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Volume II--Appendices

Part 1

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DISCLAIMER

Appendix A. Input Data and Parameters

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LIGHT DUTY VEHICLE MODULE: Fuel Economy Model					
ITEM	**CLASS. (Source)**	**DESCRIPTION**	**UNITS**	**SUBROUTINE**	**EQ #**
DISCOUNT	Parameter (A)	Discount rate used in payback calculation	Percent	FEMCALC	3
FE	Variable	Fuel economy of technology *itc*, within seven size classes	Miles per Gallon	FEMCALC	3
FEMPG	Variable	Average fuel economy by six ORNL size classes	MPG	FEMSIZE	38
FESIXC	Variable	Fuel economy for cars within six size classes	MPG	FEMSIZE	40
FESIXT	Variable	Fuel economy for light trucks within six size classes	MPG	FEMSIZE	40
FUELCOST	Variable	Projected fuel cost	$ per MMBtu	FEMCALC	1
FUELSAVE	Variable	The expected present value of fuel savings over the payback period	$	FEMCALC	3
HP	Variable	Horsepower	HP	FEMCALC	18
icl	Index	FEM vehicle size class index (7)	—	FEMSIZE	—
igp	Index	CAFE group index: 1 = domestic car, 2 = import car, 3 = domestic light truck, 4 = import light truck	—	FEMSIZE	—
INCOME	Variable	Household income	$ per year	FEMCALC	198
ino	Index	The index identifying the technologies in the superseding group	—	NOTE$SUPER	—
isno	Index	An index indicating the superseded technology	—	NOTE$SUPER	—
itc	Index	The index representing the technology under consideration	—	FEMCALC	3
MANDMKSH	Input Data (A)	Mandatory market share	Percent	FEMCALC	9
MAP	Input Data (A)	Array of mapping constants, which converts FEM to ORNL size classes	—	FEMSIZE	35
MAPSALE	Variable	Disaggregate vehicle sales	Units	FEMSIZE	35
MAPSHR	Variable	Sales shares within the disaggregate array	Percent	FEMSIZE	37
MAX$SHARE	Input Data (A)	The maximum market share of the group, *ino*	Percent	NOTE$SUPER	25
MKT$MAX	Input Data (A)	Maximum market share of technology in given class	Percent	NOTE$SUPER	25
MKT$PEN	Variable	Market share of technology in given class and year	Percent	FEMCALC	8
MMAX	Variable	The maximum market share for technology *itc*, obtained from MKT$MAX	Percent	FEMCALC	7
N	Index	Time period index (1990 = 1)	—	FEMSIZE	—
num$sup	Index	The number of technologies in the superseding group	—	NOTE$SUPER	—
NVS7SC	Variable	New vehicle sales within the seven FEM size classes	Units	TSIZE	41

LIGHT DUTY VEHICLE MODULE: Fuel Economy Model					
ITEM	**CLASS. (Source)**	**DESCRIPTION**	**UNITS**	**SUBROUTINE**	**EQ #**
ORNLMPG	Input Data (B)	Most recent (1992) fuel economy data from ORNL	MPG	FEMSIZE	39
osc	Index	ORNL size class index (6)	—	FEMSIZE	—
PAYBACK	Input Data (A)	The user-specified payback period	Years	FEMCALC	3
PERFFACT	Input Data (A)	Performance factor (multiplier for horsepower adjustment)	—	FEMCALC	19
PMAX	Parameter (A)	The institutional maximum market share, which models tooling constraints on the part of the manufacturers	Percent	FEMCALC	7
PRICE	Variable	Vehicle price	$	FEMCALC	17
PRICE$EX	Variable	The expected price of fuel	$	FEMCALC	2
PSLOPE	Variable	The fuel cost slope	—	FEMCALC	1
RATIO$LN	Variable	Log of the market share ratio of the considered vehicle class	—	CMKSCALC	31
REGCOST	Variable	A factor representing regulatory pressure to increase fuel economy	$ per MPG	FEMCALC	6
REQ$MKT	Input Data (A)	The total market share of those technologies which are required for the implementation of technology *itc*, indicating that technology's maximum share	Percent	FEMCALC	10
SYNR$DEL	Input Data (A)	The synergistic effect of two technologies on fuel economy	—	FEMCALC	13
TECHCOST	Input Data (A)	The cost of technology *itc*	$	FEMCALC	4
TOT$MKT	Variable	The total market share of the considered group of technologies	Percent	NOTES$SUPER	27
TOTNVS7	Variable	Total new vehicle sales within the six ORNL size classes	Units	FEMSIZE	36
VAL$PERF	Input Data (A)	The dollar value of performance of technology *itc*	$	FEMCALC	5
VALUEPERF	Variable	The value associated with an incremental change in performance	$	FEMCALC	5
WEIGHT	Variable	The base year vehicle weight, absent the considered technology	lbs	FEMCALC	4
YEAR	Index	Year index (*YEAR* = *N*+1)	—	FEMSIZE	—

LIGHT DUTY VEHICLE MODULE: Regional Sales Model					
ITEM	CLASS.	DESCRIPTION	UNITS	SUBROUTINE	EQ #
AHPCAR	Variable	Average automobile horsepower	HP	TSIZE	49
AHPTRUCK	Variable	Average light truck horsepower	HP	TSIZE	50
COMTSHR	Data Input (B)	Fraction of new light trucks dedicated to commercial freight	Percent	TSIZE	42
COSTMIR	Variable	The cost of driving in region *REG*	$ per Mile	TREG	52
DAF	Paramete r (C)	A demographic adjustment factor, to reflect different age groups' driving patterns	—	TEXOG	55
FLTCRAT	Paramete r (B)	Fraction of new cars purchased by fleets	Percent	TSIZE	41
FLTTRAT	Paramete r (B)	Fraction of new light trucks purchased by fleets	Percent	TSIZE	42
GROUP	Index	Index indicating domestic or imported vehicles	—	TSIZE	--
HP	Variable	Vehicle horsepower by FEM size class, group	HP	TSIZE	47
HPCAR	Variable	Average horsepower of new automobiles, by size class *SC*	HP	TSIZE	47
HPTRUCK	Variable	Average horsepower of new light trucks, by size class *SC*	HP	TSIZE	48
INCOMER	Variable	Regional per capita disposable income	$	TREG	53
LTSHRR	Variable	Non-fleet market shares of light trucks, by size class *SC*	Percent	TSIZE	46
NCS	Variable	New car sales, by size class and region	Units	TREG	57
NCSTSCC	Variable	New car sales in the modified six size classes, *SC*	Units	TSIZE	43
NLTS	Variable	New light truck sales, by size class and region	Units	TREG	58
NLTSTSCC	Variable	New light truck sales in six size classes *SC*	Units	TSIZE	44
NVS7SC	Variable	New vehicle sales in the original seven FEM size classes	Units	TSIZE	43
PASSHRR	Variable	Non-fleet market shares of automobiles, by size class *SC*	Percent	TSIZE	45

LIGHT DUTY VEHICLE MODULE: Regional Sales Model					
ITEM	CLASS	DESCRIPTION	UNITS	SUBROUTINE	EQ #
PRFEM	Data Input (D)	Ratio of female to male driving rates	—	TVMT	54
RHO	Paramete r (C)	Lag factor for the VMT difference equation	—	TVMT	54
RSHR	Variable	Regional VMT shares	Percent	TREG	57
SALESHR	Data Input (B)	Fraction of vehicle sales which are domestic/imported	Percent	TSIZE	41
SEDSHR	Variable	Regional share of the consumption of a given fuel in period *T*	Percent	TREG	51
TMC_POP16	Variable	Total regional population over the age of 16	—	TMAC	55
TMC_POPAFO	Variable	Total population in region *REG*	—	TMAC	53
TMC_SQDTRU CKSL	Variable	Total light truck sales (supplied by the MACRO module)	Units	TMAC	42
TMC_SQTRCA RS	Variable	Total new car sales (supplied by the MACRO module)	Units	TSIZE	41
TMC_YD	Variable	Estimated disposable personal income by region, *REG*	$	TMAC	51
VMT16R	Variable	Vehicle-miles traveled per population over 16 years of age	—	TREG	54
VMTEER	Variable	Total VMT in region *REG*	—	TREG	55

