7X'FED'
     6 7X'FED'7X'ACCUM'10X'STATE'9X'STATE'9X'STATE'9X'ACCUM'/
     7(5X'RATE'4X'TAX'7X'TAX'7X'TAX'7X'F.T.'11X'TAX'
     8 7X'TAX'7X'TAX'7X'S.T.'/ 15X'CPG'7X'$BILL'9X'$BILL'9X'$BILL'
     9 9X'$BILL'10X'$BILL'9X'$BILL'9X'$BILL'9X'$BILL'//)
      DAFTD = 0.0
      DASTD = 0.0
      DO 802 I=1,NYR
      DSCNT=(1.+DIS)**(-FLOAT(I+IYR-DYR))
      N=I+IYR
      FTO  = FTR(I)*SFCO(I)
      FTN  = FTR(I)*SFCN(I)
      FTD  = FTO-FTN
      DAFTD= DAFTD+FTD*DSCNT
      STO  = STR*SFCO(I)
      STN  = STR*SFCN(I)
      STD  = STO-STN
      DASTD= DASTD+STD*DSCNT
      WRITE(5,803) N,FTR(I),FTO,FTN,FTD,DAFTD,STO,STN,STD,DASTD
 802  IF((FLOAT(N)/5.).EQ.IFIX(N/5.)) WRITE(5,90)
 803  FORMAT(1X,I4,F8.2,1X,4F10.3,3X,4F10.3)
 997  WRITE(5,998)
 998  FORMAT(1H1,5X,' NEXT CASE !'//)
      GO TO 100
 999  STOP
      END
```

FIGURE 8. LISTING OF FUEL.FOR (Sheet 4 of 4)

TABLE 9. FUNCTIONS OF FUEL PROGRAM SECTIONS

Delimiting Frotran statement labels	Function of Section
----/99	Allocates storage; sets all parameters to default conditions.
100/102	Lets user make changes to parameters; sends program on to perform calculations when changes are complete; sends program to exit when user is finished.
200/299	Reads in values for arrays from disk.
300/302	Performs calculations for fuel consumption matrices and for summary table.
400/404	Outputs summary table (Fig.4).
500/599	Outputs fuel consumption matrices (Figs. 1-3).
600/603	Performs calculations for and prints out consumers impacts table (Fig.5).
700/704	Performs calculations for and prints out lifetime savings table (Fig. 6).
800/803	Performs calculations for and prints out tax impacts table (Fig. 7).
977/999	Returns to statement 100; exits from program when user types in "BYE."

feature is to be exercised, an additional data file reflecting the tax schedule of interest is required. All data files are in floating point free format with five entries per line. Figure 9 gives a computer listing of the files described in Section 2.1.1, along with the DTAX federal tax schedule mentioned in Section 2.2.3. Several of these data files reflect the assumption that the base calendar year is 1975. A change in the base year will require modification to the data files. By referring to Tables 1 through 4 and to Figure 7 the reader can see how other hypothetical data files must be arranged so as to conform to the program's indexing logic.

Modification and/or creation of data files is done with the TECO editing routine. Readers unfamiliar with TECO are referred to DECsystem10 TECO (DEC-10-ETEE-D), available from DEC.

3.2 PROGRAM EXECUTION AND SAMPLE RUN

The FUEL user must first log onto the system. Then, the program must be compiled. Finally, the user readies the program for execution by loading it into the computer. Typing in "EXE FUEL.FOR" followed by a carriage return causes the program to be compiled, loaded, and executed. The program then types out the message "INITIAL CASE?".

At this point, the user may type in simply "ANS" (again followed by a carriage return) to indicate that the default conditions for all parameters are to be employed. If, however, the user wishes to change the value of a parameter, he must indicate which one is to be changed by typing in a three character code. For those parameters which are single-valued variables, the new value is typed in immediately after the identifying character string in floating point format. For those parameters which identify the disk files to be used in assembling arrays, the user hits the carriage return and types in the name (up to five characters) of the disk file containing the desired data.