LIGHT DUTY VEHICLE MODULE: Alternative Fuel Vehicle Model					
ITEM	CLASS.	DESCRIPTION	UNITS	SUBROUTINE	EQ #
AFCOST	Variable	Alternative vehicle fuel price	$ per MMBtu	TALT3	60
APSHR11	Variable	Relative market shares of each aggregate technology	Percent	TALT1	76
APSHR22	Variable	Relative market shares of each AFV technology	Percent	TALT2	72
APSHR33	Variable	Relative market shares of each EV technology	Percent	TALT3	68
APSHR44	Variable	Absolute market shares of each technology	Percent	TALT1	79
BETACONST	Parameter (F)	Constant associated with each considered technology *IT*	—	TALT3	66
BETACONST1	Parameter (F)	Constant associated with each considered technology	—	TALT1	74
BETACONST2	Parameter (F)	Constant associated with each considered AFV technology	—	TALT2	70
BETAEM	Parameter (F)	Coefficient associated with vehicle emissions	—	TALT3	66
BETAEM2	Parameter (F)	Coefficient associated with the square of vehicle emissions	—	TALT3	66
BETAFA	Parameter (F)	Coefficient associated with fuel availability	—	TALT3	66
BETAFA2	Parameter (F)	Coefficient associated with the square of fuel availability	—	TALT3	66
BETAFC	Parameter (F)	Coefficient associated with fuel cost	$(\$)^{-1}$	TALT3	66
BETAVP	Parameter (F)	Coefficient associated with vehicle price	$(\$)^{-1}$	TALT3	66
BETAVR	Parameter (F)	Coefficient associated with vehicle range	$(\text{Miles})^{-1}$	TALT3	66
BETAVR2	Parameter (F)	Coefficient associated with the square of vehicle range	$(\text{Miles})^{-2}$	TALT3	66
COMAV	Input Data (E)	Commercial availability of each AFV technology	—	TALT3	59
COPCOST	Variable	Fuel operating costs for each AFV technology	Cents per Mile	TALT3	65
COPCOST1	Variable	Fuel operating costs for conventional and alternative vehicles	Cents per mile	TALT1	74
COPCOST2	Variable	Fuel operating costs for alternative vehicles	Cents per mile	TALT2	70
EMISS1	Input Data (E)	Emissions levels relative to gasoline ICE's	—	TALT1	74
EMISS2	Input Data (E)	AFV emissions levels relative to gasoline ICE's	—	TALT2	70
EMISS3	Input Data (E)	EV emissions levels relative to gasoline ICE's	Percent	TALT3	66
EVC1	Variable	Exponentiated value of vehicle utility vector	—	TALT1	75
EVC2	Variable	Exponentiated value of alternative vehicle utility vector	—	TALT2	71

LIGHT DUTY VEHICLE MODULE: Alternative Fuel Vehicle Model					
ITEM	CLASS	DESCRIPTION	UNITS	SUBROUTINE	EQ #
EVC3	Variable	Exponentiated value of electric vehicle utility vector	—	TALT3	67
FAVAIL	Input Data (E)	Availability of each alternative fuel relative to gasoline	Percent	TALT3	60
FAVAIL11	Input Data (E)	Fuel availability for conventional and alternative technologies	Percent	TALT1	74
FAVAIL22	Input Data (E)	Alternative technology fuel availability	Percent	TALT2	70
FAVAIL33	Input Data (E)	Fuel availability for EV technologies	Percent	TALT3	66
FEC3SC	Variable	Automobile fuel economy within the three reduced size classes	MPG	TALT3	61
FET3SC	Variable	Light truck fuel economy within the three reduced size classes	MPG	TALT3	62
IT	Index	Index of the sixteen engine technologies considered by the model	—	TALT3	—
RFP	Variable	Regional fuel price	Dollars per MMBtu	TALT3	50
TT50	Input Data (X)	The exogenously specified year in which 50% of the demand for technology *IT* can be met	Year	TALT3	59
VC1	Variable	Utility vector for conventional and alternative vehicles	—	TALT1	74
VC1	Variable	Utility vector for conventional and alternative vehicles	—	TALT1	74
VC2	Variable	Utility vector for alternative vehicles	—	TALT2	70
VC3	Variable	Utility vector for electric vehicles	—	TALT3	66
VEFF	Input Data (E)	Fuel economy of technology *IT*, relative to gasoline baseline	—	TALT3	64
VEFFACT	Variable	Baseline efficiency of gasoline ICE's, in MPG	Miles per MMBtu	TALT3	63
VPRICE1	Input Data (E)	Price of each considered technology in 1990$	1990 $	TALT1	74
VPRICE2	Input Data (E)	Price of each considered AFV technology in 1990$	1990 $	TALT2	70
VPRICE3	Input Data (E)	Price of each considered EV technology in 1990$	1990 $	TALT3	66
VRANGE1	Input Data (E)	Vehicle range of the considered technology	Miles	TALT1	74
VRANGE2	Input Data (E)	Vehicle range of the considered AFV technology	Miles	TALT2	70
VRANGE3	Input Data (E)	Vehicle range of the considered EV technology	Miles	TALT3	66

LIGHT DUTY VEHICLE STOCK MODULE					
ITEM	CLASS.	DESCRIPTION	UNITS	SUBROUTINE	EQ #
ADJVMTPC	Variable	Demographically-adjusted per capita VMT	Vehicle-miles	TVMT	142
AMPGC	Variable	The average MPG of cars within the reduced AFV size class	Miles per gallon	TMPGSTK	129
AMPGT	Variable	The average MPG of trucks within the reduced AFV size class	Miles per gallon	TMPGSTK	129
ANCMPG	Variable	Average new car MPG	Miles per gallon	TMPGSTK	133
ANTMPG	Variable	Average new light truck MPG	Miles per gallon	TMPGSTK	133
APSHRNC	Variable	Absolute market share of new cars, by technology, from the AFV model	Percent	TMPGSTK	133
APSHRNT	Variable	Absolute market share of new light trucks, by technology, from the AFV model	Percent	TMPGSTK	133
ASC	Index	The three AFV size classes, onto which the six primary size classes are mapped	—		—
CCMPGLDV	Variable	New car MPG, by technology *IT*	MPG	TMPGAG	156
CMPGSTK	Variable	Automobile stock MPG, by vintage and technology	Miles per gallon	TMPGSTK	135
CMPGT	Variable	Automobile stock MPG	Miles per gallon	TMPGSTK	135
COSTMI	Variable	Cost of driving per mile	$ per mile	TVMT	139
DAF	Input Data (C)	Demographic adjustment factor	—	TVMT	142
FLTECHSAL	Variable	Fleet sales by size, technology, and fleet type	Units	TMPGAG	153
FLTECHSALT	Variable	Vehicle purchases by fleet type and technolgy	Units	TMPGAG	153
FLTECHSTK	Variable	Total fleet vehicle stock, by technology and fleet type	Units	TMPGAG	155
FLTMPG	Variable	Fleet vehicle MPG by vehicle type, size class, and technology	MPG	TMPGAG	154
FLTMPGNEW	Variable	New fleet vehicle MPG, by vehicle type and technology *ITECH*	MPG	TMPGAG	156
FLTSTOCK	Variable	New fleet stock, by vehicle type and technology *ITECH*	Units	TMPGAG	155
FLTVMT	Variable	Fleet VMT	Vehicle-miles	TVMT	144
FLVMTSHR	Variable	VMT-weighted shares by size class and technology	Percent	TFREISMOD	148
FVMTSC	Variable	Freight VMT by size class	Vehicle-miles	TVMT	144
INCOME	Variable	Per capita disposable personal income	$	TVMT	140
IS	Index	Index of size class (1-3)	—	TMPGAG	—
IT	Index	Index of vehicle technology (1-16)	—	TMPGAG	—

LIGHT DUTY VEHICLE STOCK MODULE					
ITEM	CLASS	DESCRIPTION	UNITS	SUBROUTINE	EQ #
IT2	Index	Reassigned indices of vehicle technology *IT2* = 1-16; *IT* = 16,15,1-14	—	TMPGAG	—
ITECH	Index	Index of fleet vehicle technologies which correspond to the *IT* index	—	TMPGAG	—
ITY	Index	Index of fleet type: Business, Government, Utility	—	TMPGAG	—
LTSTK	Variable	Surviving light truck stock, by technology and vintage	Units	TSMOD	120
LVMT	Variable	Average light truck VMT, by vintage, from RTECS	Vehicle miles traveled	TEXOG	134
MPGC	Variable	New car fuel efficiency, by engine technology	Miles per gallon	TMPGSTK	131
MPGC	Variable	New car MPG. by technology *IT*	MPG	TMPGAG	156
MPGFLT	Variable	Stock MPG for all light duty vehicles	Miles per gallon	TMPGSTK	137
MPGT	Variable	New light truck fuel efficiency, by engine technology	Miles per gallon	TMPGSTK	131
MPGTECH	Variable	Average stock MPG by technology	MPG	TMPGSTK	138
NCMPG	Variable	New car MPG, from the FEM model	Miles per gallon	TMPGSTK	132
NCS3A	Variable	New car sales by reduced size class and engine technology: *IS* = 1, *OSC* = 1,6; *IS* = 2, *OSC* = 2,3; *IS* = 3, *OSC* = 4.5	Units	TMPGSTK	125
NCS3SC	Variable	Total new car sales by reduced size class	Units	TMPGSTK	127
NCSR	Variable	Regional new car sales by reduced size class	Units	TMPGSTK	126
NCSTECH	Variable	New car sales. by region. size class, and technology, from the AFV Module	Units	TSMOD	119
NLT3A	Variable	New light truck sales by reduced size class and technolgy: *IS* = 1, *OSC* = 1,3; *IS* = 2, *OSC* = 2.5: *IS* = 3. *OSC* = 4,6	Units	TMPGSTK	125
NLTECH	Variable	New light truck sales, by region, size class, and technology	Units	TSMOD	119
NLTMPG	Variable	New light truck MPG, from the FEM model	Miles per gallon	TMPGSTK	132
NLTS3SC	Variable	Total new light truck sales by reduced size class	Units	TMPGSTK	127
NLTSR	Variable	Regional new light truck sales by reduced size class	Units	TMPGSTK	126
NNCSCA	Variable	New conventional car sales by six size classes	Units	TMPGSTK	128
NNLTCA	Variable	New conventional light truck sales by six size classes	Units	TMPGSTK	128
OLDFSTK	Variable	Number of fleet vehicles rolled over into corresponding private categories	Units	TSMOD	122

LIGHT DUTY VEHICLE STOCK MODULE					
ITEM	CLASS	DESCRIPTION	UNITS	SUBROUTINE	EQ #
PASSTK	Variable	Surviving automobile stock, by technology and vintage	Units	TSMOD	120
PrFem	Data Input (C)	The ratio of per capita female driving to per capita male driving.	—	TVMT	141
PVMT	Variable	Average automobile VMT, by vintage, from RTECS	Vehicle miles traveled	TEXOG	134
RATIO	Variable	Light truck MPG adjustment factor	—	TMPGSTK	130
RHO	Parameter (C)	Difference equation lag factor, estimated, using the Cochrane-Orcutt iterative procedure, to be 0.72	—	TVMT	141
SCMPG	Variable	Stock MPG for automibles	Miles per gallon	TMPGSTK	136
SSURVLT	Input Data (B)	Fraction of a given vintage's light trucks which survive	Percent	TSMOD	120
SSURVP	Input Data (B)	Fraction of a given vintage's automobiles which survive	Percent	TSMOD	120
STKCAR	Variable	Total stock of non-fleet automobiles in year *T*	Units	TSMOD	123
STKCT	Variable	Stock of non-fleet vehicles, by technology	Units	TMPGAG	158
STKTR	Variable	Total stock of non-fleet light trucks in year *T*	Units	TSMOD	123
STMPG	Variable	Stock MPG for light trucks	Miles per gallon	TMPGSTK	136
STOCKLDV	Variable	Total stock of fleet and non-fleet vehicles, by technology	Units	TMPGAG	158
TECHNCS	Variable	Non-fleet new car sales, by technology *IT*	Units	TMPGAG	156
TECHNCS	Variable	Total new car sales, by technology	Units	TSMOD	119
TECHNLT	Variable	Total new light truck sales, by technology	Units	TSMOD	119
TECHNLT	Variable	Non-fleet new light truck sales, by technology *IT*	Units	TMPGAG	157
TLDVMPG	Variable	Average fuel economy of light-duty vehicles	MPG	TMPGAG	161
TMC_POPAFO	Variable	Total population, from MACRO module	Units	TVMT	140
TMC_SQDTRUCKSL	Variable	Total light truck sales, from MACRO module	Units	TFREISMOD	147
TMC_YD	Variable	Total disposable personal income, from MACRO module	$	TVMT	140
TMPGLDVSTK	Variable	Average MPG by vehicle type *VT*	MPG	TMPGAG	160
TMPGT	Variable	Light truck stock MPG	Miles per gallon	TMPGSTK	135
TOTMICT	Variable	Total miles driven by cars	Miles	TMPGSTK	134
TOTMITT	Variable	Total miles driven by light trucks	Miles	TMPGSTK	134
TPMGTR	Variable	Price of motor gasoline	$ per gallon	TVMT	139
TRFLTMPG	Variable	Average light truck MPG	MPG	TFREISMOD	152

LIGHT DUTY VEHICLE STOCK MODULE					
ITEM	**CLASS.**	**DESCRIPTION**	**UNITS**	**SUBROUTINE**	**EQ #**
TRSAL	Variable	Light truck sales for freight	Units	TFREISMOD	147
TRSALTECH	Variable	Light truck sales by technology	Units	TFREISMOD	148
TRSTK	Variable	Total light truck stock	Units	TFREISMOD	151
TRSTKTECH	Variable	Light truck stock by technology	Units	TFREISMOD	149
TRSTKTOT	Variable	Total light truck stock by technology	Units	TFREISMOD	150
TSTOCKLDV	Variable	Total stock by vehicle type *VT*	Units	TMPGAG	159
TTMPGLDV	Variable	New light truck MPG, by technology *IT*	MPG	TMPGAG	157
TTMPGSTK	Variable	Light truck stock MPG, by vintage and technology	Miles per gallon	TMPGSTK	135
VDF	Input Data (N)	Vehicle fuel efficiency degradation factor	Percent	TMPGSTK	135
VMTECH	Variable	Personal travel VMT by technology	Vehicle-miles	TVMT	145
VMTEE	Variable	VMT for personal travel	Vehicle-miles	TVMT	144
VMTLDV	Variable	Total VMT for light duty vehicles	Vehicle-miles	TVMT	143
VSPLDV	Variable	The light duty vehicle shares of each of the sixteen vehicle technologies	Percent	TSMOD	124
VT	Index	Index of vehicle type: 1 = cars, 2 = light trucks	—	TMPGAG	—
XLDVMT	Variable	Fractional change of VMT over base year (1990)	Percent	TVMT	146

LIGHT DUTY VEHICLE FLEET MODULE					
ITEM	CLASS.	DESCRIPTION	UNITS	SUBROUTINE	EQ #
APSHR55	Variable	Absolute regional market shares of adjusted vehicle sales	Percent	TLEGIS	102
APSHRFLTB	Variable	Market shares of business fleet by vehicle type and technology	Percent	TLEGIS	106
APSHRFLTB	Variable	Alternative technology shares for the business fleet	Percent	TLEGIS	84
APSHRFLTOT	Variable	Aggregate market shares of fleet vehicle technologies	Percent	TLEGIS	105
APSHRNC	Variable	Market shares of new cars by technology	Percent	TLEGIS	104
APSHRNT	Variable	Market shares of new light trucks by technology	Percent	TLEGIS	104
AVSALES	Variable	Regional adjusted vehicle sales by size class	Units	TLEGIS	97
AVSALEST	Variable	Total regional adjusted vehicle sales by size class	Units	TLEGIS	100
ELECVSAL	Variable	Regional electric vehicle sales	Units	TLEGIS	92
ELECVSALSC	Variable	Regional ZEV sales within corresponding regions	Units	TLEGIS	96
EPACT	Parameter (H)	Legislative mandates for AFV purchases, by fleet type	Percent	TEXOG	81
FLTALT	Variable	Number of AFV's purchased by each fleet type in a given year	Units	TFLTSTKS	81
FLTAPSHR1	Input Data (G)	Fraction of each fleets' purchases which are AFV's, from historical data	Percent	TEXOG	81
FLTCONV	Variable	Fleet purchases of conventional vehicles	Units	TFLTSTKS	82
FLTCRAT	Input Data (G)	Fraction of total car sales attributed to fleets	Percent	TEXOG	80
FLTCSHR	Input Data (G)	Fraction of fleet cars purchased by a given fleet type	Percent	TEXOG	80
FLTECH	Variable	Vehicle purchases by fleet type and technology	Units	TFLTSTKS	85
FLTECHSAL	Variable	Fleet sales by size, technology, and fleet type	unts	TFLTSTKS	84
FLTECHSHR	Input Data (G)	Alternative technology shares for the government and utility fleets	Percent	TEXOG	84
FLTFCLDVBTU	Variable	Fuel consumption by vehicle type and technology	MMBtu	TFLTCONS	117
FLTFCLDVBTUR	Variable	Regional fuel consumption by fleet vehicles, by technology	MMBtu	TFLTCONS	118
FLTLDVC	Variable	Fuel consumption by technology, vehicle and fleet type	MMBtu	TFLTCONS	116
FLTMPG	Variable	New fleet vehicle fuel efficiency, by fleet type and engine technology	Miles per Gallon	TFLTMPG	110
FLTMPGTOT	Variable	Overall fuel efficiency of new fleet cars and light trucks	MPG	TFLTMPG	112
FLTSAL	Variable	Sales to fleets by vehicle and fleet type	Units	TFLTSTKS	80
FLTSLSCA	Variable	Fleet purchases of AFV's, by size class	Units	TFLTSTKS	83