```
TY REG02.DAT
 5.48  6.60  7.17  7.58  8.74
 8.35  7.58  8.42  8.46  7.22
 8.46  9.06  9.74  7.41  7.20
 8.54  8.71  8.89  9.06  9.25
 9.43  9.62  9.81 10.01 10.21
10.41 10.62 10.83 11.05 11.27
11.50 11.73 11.96 12.20 12.44
12.69 12.95 13.20 13.47 13.74
14.01 14.29 14.58 14.87 15.17
15.47 15.78 16.10 16.42 16.75

.TY MILE1.DAT
 18.0 15.1 13.4 12.2 11.3
 10.5  9.9  9.3  8.8  8.4
  8.0  7.6  7.3  7.0  6.7

.TY SURV1.DAT
  0.998 0.993 0.982 0.962 0.929
  0.873 0.784 0.661 0.519 0.384
  0.273 0.191 0.134 0.095 0.067

.TY OLIFE.DAT
 15.0 15.0 15.0 15.0 15.0
 14.9 14.9 14.3 14.1 14.1
 13.7 13.5 13.0 12.9 14.8

.TY BASE.DAT
 16.9 17.8 18.0 19.0 20.0
 20.0 20.0 20.0 20.0 20.0
 20.0 20.0 20.0 20.0 20.0
 20.0 20.0 20.0 20.0 20.0
 20.0 20.0 20.0 20.0 20.0
 20.0 20.0 20.0 20.0 20.0

.TY PSID.DAT
 16.9 17.8 18.0 19.0 20.0
 21.5 23.0 24.5 26.0 27.5
 27.5 27.5 27.5 27.5 27.5
 27.5 27.5 27.5 27.5 27.5
 27.5 27.5 27.5 27.5 27.5
 27.5 27.5 27.5 27.5 27.5

.TY DTAX.DAT
 0.04 0.04 0.04 0.04 0.04
 0.09 0.14 0.19 0.24 0.24
 0.24 0.24 0.24 0.24 0.24
 0.24 0.24 0.24 0.24 0.24
 0.24 0.24 0.24 0.24 0.24
 0.24 0.24 0.24 0.24 0.24

.
```

FIGURE 9. COMPUTER LISTING OF DATA FILES

When parameter changes are complete, the user types in "ANS" to implement the rest of the program. After the desired tables are printed out, the program types "NEXT CASE?". The user may then make further parameter changes and, again, execute the program. Or, the user may exit from the program by typing in the message "BYE". Table 10 gives a list of parameters with their identifiers and default values.

Figure 10 illustrates the implementation of FUEL. In this example, the user logged-in, compiled and loaded the program, and initiated its execution. The program typed the message "INITIAL CASE?". The user set the number of years examined (NYR) to twenty and the discount rate (DIS) to eight percent. The user then typed in "ANS" to get a summary of fuel conservation benefits through 1995 attributable to the implementation of fuel economy schedule RSDA versus schedule BASE.

The program typed the message "NEXT CASE?" to signify its readiness for parameter changes and execution, or for exit. The improved fuel economy schedule was changed to RSDG and the number of years examined was changed back to the default value of twenty-five. Also, the user opted for calculation and print-out of the lifetime operating savings table by setting the TB2 parameter equal to 1.0. The discount rate was left at eight percent. "ANS" implemented the calculations and printout.

Again, the message "NEXT CASE?" was typed out. The user exited from the program by typing "BYE", and then logged-out of the computer with "K/F" (kill/fast).

The tables prepared by FUEL are too wide to fit on one line of a remote terminal carriage. The tables were meant to be printed on a line printer. Actually, the tables shown in Figure 9 were prepared by FUEL1, a version of FUEL which omits the last two columns of the summary table and prints the remaining columns closer together. Of course, output from FUEL itself may be printed on a remote terminal, but the tables will be inconvenient for easy reading.

TABLE 10. LIST OF INPUT PARAMETERS WITH THEIR TERMINAL IDENTIFIERS

Parameter*	Terminal Identifier	Default Value
DIS	DIS	0.10
DPB	DPB	13.00
DYR	DYR	1980
FEBAS	FEB	'BASE'
FENEW	FEN	'RSDA'
GPB	GPB	42.00
IYR	IYR	1975
MILES	VMT	0.00
NOP	NOP	15
NYR	NYR	25
OLDFE	OFE	'OLDFE'
REGIS	REG	'REG02'
STR	STR	0.08
SURVL	SUR	'SURV1'
TAX	TAX	'ATAX'
TB0	TB0	1.00
TB1	TB1	0.00
TB2	TB2	0.00
TB3	TB3	0.00

*Parameter definitions appear in the glossary.