LIGHT DUTY VEHICLE FLEET MODULE					
ITEM	CLASS	DESCRIPTION	UNITS	SUBROUTINE	EQ #
FLTSLSCC	Variable	Fleet purchases of conventional vehicles, by size class	Units	TFLTSTKS	83
FLTSSHR	Input Data (G)	Percentage of fleet vehicles in each size class, from historical data	Percent	TEXOG	83
FLTSTKVN	Variable	Fleet stock by fleet type, technology, and vintage	Units	TFLTSTKS	86
FLTTOTMPG	Variable	Fleet vehicle average fuel efficiency for cars and light trucks	Miles per Gallon	TFLTMPG	115
FLTTRAT	Input Data (G)	Fraction of total truck sales attributed to fleets	Percent	TEXOG	80
FLTTSHR	Input Data (G)	Fraction of fleet trucks purchased by a given fleet type	Percent	TEXOG	80
FLTVMT	Variable	Total VMT driven by fleet vehicles	Vehicle Miles Traveled	TFLTVMTS	108
FLTVMTECH	Variable	Fleet VMT by technology, vehicle type, and fleet type	Vehicle Miles Traveled	TFLTVMTS	109
FLTVMTYR	Variable	Annual miles of travel per vehicle, by vehicle and fleet type	Miles	TFLTVMTS	108
FMSHC	Variable	The market share of fleet cars, from the AFV model	Percent	TFLTMPG	110
FMSHLT	Variable	The market share of fleet light trucks, from the AFV model	Percent	TFLTMPG	110
IR	Index	Corresponding regions: *ST* = CA, MA, NY; *IR* = 9,1,2	—	TLEGIS	—
IS	Index	Index of size classes: 1 = small, 2 = medium, 3 = large	—	TFLTSTKS	—
ITECH	Index	Index of engine technologies: 1-5 = alternative fuels (neat), 6 = gasoline	—	TFLTSTKS	—
ITF	Index	Index of fleet vehicle technologies, corresponding to *IT* = 3,5,7,8,9	—	TLEGIS	—
ITY	Index	Index of fleet type: 1 = business, 2 = government, 3 = utility	—	TFLTVMTS	—
MAXVINT	Index	Maximum *IVINT* index associated with a given vehicle and fleet type	—	TFLTMPG	—
MPGFLTSTK	Variable	Fleet MPG by vehicle and fleet type, and technology, across vintages	Miles per Gallon	TFLTMPG	114
MPGFSTK	Variable	Fleet MPG by vehicle and fleet type, technology, and vintage	Miles per Gallon	TFLTMPG	113
NAMPG	Variable	New AFV fuel efficiency, from the AFV model	Miles per Gallon	TALT3	110
NCSTECH	Variable	Regional new car sales by technology, within six size classes: *OSC* = 1-6: *IS* = 2,1,1,3,3,2	Units	TLEGIS	107
NLTECH	Variable	Regional light truck sales by technology, with six size classes: *OSC* = 1-6: *IS* = 1,2,1,3,2,3	Units	TLEGIS	107

LIGHT DUTY VEHICLE FLEET MODULE					
ITEM	**CLASS.**	**DESCRIPTION**	**UNITS**	**SUBROUTINE**	**EQ #**
OLDFSTK	Variable	Old fleet stocks of given types and vintages, transferred to the private sector	Units	TFLTSTKS	87
QBTU	Input Data (I)	Energy content of the fuel associated with each technology	Btu/Gal	TFLTCONS	117
RSHR	Variable	Regional VMT shares, from the Regional Sales Module	Percent	TREG	118
ST	Index	Index of participating state: CA, MA, NY	—	TLEGIS	—
STATESHR	Variable	Share of national vehicle sales attributed to a given state	Percent	TLEGIS	94
SURVFLTT	Input Data (G)	Survival rate of a given vintage	Percent	TFLTSTKS	86
TFLTECHSTK	Variable	Total stock within each technology and fleet type	Units	TFLTSTKS	88
TMC_SQDTRUCKSL	Variable	Total light truck sales in a given year	Units	TMAC	80
TMC_SQTRCARS	Variable	Total automobile sales in a given year	Units	TMAC	80
TOTFLTSTK	Variable	Total of all surviving fleet vehicles	Units	TFLTSTKS	89
ULEV	Data Input (J)	State-mandated minimum sales share of ULEV's	Percent	TLEGIS	94
ULEVST	Variable	State-mandated minimum sales of ULEV's	Units	TLEGIS	94
VFSTKPF	Variable	Share of fleet stock by vehicle type and technology	Percent	TFLTSTKS	90
VSALES	Variable	Total disaggregate vehicle sales	Units	TLEGIS	91
VSALESC16	Variable	Total new car sales by technology: $IS = 1$, $OSC = 2,3$; $IS = 2$, $OSC = 1,6$; $IS = 3$, $OSC = 4,5$	Units	TLEGIS	103
VSALEST	Variable	Total regional vehicle sales, by size class	Units	TLEGIS	93
VSALEST16	Variable	Total new light truck sales by technology: $IS = 1$, $OSC = 1,3$; $IS = 2$, $OSC = 2,5$; $IS = 3$, $OSC = 4,6$	Units	TLEGIS	103
VT	Index	Index of vehicle type: 1 = cars, 2 = light trucks	—	TFLTSTKS	—
ZEV	Data Input (J)	State-mandated minimum sales share of ZEV's	Percent	TLEGIS	94
ZEVST	Variable	State-mandated minimum sales of ZEV's	Units	TLEGIS	94
ZEVSTSC	Variable	Mandated ZEV sales by size class and state	Units	TLEGIS	95

AIR TRAVEL MODULE: Air Travel Demand Model					
ITEM	CLASS.	DESCRIPTION	UNITS	SUBROUTINE	EQ #
DFRT	Parameter (O)	Fraction of freight ton-miles transported on dedicated carriers.	Percent	TAIRT	199
DI	Parameter (O)	Demographic air travel index, reflecting public's propensity to fly	—	TAIRT	201
EQSM	Input Data (O)	Equivalent seat-miles conversion factor; used to transform freight RTMs to seat-miles	—	TAIRT	204
LFDOM	Parameter (O)	Load factor, the average fraction of seats which are occupied in domestic travel.	Percent	TAIRT	204
LFINTER	Parameter (O)	Load factor for international travel.	Percent	TAIRT	204
OPCST	Input Data (O)	Airline operating costs.	Dollars per Aircraft-Mile	TAIRT	195
PCTINT	Parameter (O)	Proportionality factor relating international to domestic travel levels	—	TAIRT	198
RPMB	Variable	Revenue passenger miles of domestic travel for business purposes.	Passenger Miles	TAIRT	200
RPMBPC	Variable	Per capita domestic RPM for business travellers.	Miles per Capita	TAIRT	196
RPMD	Variable	Total domestic revenue passenger miles.	Passenger Miles	TAIRT	203
RPMI	Variable	Revenue passenger miles of international travel.	Passenger Miles.	TAIRT	202
RPMIPC	Variable	Per capita international RPM	Miles per Capita	TAIRT	198
RPMP	Variable	Revenue passenger miles of domestic travel for personal purposes.	Passenger Miles	TAIRT	201
RPMPPC	Variable	Per capita domestic RPM for personal travel.	Miles per Capita	TAIRT	197
RTM	Variable	Revenue ton miles of cargo.	Ton Miles	TAIRT	199
ASMDEMD	Variable	Total seat-miles demanded for domestic and international travel	Seat Miles	TAIRT	204
TMC_GDP	Variable	Real gross domestic product	Dollars per Capita	TMAC	196
TMC_POPAFO	Variable	U.S. population	People	TMAC	196
TMC_YD	Variable	Real gross disposable personal income	Dollars per Capita	TMAC	197
TPJFTR	Variable	Price of Jet Fuel.	Dollars per Gallon	TMAC	195
YIELD	Variable	Airline revenue per passenger mile	Dollars per Passenger-Mile	TAIRT	195

AIR TRAVEL MODULE: Aircraft Fleet Efficiency Model					
ITEM	**CLASS.**	**DESCRIPTION**	**UNITS**	**SUBROUTINE**	**EQ #**
AGD	Variable	Demand for aviation gasoline, in gallons	Gallons	TAIREFF	226
AGDBTU	Variable	Aviation gasoline demand, in Btu	Btu	TAIREFF	224
AIRHRS	Input Data (P)	Average number of airborne hours per aircraft, by type.	Hours per Year	TAIREFF	205
ASMDEMD	Variable	Demand for available seat-miles, by aircraft type	Seat Miles	TAIREFF	207
ASMP	Variable	The available seat-miles per plane, by type	Seat Miles	TAIREFF	205
AVSPD	Input Data (P)	Average flight speed, by type.	Miles per Hour	TAIREFF	205
BASEAGD	Parameter	Baseline demand for aviation gasoline	Gallons	TAIREFF	223
BASECONST	Parameter	Baseline constant, used to anchor the technology penetration curve	—	TAIREFF	216
COSTFX	Parameter	Factor reflecting the magnitude of the difference between the price of jet fuel and the trigger price of the considered technology	—	TAIREFF	215
DELTA	Parameter	User-specified rate of passenger shifts between aircraft types	—	TAIREFF	206
EFFIMP	Input Data (P)	Fractional improvement associated with a given technology	Percent	TAIREFF	218
FRACIMP	Variable	Fractional improvement over base year (1990) fuel efficiency, by type	Percent	TAIREFF	218
GAMMA	Parameter (P)	Baseline adjustment factor	—	TAIREFF	223
IFX	Index	Index of technology improvements (1-6)	—	TAIREFF	—
IT	Index	Index of aircraft type: 1 = narrow body, 2 = wide body	—	TAIREFF	—
IVINT	Index	Index of aircraft vintage	—	TAIREFF	—
IYEAR	Index	Current year	—	TAIREFF	—
JFBTU	Variable	Jet fuel demand, in Btu	Btu	TAIREFF	224
JFGAL	Variable	Consumption of jet fuel, in gallons	Gallons	TAIREFF	222
KAPPA	Parameter (P)	Exogenously-specified decay constant	—	TAIREFF	223
NEWSMPG	Variable	Average seat-miles per gallon of new aircraft purchases	SMPG	TAIREFF	219
NPCHSE	Variable	Number of aircraft purchased, by body type.	Aircraft	TAIREFF	209
NSURV	Variable	Number of surviving aircraft, by body type.	Aircraft	TAIREFF	212
QAGR	Variable	Regional demand for aviation gasoline	Btu	TAIREFF	225
QJETR	Variable	Regional demand for jet fuel	Btu	TAIREFF	225
RHO	Parameter (P)	Average historic rate of growth of fuel efficiency	—	TAIREFF	220

AIR TRAVEL MODULE: Aircraft Fleet Efficiency Model					
ITEM	CLASS.	DESCRIPTION	UNITS	SUBROUTINE	EQ #
SEAT	Input Data (P)	Average number of seats per aircraft, by type.	Seats per Aircraft	TAIREFF	205
SMFRACN	Variable	Fraction of seat-mile demand on narrow-body planes	Percent	TAIREFF	206
SMFRACN	Variable	Fraction of seat miles handled by surviving stock and new purchases, by type.	—	TAIREFF	221
SMPG	Variable	Average seat miles per gallon for new purchases and surviving fleet, by type.	Seat Miles per Gallon	TAIREFF	219
SMPGT	Variable	Overall fleet average seat-miles per gallon	SMPG	TAIREFF	221
SMSURV	Variable	Surviving travel capacity by body type.	Seat Miles	TAIREFF	209
SSURVPCT	Parameter (P)	Marginal survival rate of planes of a given vintage	Percent	TAIREFF	208
STKOLD	Variable	Fraction of planes older than one year, by aircraft type	Percent	TAIREFF	213
SURVK	Parameter (P)	User-specified proportionality constant	—	TAIREFF	208
SURVPCT	Input Data (P)	Survival rate of planes of a given vintage *IVINT*	Percent	TAIREFF	208
T50	Parameter (P)	User-specified vintage at which stock survival is 50%	Years	TAIREFF	208
TIMECONST	Parameter (P)	User-specified scaling constant, reflecting the importance of the passage of time	—	TAIREFF	214
TIMEFX	Parameter (P)	Factor reflecting the length of time an aircraft technology improvement has been commercially viable	—	TAIREFF	214
TOTALFX	Parameter (P)	Overall effect of fuel price and time on implementation of technology *IFX*	—	TAIREFF	216
TPJFGAL	Variable	Price of jet fuel	$ per Gallon	TAIREFF	215
TPN	Variable	Binary variable (0,1) which tests whether current fuel price exceeds the considered techology's trigger price	—	TAIREFF	214
TPZ	Variable	Binary variable which tests whether implementation of the considered technology is dependent on fuel price	—	TAIREFF	215
TRIGPRICE	Parameter (P)	Price of jet fuel above which the considered technology is assumed to be commercially viable	$ per Gallon	TAIREFF	215
TYRN	Variable	Binary variable which tests whether current year exceeds the considered technology's year of introduction	—	TAIREFF	215
XAIR	Variable	Fractional change in air travel from base year	Percent	TAIREFF	226
XAIREFF	Variable	Fractional change in aircraft fuel efficiency from base year	Percent	TAIREFF	226

FREIGHT TRANSPORT MODULE					
ITEM	CLASS.	DESCRIPTION	UNITS	SUBROUTINE	EQ #
FAC	Input Data (Q)	Freight Adjustment Coefficient—relates growth in value added in industry I to growth in freight transportation	—	TFREI	162
FBENCH	Parameter (I)	Benchmarking factor to ensure congruence with 1990 data	—	TFREI	168
FERAIL	Input Data (B)	Rail fuel efficiency	Miles per gallon	TRAIL	182
FESHIP	Input Data (B)	Domestic freighter fuel efficiency		TSHIP	188
FFD	Variable	Truck Fuel Demand, by type of fuel and class of vehicle.	MMBtu	TFREI	176
FFDT	Variable	Total fuel demand, by technology, in MMBtu	Gallons	TFREI	178
FFMPG	Variable	Average truck fuel economy for second size class for use in TMISC -	MPG	TFREI	177
FFVMT	Variable	Total freight truck vehicle-miles traveled in industry group *IX*	Vehicle-miles	TFREI	165
FLVMTSHR	Variable	Share of fuel technology in total truck VMT	Percent	TFREI	169
FMPG	Variable	Truck Fuel Efficiency, by class of truck.	Miles per Gallon	TFREI	174
FRLOAD	Parameter (Q)	Load factor associated with a given industry's output	—	TFREI	163
FSHR	Variable	Adjusted technology share of VMT demand	Percent	TFREI	169
FTMT	Variable	Total highway freight traffic, by industry	Ton Miles	TFREI	162
FTOTVMT	Variable	Total VMT demand for trucks	Vehicle miles	TFREI	166
FVMT	Variable	Freight transport demand by class of truck.	Vehicle Miles	TFREI	163
FVMTECHSC	Variable	Total highway freight VMT, by size class and fuel technology	Vehicle Miles	TFREI	172
FVMTSC	Variable	Total highway freight VMT, by size class	Vehicle Miles	TFREI	168
GROSST	Variable	Value of gross trade (imports + exports)	$	TSHIP	191
GROWTH	Parameter	Factor which specifies changes in truck VMT by each fuel technology over time	—	TFREI	169
IF	Index	Index of fuel type	—	TRAIL	—
IS	Index	Index of truck size class (1-3)	—	TFREI	—
ISFD	Variable	International freighter energy demand, by fuel	MMBtu	TSHIP	192
ISFDT	Variable	Total international shipping energy demand	MMBtu	TSHIP	191
ISFSHARE	Parameter (B)	International shipping fuel allocation factor	—	TSHIP	192
IX	Index	Place holder for industry group	—	TFREI	—