```
^C

.LOGIN[2147,2511]
JOB 16 TSC IECS\STEM-10/KL #3 TTY41
[APE: PHYSLOAD]
1145    10-AUG-77        WED

.EXE FUEL1.FOR
FORTRAN: FUEL1
MAIN.
LINK:    LOADING
[LNKXCT FUEL1 EXECUTION]

  INITIAL CASE ?

N/R20.0
D150.09
PAS
```


SUMMARY OF FUEL CONSERVATION BENEFITS

EFFECTED BY SHIFT FROM FE SCHEDULE BASE TO SCHEDULE ASIA
CASH SAVINGS DISCOUNTED AT 6.0 PERCENT TO 1960
GALLONS PER BARREL : 42.00 DOLLARS PER BARREL : 13.00

YEAR	BASE FUEL ECON MPG	NEW FUEL ECON MPG	FLEET FUEL ECON MPG	BASE FUEL CONS EG	NEW FUEL CONS EG	DELTA FUEL CONS EG	ACCUM FUEL SAVED BB	ACCUM CASH SAVED $B
1976	16.90	16.90	14.26	60.50	60.50	0.00	0.00	0.00
1977	17.00	17.00	14.76	59.15	59.15	0.00	0.00	0.00
1978	18.00	18.00	15.25	57.93	57.93	0.00	0.00	0.00
1979	19.00	19.00	15.87	56.42	56.42	0.00	0.00	0.00
1980	20.00	20.00	16.59	54.74	54.74	0.00	0.00	0.00
1981	20.00	21.50	17.46	53.44	52.85	0.59	0.01	0.17
1982	20.00	23.00	18.46	52.54	50.92	1.62	0.05	0.60
1983	20.00	24.50	19.55	51.99	49.00	2.99	0.12	1.33
1984	20.00	26.00	20.72	51.79	47.16	4.64	0.23	2.39
1985	20.00	27.50	21.96	51.92	45.42	6.50	0.39	3.76
1986	20.00	27.50	23.09	52.25	44.07	8.18	0.58	5.35
1987	20.00	27.50	24.09	52.76	43.07	9.69	0.81	7.10
1988	20.00	27.50	24.97	53.43	42.37	11.05	1.08	8.95
1989	20.00	27.50	25.69	54.29	42.04	12.25	1.37	10.85
1990	20.00	27.50	26.25	55.26	41.99	13.27	1.69	12.75
1991	20.00	27.50	26.67	56.30	42.16	14.14	2.02	14.63
1992	20.00	27.50	26.97	57.38	42.53	14.85	2.38	16.45
1993	20.00	27.50	27.19	58.50	43.04	15.46	2.74	18.21
1994	20.00	27.50	27.31	59.66	43.68	15.97	3.12	19.90
1995	20.00	27.50	27.40	60.85	44.41	16.43	3.52	21.50

FIGURE 10. SAMPLE RUN (Sheet 1 of 3)

```
NEXT CASE ?