FREIGHT TRANSPORT MODULE					
ITEM	**CLASS**	**DESCRIPTION**	**UNITS**	**SUBROUTINE**	**EQ #**
OUTPUT	Variable	Value of output of each industry in base year dollars.	Dollars	TFREI	162
QBTU	Input Data (I)	Heat content of fuel used by each technology	MMBtu per gallon	TFREI	176
RTMT	Variable	Total rail freight traffic, by industry	Ton Miles	TRAIL	180
RTMTT	Variable	Total rail ton-miles traveled	Ton Miles	TRAIL	181
SEDSHR	Parameter (K)	Regional shares of shipping fuel demand	Percent	TFREI	179
SFD	Variable	Domestic freighter energy demand, by fuel	MMBtu	TSHIP	189
SFDBENCH	Parameter (I)	Benchmark factor to ensure congruence with 1990 data	—	TSHIP	188
SFDT	Variable	Domestic freighter energy demand	MMBtu	TSHIP	188
SFSHARE	Parameter (B)	Domestic shipping fuel allocation factor	—	TSHIP	189
STMT	Variable	Total waterborne freight traffic, by industry	Ton Miles	TSHIP	186
STMTT	Variable	Total ship ton-miles traveled	Ton Miles	TSHIP	187
SUMFVMT	Variable	Total freight VMT for the second size class for use in TMISC	Vehicle Miles	TFREI	173
TBETA1	Parameter	Base rate of fuel economy growth, by size class	Percent	TFREI	174
TBETA2	Parameter	Fuel-price sensitive rate of fuel economy growth, by size class	Percent	TFREI	174
TECH	Index	Index of engine technology (1-5)	—	TFREI	—
TMC_YD	Variable	Disposable personal income, from the MACRO module	$	TFREI	165
TPMGTR	Variable	Price of motor gasoline used for highway transport	$ per Gallon	TFREI	174
TQFREIR	Variable	Total regional truck fuel consumption for each technology	MMBtu	TFREI	179
TQFREIRSC	Variable	Total regional freight energy demand by technology and size class	MMBtu	TFREI	179
TQISHIPR	Variable	Total regional energy demand by international freighters	MMBtu	TSHIP	193
TQRAIL	Variable	Total demand for each fuel by rail freight sector in year *T*	MMBtu	TRAIL	183
TQRAILR	Variable	Total regional rail fuel consumption for each technology	MMBtu	TRAIL	184
TQRAILT	Variable	Total energy consumption by freight trains in year *T*	MMBtu	TRAIL	182
TQSHIPR	Variable	Total regional energy demand by domestic freighters, by fuel type	MMBtu	TSHIP	190

FREIGHT TRANSPORT MODULE					
ITEM	CLASS.	DESCRIPTION	UNITS	SUBROUTINE	EQ #
TRSCSHR	Input Data (B)	Travel share distribution factors, held constant	—	TFREI	168
TSIC	Variable	Value of output of industry *I*, in base year (1990) dollars	$	TFREI	162
TSIC90	Input Data (I)	Base year value of industrial output	$	TFREI	165
TYD8290	Input Data (I)	Base year disposable personal income	$	TFREI	165
XFREFF	Variable	Fuel economy improvement over base year	Percent	TFREI	175
XRAIL	Variable	Growth in rail travel from base year	Percent	TRAIL	185
XRAILEFF	Variable	Growth in rail efficiency from base year	Percent	TRAIL	185
XSHIP	Variable	Growth in ship travel from base year	Percent	TSHIP	194
XSHIPEFF	Variable	Growth in ship efficiency from base year	Percent	TSHIP	194
XTOTVMT	Variable	Fractional growth in freight VMT over base year	Percent	TFREI	167

MISCELLANEOUS ENERGY DEMAND MODULE					
ITEM	CLASS.	DESCRIPTION	UNITS	SUBROUTINE	EQ #
BETALUB	Parameter (K)	Coefficient of proportionality, relating highway travel to lubricant demand	—	TMISC	238
BETAMS	Parameter (B)	Coefficient of proportionality, relating mass transit to LDV travel	—	TMISC	230
BETAREC	Parameter (B)	Coefficient of proportionality relating income to fuel demand for boats	—	TMISC	234
FLTVMT	Variable	Total fleet vehicle VMT, from the Fleet Module	Vehicle Miles	TFLTVMTS	237
FMPG	Variable	Fuel efficiency for mass transit vehicles, by vehicle type, from the Freight Module	Miles per gallon	TFREI	231
FMPG89	Data Input (B)	Base-year fuel efficiency for mass transit vehicles, by vehicle type, from the Freight Module	Miles per gallon	TEXOG	231
FTVMT	Variable	Total freight truck VMT, from the Freight Module	Vehicle Miles	TMISC	236
FVMTSC	Variable	Freight truck VMT, by size class		TMISC	236
HYWAY	Variable	Total highway VMT	Vehicle Miles	TMISC	237
IF	Index	Index of fuel type: 1=Distillate, 2=Naphtha, 3=Residual, 4=Kerosene	—	TMISC	—
IM	Index	Index of transportation mode: 1 = LDV's, 2-4 = Buses, 5-7 = Rail	—	TMISC	—
IM	Index	Index of transportation mode: 1 = LDV's, 2-4 = Buses, 5-7 = Rail		TMISC	—
LUBFD	Variable	Total demand for lubricants in year T	MMBtu	TMISC	238
MFD	Variable	Total military consumption of each fuel in year T	MMBtu	TMISC	228
MILTARGR	Variable	The growth in the military budget from the previous year	Percent	TMISC	227
MILTRSHR	Input Data (L)	Regional consumption shares, from 1991 data, held constant	Percent	TMISC	229
QLUBR	Variable	Regional demand for lubricants in year T	MMBtu	TMISC	239
QMILTR	Variable	Regional military fuel consumption, by fuel type	MMBtu	TMISC	229
QMODR	Variable	Regional consumption of fuel, by mode	MMBtu	TMISC	233
QRECR	Variable	Regional fuel consumption by recreational boats in year T	MMBtu	TMISC	235
RECFD	Variable	National recreational boat gasoline consumption in year T	MMBtu	TMISC	234
TMC_GFML87	Variable	Total defense budget in year T, from the macro economic segment of NEMS	$	TMAC	227
TMC_POPAFO	Variable	Regional population forecasts, from the Macro Module	People	TMAC	233
TMC_YD	Variable	Total disposable personal income, from the Macro Module	$	TMAC	234

MISCELLANEOUS ENERGY DEMAND MODULE					
ITEM	**CLASS.**	**DESCRIPTION**	**UNITS**	**SUBROUTINE**	**EQ #**
TMEFF89	Input Data (B)	Base-year Btu per vehicle-mile, by mass transit mode	Btu per vehicle mile	TMISC	231
TMEFFL	Variable	Btu per passenger-mile, by mass transit mode	Btu per passenger mile	TMISC	231
TMFD	Variable	Total mass-transit fuel consumption by mode	Gallons	TMISC	232
TMOD	Variable	Passenger-miles traveled, by mode	Passenger miles	TMISC	230
TMLOAD89	Data Input (B)	Average passengers per vehicle, by mode, held constant at 1989 values (1=LDV's)	Units	TMISC	230
TYPE	Index	Vehicle type, from the Freight Module: 1 = Mid-size trucks, 2 = Rail	—	TFREI	231
VMTEE	Variable	LDV vehicle-miles traveled, from the VMT module	Vehicle miles	TVMT	230

TRANSPORTATION EMISSIONS MODULE					
ITEM	CLASS	DESCRIPTION	UNITS	SUBROUTINE	EQ #
EFACT	Parameter (M)	Emissions factor relating measures of travel to pollutant emissions	—	TEMISS	240
EMISS	Variable	Regional emissions of a given pollutant, by mode of travel	Tons per year	TEMISS	240
IE	Index	Index of pollutants: 1 = SO_x, 2 = NO_x, 3 = C, 4 = CO_2, 5 = CO, 6 = VOC	—	TEMISS	240
IM	Index	Index of travel mode: references individual vehicle types used in the preceding modules	—	TEMISS	240
IR	Index	Index identifying census region	—	TEMISS	240
U	Variable	Measure of travel demand, by mode: units in VMT for highway travel, gallons of fuel consumption for other modes	—	TEMISS	240