FEN
PSIG
INP25.0
TB21.0
RNS
```

SUMMARY OF FUEL CONSERVATION BENEFITS

EFFECTED BY SHIFT FROM FE SCHEDULE BASE TO SCHEDULE PSIG
CASH SAVINGS DISCOUNTED AT 8.0 PERCENT TO 1960
GALLONS PER BARREL = 42.00 DOLLARS PER BARREL = 13.00

YEAR	BASE FUEL ECON MPG	NEW FUEL ECON MPG	FLEET FUEL ECON MPG	BASE FUEL CONS BG	NEW FUEL CONS BG	DELTA FUEL CONS BG	ACCUM FUEL SAVED BB	ACCUM CASH SAVED B$
1976	16.90	16.90	14.26	60.50	60.50	0.00	0.00	0.00
1977	17.80	17.80	14.76	59.15	59.15	0.00	0.00	0.00
1978	18.00	18.00	15.26	57.93	57.93	0.00	0.00	0.00
1979	19.00	19.00	15.87	56.42	56.42	0.00	0.00	0.00
1980	20.00	20.00	16.59	54.74	54.74	0.00	0.00	0.00
1981	20.00	22.00	17.52	53.44	52.67	0.77	0.02	0.02
1982	20.00	24.00	18.62	52.54	50.46	2.08	0.07	0.11
1983	20.00	26.00	19.88	51.99	48.19	3.80	0.16	1.71
1984	20.00	27.00	21.15	51.79	46.21	5.59	0.29	3.56
1985	20.00	27.50	22.37	51.92	44.59	7.33	0.47	4.92
1986	20.00	27.50	23.46	52.25	43.34	8.91	0.66	7.48
1987	20.00	27.50	24.46	52.76	42.42	10.34	0.98	9.13
1988	20.00	27.50	25.31	53.43	41.82	11.61	1.20	10.07
1989	20.00	27.50	25.98	54.29	41.58	12.71	1.50	12.04
1990	20.00	27.50	26.48	55.26	41.63	13.64	1.83	13.99
1991	20.00	27.50	26.84	56.30	41.89	14.41	2.17	15.90
1992	20.00	27.50	27.09	57.38	42.34	15.05	2.53	17.19
1993	20.00	27.50	27.25	58.50	42.91	15.59	2.90	19.03
1994	20.00	27.50	27.37	59.66	43.60	16.06	3.25	21.02
1995	20.00	27.50	27.44	60.85	44.36	16.49	3.58	22.83
1996	20.00	27.50	27.47	62.06	45.18	16.88	4.19	24.35
1997	20.00	27.50	27.49	63.31	46.06	17.25	4.49	25.80
1998	20.00	27.50	27.50	64.57	46.96	17.61	4.91	27.16
1999	20.00	27.50	27.50	65.86	47.90	17.96	5.34	28.48
2000	20.00	27.50	27.50	67.18	48.86	18.32	5.77	29.67

FIGURE 10. SAMPLE RUN (Sheet 2 of 3)

```
LIFETIME OPERATING COST SAVINGS (PER AUTO) BY MODEL YEAR, $1000'S

EFFECTED BY SHIFT FROM FE SCHEDULE BASE  TO SCHEDULE PSDG
15 YEAR OPERATING LIFETIME ASSUMED
SAVINGS DISCOUNTED AT  8.0 PERCENT TO 1960

 MODEL     FUEL      65       95       125      150      175      200
 YEAR      SAVED     CPG      CPG      CPG      CPG      CPG      CPG
           MGAL

 1976      0.000    0.000    0.000    0.000    0.000    0.000    0.000
 1977      0.000    0.000    0.000    0.000    0.000    0.000    0.000
 1978      0.000    0.000    0.000    0.000    0.000    0.000    0.000
 1979      0.000    0.000    0.000    0.000    0.000    0.000    0.000
 1980      0.000    0.000    0.000    0.000    0.000    0.000    0.000

 1981      0.477    0.223    0.325    0.428    0.514    0.599    0.685
 1982      0.875    0.378    0.552    0.727    0.972    1.017    1.163
 1983      1.211    0.465    0.708    0.932    1.118    1.304    1.491
 1984      1.360    0.504    0.737    0.969    1.163    1.357    1.551
 1985      1.431    0.491    0.717    0.944    1.133    1.322    1.511

 1986      1.431    0.455    0.664    0.874    1.049    1.224    1.399



   NEXT CASE ?