SOURCES OF DATA INPUTS AND PARAMETERS USED IN THE NEMS TRANSPORTATION MODEL

CODE	SOURCE
A	*Conventional Light-Duty Vehicle Fuel Economy*, Decision Analysis Corporation of Virginia and Energy and Environmental Analysis, Inc., Prepared For: Energy Information Administration, U.S. Department of Energy, Washington D.C., November, 1992.
B	*Transportation Energy Data Book: Edition 12*, Oak Ridge National Laboratory, Prepared For: Office of Transportation Technologies, U.S. Department of Energy, Washington, D.C., March 1992.
C	*Revised VMT Forecasting Model*, Unpublished Memorandum, U.S. Department of Energy, February 22, 1993.
D	*1990 National Personal Transportation Survey*, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., March 1992.
E	*Alternative-Fuel Vehicle Module*, Decision Analysis Corporation of Virginia, Prepared For: Energy Information Administration, U.S. Department of Energy, Washington, D.C., September 1992.
F	*Demand for Clean-Fuel Personal Vehicles in California: A Discrete-Choice Stated Preference Survey*, D. S. Bunch, *et. al.*, University of California, Davis, UCD-ITS-RR-91-14, December 1991.
G	*Fleet Vehicles in the United States*, Oak Ridge National Laboratories, Prepared For: Office of Transportation Technologies and Office of Policy, Planning and Analysis, U.S. Department of Energy, Washington, D.C., March 1992.
H	*Assessment of Costs and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation Sector; Technical Report Ten: Analysis of Alternative-Fuel Fleet Requirements*, Office of Domestic and International Energy Policy, U.S. Department of Energy, May 1992.
I	*Annual Energy Outlook 1993*, Energy Information Administration, Office of Integrated Analysis and Forecasting, U.S. Department of Energy, Washington, D.C., January 1993.
J	*Proposed Regulations for Low-Emission Vehicles and Clean Fuels*, State of California Air Resources Board, August 13, 1990.
K	*State Energy Data Survey 1991*, Energy Information Administration, Office of Energy Markets and End Use, U.S. Department of Energy, Washington, D.C., May 1993.
L	*Fuel Oil and Kerosene Sales 1991*, Energy Information Administration, Office of Oil and Gas, U.S. Department of Energy, Washington D.C., November 1992.
M	*Emissions Regulations, Inventories, and Emission Factor for the NEMS Transportation Energy and Research Forecasting Model*, Decision Analysis Corporation of Virginia, Prepared For: Energy Information Administration, U.S. Department of Energy, Washington, D.C., September 1992.
N	*Fuel Efficiency Degradation Factor*, Decision Analysis Corporation of Virginia, Prepared For: Energy Information Administration, U.S. Department of Energy, Washington, D.C., August 1992.
O	*Proposed Methodology for Projecting Air Transportation Demand*, Decision Analysis Corporation of Virginia, Prepared For: Energy Information Administration, U.S. Department of Energy, Washington, D.C., July 1992.
P	*Preliminary Estimation of the NEMS Aircraft Fleet Efficiency Module*, Decision Analysis Corporation of Virginia, Prepared For: Energy Information Administration, U.S. Department of Energy, Washington, D.C., September 1992.
Q	*Freight Transportation Requirements Analysis for the NEMS Transportation Sector Model*, Decision Analysis Corporation of Virginia, Prepared For: Energy Information Administration, U.S. Department of Energy, Washington, D.C., August 1992.

Table A-2. Light Duty Vehicle Market Classes

CLASS	DEFINITION	EXAMPLE MODEL
	AUTOMOBILES (Domestic and Import)	
Minicompact	Interior passenger volume < 79 ft^3	Geo Metro, Toyota Paseo (no domestic cars)
Subcompact	Passenger volume between 79 ft^3 and 89 ft^3	Nissan Sentra, Honda Civic, GM Saturn. Ford Escort
Sports	Two door high performance cars costing less than $25,000	VW Corrado, Honda Prelude, Chevy Camaro, Ford Mustang
Compact	Passenger volume between 89 and 95 ft^3	Honda Accord, Toyota Camry, Ford Tempo, Pontiac Grand Am
Intermediate	Passenger volume between 96 and 105 ft^3	Nissan Maxima, Ford Taurus, Chevy Lumina
Large	Passenger volume >105 ft^3	Ford Crown Victoria, Pontiac Bonneville (no imports)
Luxury	Cars over $25,000	Lincoln Continental, Cadillac, all Mercedes, Lexus LS400
	LIGHT TRUCKS (Domestic and Import)	
Compact Pickup	Trucks with inertia weight between 2750 and 4000 lbs.	All import trucks, Ford Ranger, GM S-10/15
Compact Van	Vans with inertia weight between 3000 and 4250 lbs.	All import vans, Plymouth. Voyager, Ford Aerostar
Compact Utility	Utility vehicles with inertia weight between 3000 and 4250 lbs.	Nissan Pathfinder, Toyota SR-5, Ford Bronco II, Jeep Cherokee
Standard Pickup	Trucks with inertia weight over 4000 lbs.	GM C-10. Ford F-150 (no imports)
Standard Van	Vans with inertia weight over 4250 lbs.	GM C15 van. Ford E-150 (no imports)
Standard Utility	Utility vehicles with inertia weight over 4250 lbs.	Toyota Land Cruiser, GM Suburban. Ford Blazer
Mini-truck	Utility/trucks below 2750 lbs. inertia weight	Suzuki Samurai (no domestics)

Table A-3. Maximum Light Duty Vehicle Market Penetration Parameters

Old Market Share	New PMAX (Automobiles)	New PMAX (Light Trucks)
≤ 1%	1%	1%
1.1-2%	2%	2%
2.1-3%	5%	5%
3.1-6%	12%	10%
6.1-10%	28%	22%
10.1-12%	32%	26%
12.1-14%	36%	30%
14.1-17%	41%	35%
17.1-20%	47%	40%
20.1-24%	53%	47%
24.1-27%	56%	50%
27.1-31%	60%	54%
31.1-35%	64%	58%
35.1-40%	68%	62%
40.1-45%	73%	67%
45.1-53%	78%	73%
53.1-62%	83%	79%
62.1-73%	88%	85%
73.1-85%	94%	92%
85.1-100%	100%	100%

Table A-4. Aircraft Fleet Efficiency Model Adjustment Factors

Year	DI	PCTINT	DFRT
1979	0.974	0.27	0.509
1980	0.976	0.32	0.523
1981	0.978	0.30	0.514
1982	0.980	0.28	0.509
1983	0.982	0.27	0.508
1984	0.985	0.28	0.522
1985	0.988	0.28	0.518
1986	0.991	0.25	0.520
1987	0.994	0.28	0.540
1988	0.996	0.30	0.545
1989	0.998	0.33	0.551
1990	1.000	0.35	0.555
1991	1.003	0.38	0.564
1992	1.004	0.40	0.569
1993	1.005	0.41	0.573
1994	1.007	0.42	0.577
1995	1.008	0.43	0.579
1996	1.007	0.44	0.584
1997	1.007	0.45	0.585
1998	1.006	0.46	0.591
1999	1.006	0.46	0.593
2000	1.005	0.47	0.598
2001	1.003	0.47	0.601
2002	1.001	0.48	0.604
2003	0.998	0.48	0.604
2004	0.996	0.48	0.604
2005	0.994	0.48	0.604
2006	0.992	0.49	0.604
2007	0.989	0.49	0.604
2008	0.987	0.49	0.604
2009	0.985	0.49	0.604
2010	0.983	0.49	0.604
2011	0.980	0.49	0.604
2012	0.978	0.49	0.604
2013	0.975	0.50	0.604
2014	0.972	0.50	0.604
2015	0.970	0.50	0.604
2016	0.967	0.50	0.604
2017	0.965	0.50	0.604
2018	0.962	0.50	0.604
2019	0.960	0.50	0.604
2020	0.957	0.50	0.604
2021	0.956	0.50	0.604
2022	0.954	0.50	0.604
2023	0.952	0.50	0.604
2024	0.951	0.50	0.604
2025	0.949	0.50	0.604
2026	0.948	0.50	0.604
2027	0.946	0.50	0.604
2028	0.944	0.50	0.604
2029	0.943	0.50	0.604
2030	0.941	0.50	0.604

Table A-5. List of Expected Aircraft Technology Improvements

Proposed Technology	Intro. Year	Jet Fuel Price[1] ('87 $/Gal)	SMPG Gain Over 1990's	
			Narrow Body	Wide Body
ENGINES:				
Ultra-high Bypass	1995	$0.69	10%	10%
Propfan	2000	$1.36	23%	0%
AERODYNAMICS:				
Hybrid Laminar Flow	2020	$1.53	15%	15%
Advanced Aerodynamics	2000	$1.70	18%	18%
OTHER:				
Weight Reducing Materials	2000	—	15%	15%
Thermodynamics	2010	$1.22	20%	20%

[1] These figures represent the minimum jet fuel prices (1987 $) at which the corresponding technologies are assumed to become cost-effective.