BYE
STOP

END OF EXECUTION
CPU TIME:  1.91   ELAPSED TIME:  7:45.00
EXIT

.R/F
JOB 16   USER HORTON [3147,2513]
LOGGED-OFF TTY41   AT 11:53:42   ON 10-AUG-77
RUNTIME:  0:00:04,  KCS:96,  CONNECT TIME:  0:08:24
DISK READS:278,  WRITES:90,  BLOCKS SAVED:231

ESTIMATED COST:
   CONNECT TIME COST   $   .50   DISK ACCESS COST   $   .09
   CPU COST    $   .53     TOTAL COST    $   1.12
```

FIGURE 10. SAMPLE RUN (Sheet 3 of 3)

Ordinarily, the user will execute FUEL as a batch job using a control file and the DEC10 SUBMIT routine. The control file contains the sequence of commands the user himself would type-in if he were on-line. As a batch job is performed, the computer assembles a LOG file containing all inputs and outputs. After the job is completed, the LOG file is printed on a line printer.* Figure 11 illustrates the preparation and submission of a control file for the example run described above.

*The user should occasionally purge both control and log files as they tend to clutter a user's disk area. Also, the log files are especially large and will add considerably to disk storage costs.

```
.
^C

.LOGIN[3147,251]
JOB 46 TSC [ECSYSTEM-10/KL #3 TTY52
Name: Password:
1625    10-Aug-77       Wed

.RUN E:EXMPL.CTL

*IE:E FUEL.FOR
MAP20.0
D150.00
FHS
FEN
FSIG
MAP25.0
TE21.0
FHS
BYE
^C
*HT^C
EXE FUEL.FOR
MAP20.0
D150.00
FHS
FEN
FSIG
MAP25.0
TE21.0
FHS
BYE
*EXIT

.SUBMIT E:EXMPL.CTL+E:EXMPL.LOG
JOB EXMPL SUBMITTED

.R/F
JOB 46  User HORTON [3147,251]
LOGGED-OFF TTY52  AT 16:27:19  ON 10-Aug-77
ANOTHER JOB IS STILL LOGGED-IN UNDER [3147,251]
RUNTIME: 0:00:40, KCS:7, CONNECT TIME: 0:02:14
DISK READS:87, WRITES:9

ESTIMATED COST:
   CONNECT TIME COST   $   .12   DISK ACCESS COST   $   .02
   CPU COST   $   .00     TOTAL COST   $   .14
```

FIGURE 11. SAMPLE CONTROL FILE AND SUBMIT COMMAND

GLOSSARY

VARIABLE	INDEX	DEFINITION
	I	Calendar year index
	J	Vehicle age index (1 to 15)
	K	Model year index
AFS	I	Accumulated fuel savings through year i, billions of barrels
CS065-CS200	(I)*	Consumer cash saving for motor fuel price of 65 CPG, ..., 200 CPG, billions of gallons
DACS	I	Discounted accumulated cash savings through year i arising from reduced purchases of crude oil, billions of dollars
DAFTD	(I)	Discounted accumulated federal tax delta, billions of dollars
DASTD	(I)	Discounted accumulated state tax delta, billions of dollars
DAS065 - DAS200	(I)	Discounted accumulated consumer cash saving for motor fuel price of 65 CPG, 95 CPG, etc.
DIS	-	Fractional discount rate; default = 0.10 (10 percent per annum)

*Parentheses around an index indicate that it was not necessary to index the variable within the computer program; however, the variable does take on different values for different calendar or model years.

GLOSSARY (Cont.)

VARIABLE	INDEX	DEFINITION
DPB	-	Assumed price for crude oil; default = $13/bbl
DSCNT	(I)	Discount factor; used where the value of $(1+DIS)^{-(i+IYR-DYR)}$ for a given i is needed several times
DYR	-	Year to which cash savings are discounted; default = 1980
FCB	I,J	Fuel consumption during year i by all vehicles of age j for baseline fuel economy schedule, billions of gallons
FCD	I,J	Fuel consumption delta during year i for all vehicles between baseline and improved fuel economy schedule cases: FCD(I,J) = FCB(I,J) - FCN (I,J), billions of gallons
FCN	I,J	Fuel consumption during year i by all vehicles of age j for new fuel economy schedule of gallons, billions of gallons
FEB	K	Average new car fuel economy of model year k under baseline schedule, mpg
FEBAS	-	Alphanumeric variable used to identify data file containing baseline schedule, default = BASE
FEN	K	Average new car fuel economy of model year k under new (improved) schedule, mpg

GLOSSARY (Cont.)

VARIABLE	INDEX	DEFINITION
FENEW	-	Alphanumeric variable used to identify data file containing new (improved) schedule, default = RSDA
FFE	I	Total fleet fuel economy in year i as it evolves under the improved fuel economy schedule, mpg
FS	I	Total fleet size in year i, millions of vehicles
FTB	(I)	Federal tax revenues for baseline schedule case, billions of dollars
FTD	(I)	Federal tax revenue delta between baseline and improved schedule cases, billions of dollars
FTN	(I)	Federal tax revenue for improved schedule case, billions of dollars
FTR	I	Federal tax rate in year i, dollars per gallon
FVMT	I	Total fleet vehicle miles traveled in year i, billions of vehicle miles
GAL	-	Utility variable used when $SFCD_i$ for a given i is needed several times
GPB	-	Number of gallons of motor fuel assumed equivalent to one barrel of crude oil, default = 42
IYR	-	Initial year of case study, default = 1975

VARIABLE	INDEX	DEFINITION
LDFS	(K)	Lifetime discounted fuel saving (per auto), intermediate variable used in calculation of LDS065, LDS095,..., LDS200
LDS065 - LDS200	(K)	Lifetime discounted cash saving (per auto), thousands of dollars
LFS	(K)	Lifetime fuel saving, thousands of gallons
MILES	-	Alphanumeric variable used to identify data file containing schedule of vehicle travel as a function of age, default = MILE1
MTX	-	Output flag: if MTX = 0.0 printout of FC_{ij} matrices (Figures 1-3) is suppressed, default = 0.0
N	-	Utility variable, usually equal to (I+IYR)
NOP	-	Maximum lifetime of a car assumed for purposes of calculating lifetime operating savings, default = 15 years
NYR	-	Number of calendar years for which impacts are to be calculated, default = 25
OFE	K	Average new car fuel economy of the existing fleet by model year for 15 model years beginning with (IYR-14), mpg

GLOSSARY (Cont.)

VARIABLE	INDEX	DEFINITION
OLDFE	-	Alphanumeric variable used to identify data file containing schedule of average new car fuel economy of the existing fleet by model year, default = OLDFE
PCT	-	Percentage discount rate (=100xDIS)
Q	-	State tax rate in CPG (=100xSTR)
REG	K	New car registraticns (sales) by model year, millions
REGIS	-	Alphanumeric variable used to identify data file containing schedule of new car registrations, default = REG02
SFCB	I	Total fleet fuel consumption under the baseline schedule during year i, billions of gallons
SFCD	I	Total fleet fuel consumption delta between baseline and improved schedule cases in year i, billions of gallons
SFCN	I	Total fleet fuel consumption under the improved schedule during year i, billions of gallons
STB	(I)	State tax revenues for baseline schedule case, billions of dollars

VARIABLE	INDEX	DEFINITION
STD	(I)	State tax revenue delta between baseline and improved schedule cases, billions of dollars
STN	(I)	State tax revenues for improved schedule case, billions of dollars
STR	-	State tax rate, dollars per gallon
SURV	J	Probability that a car will survive to age j
SURVL	-	Alphanumeric variable used to identify data file containing schedule of vehicle survival probability, default = SURV1
TAX	-	Alphanumeric variable used to identify data file containing federal excise tax schedule, default = ATAX
TB0	-	Output flag: if TB0=0.0 printout of summary table (Fig. 4) is suppressed, default = 1.0
TB1	-	Output flag: if TB1=0.0 printout of consumer outlay impacts table (Fig. 5) is suppressed, default = 0.0
TB2	-	Output flag: if TB2=0.0 printout of lifetime operating savings table (Fig. 6) is suppressed, default = 0.0

GLOSSARY (Cont.)

VARIABLE	INDEX	DEFINITION
TB3	-	Output flag: if TB3=0.0 printout of tax revenue impact table (Fig. 7) is suppressed, default = 0.0
VM	J	Yearly travel of cars of age j, thousands of miles per car

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