Appendix B. Mathematical Representation

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Introduction

This appendix provides a detailed mathematical description of the transportation model. Equations are presented in the order in which they are encountered in the code, identified by subroutine and model component. The equations follow the logic of the FORTRAN source code very closely to facilitate an understanding of the code and its structure. In several instances, a variable name will appear on both sides of an equation. This is a FORTRAN programming device that allows a previous calculation to be updated (for example, multiplied by a factor) and re-stored under the same variable name.

In the interest of clarity, initialization statements, variable name reassignments, and error-trapping tests are omitted, except where such descriptions are essential to an understanding of the process. Representative equations are also employed in those instances where the model specifies numerous, but essentially identical, calculations (most notably in the emissions component).

FUEL ECONOMY MODEL　　　　　　　　　　　　　　　　　　Subroutine FEMCALC

1) Calculate the fuel cost slope, used to linearly extrapolate expected fuel cost over the desired payback period:

$$PSLOPE = \frac{MAX\ (0\ , FUELCOST_{YEAR-3} - FUELCOST_{YEAR-5})}{2} \quad \text{(B-1)}$$

where:

PSLOPE = The fuel cost slope
FUELCOST = The cost of fuel in the specified prior years

2) Calculate the expected fuel price in year i (where i goes from 1 to PAYBACK):

$$PRICESEX_i = PSLOPE*(i+2) + FUELCOST_{YEAR-3} \quad \text{(B-2)}$$

where:

$PRICESEX_i$ = The expected price of fuel

3) Calculate the expected present value of fuel savings over the payback period:

$$FUELSAVE_{itc} = \sum_{i=1}^{PAYBACK} VMT_i * \left(\frac{1}{FE_{itc,YEAR-1}} - \frac{1}{(1 + DELSFE_{itc} * FE_{itc,YEAR-1})} \right) * PRICESEX_i * (1 + DISCOUNT)^{-i} \quad \text{(B-3)}$$

where:

itc = The index representing the technology under consideration
FE = The fuel economy of technology *itc*
DELSFE = The fractional change in fuel economy associated with technology *itc*
PAYBACK = The user-specified payback period
DISCOUNT = The user-specified discount rate

4) Calculate the cost of technology *itc*:

$$TECHCOST_{itc} = DEL\$COSTABS_{itc} - \left(DEL\$COSTWGT_{itc} * DEL\$WGTWGT_{itc} * WEIGHT_{BASEYR}\right) \tag{B-4}$$

where:

DEL$COSTABS = The fixed dollar cost of technology *itc*
DEL$COSTWGT = The weight-based change in cost ($/lb)
DEL$WGTWGT = The fractional change in weight associated with technology *itc*
WEIGHT = The original vehicle weight

5) Calculate the perceived value of performance associated with technology *itc*:

$$VAL\$PERF_{itc} = VALUEPERF_{itc} * \frac{INCOME_{YEAR}}{INCOME_{YEAR-1}} * \frac{FE_{YEAR-1} * (1 + DEL\$FE_{itc})}{FE_{YEAR-1}} * \frac{FUELCOST_{YEAR-1}}{PRICE\$EX_{1}} * DEL\$HP_{itc} \tag{B-5}$$

where:

VAL$PERF = The dollar value of performance of technology *itc*
VALUEPERF = The value associated with an incremental change in performance
DEL$HP = The fractional change in horsepower of technology *itc*
PRICE$EX = The expected price of fuel
FUELCOST = The actual price of fuel (in the previous year)

6) Calculate the cost effectiveness of technology *itc*:

$$COSTEFFECT_{itc} = \frac{FUELSAVE_{itc} - TECHCOST_{itc} - VAL\$PERF_{itc} + \left(REGCOST * FE_{YEAR-1} * DEL\$FE_{itc}\right)}{ABS\left(TECHCOST_{itc}\right)} \tag{B-6}$$

where:

COSTEFFECT = A unitless measure of cost effectiveness
REGCOST = A factor representing regulatory pressure to increase fuel economy
TECHCOST = The cost of the considered technology
VAL$PERF = The performance value associated with technology *itc*

7) Calculate the preliminary economic market share of technology *itc*:

$$ACTUAL\$MKT_{itc} = MMAX_{itc} * PMAX_{itc} * \left(1 + e^{-2 * COSTEFFECT_{itc}}\right)^{-1} \tag{B-7}$$

where:

ACTUAL$MKT = The economic share, prior to consideration of engineering or regulatory constraints. The subsequent adjusted value is stored in the variable MKT$PEN.

MMAX = The maximum market share for technology *itc*, obtained from MKT$MAX

PMAX = The institutional maximum market share, which models tooling constraints on the part of the manufacturers, and is set in the subroutine FUNCMAX.

8) Ensure that existing technologies maintain market share in the absence of competing technologies:

$$ACTUAL\$MKT_{itc} = MAX\left(MKT\$PEN_{YEAR-1}, ACTUAL\$MKT_{itc}\right) \tag{B-8}$$

where:

$MKT\$PEN_{Year-1}$ = The previous year's market share of technology *itc*

9) Apply mandatory constraints:

$$ACTUAL\$MKT_{itc} = MAX\left(ACTUAL\$MKT_{itc}, MANDMKSH_{itc}\right) \tag{B-9}$$

where:

MANDMKSH = The minimum market share of technology *itc* required by legislative mandate.

10) Apply required engineering constraints (following a call to the subsequent subroutine NOTE$SUPER):

a) Sum the market shares of the required technologies (*req*):

$$REQ\$MKT = MIN\left(\sum_{req} ACTUAL\$MKT_{req}, 1.0\right) \tag{B-10}$$

where:

REQ$MKT = The total market share of those technologies which are required for the implementation of technology *itc*, indicating that technology's maximum share

b) Compare REQ$MKT to the market share of technology referred to by the engineering note, $ACTUAL\$MKT_{itc}$, selecting the smaller share:

$$ACTUAL\$MKT_{itc} = MIN\left(ACTUAL\$MKT_{itc}\ ,\ REQ\$MKT\right) \tag{B-11}$$

11) Assign the preliminary market share value to the permanent variable:

$$MKT\$PEN_{icl,igp,itc,year} = ACTUAL\$MKT_{itc} \tag{B-12}$$

where:

MKT$PEN = The market penetration of technology *itc* by vehicle group *igp* and vechilce class *icl*

12) Apply synergistic engineering constraints to those technologies whose combination provide non-additive benifits to fuel economy:

$$FE_{YEAR} = FE_{YEAR} + \left(MKT\$PEN_{itc1,YEAR} - MKT\$PEN_{itc1,YEAR-1}\right) * \left(MKT\$PEN_{itc2,YEAR} - MKT\$PEN_{itc2,YEAR-1}\right) * SYNR\$DEL_{itc1,itc2} \tag{B-13}$$

where:

itc1 = First synergistic technology

itc2 = Second synergistic technology

SYNR$DEL = The synergistic effect of the two technologies on fuel economy

13) Calculate the change in market share for a given technology:

$$DELTA\$MKT_{itc} = MKT\$PEN_{itc,YEAR} - MKT\$PEN_{itc,YEAR-1} \tag{B-14}$$

where:

$DELTA\$MKT_{itc}$ = The change in market share for technology *itc*

14) Calculate current fuel economy for the considered vehicle class:

$$FE_{YEAR} = FE_{YEAR-1} + \sum_{itc=1}^{NUMTECH} FE_{YEAR-1} * DELTA\$MKT_{itc} * DEL\$FE_{itc} \qquad \text{(B-15)}$$

where:

DEL\$FEitc = The fractional change in fuel economy attributed to technology *itc*

15) Calculate average vehicle weight for the considered class:

$$WEIGHT_{YEAR} = WEIGHT_{YEAR-1} + \sum_{itc=1}^{NUMTECH} DELTA\$MKT_{itc} * \left[DEL\$WGTABS_{itc} + \left(WEIGHT_{BASEYR} * DEL\$WGTWGT_{itc}\right)\right] \qquad \text{(B-16)}$$

where:

DEL\$WGTABS = The change in weight (lbs) associated with technology *itc*
DEL\$WGTWGT = The fractional change in vehicle weight due to technology *itc*
$WEIGHT_{BASEYEAR}$ = The base year vehicle weight, absent the considered technology

16) Calculate the average vehicle price for the considered class:

$$PRICE_{YEAR} = PRICE_{YEAR-1} + \sum_{itc=1}^{NUMTECH} DELTA\$MKT_{itc} * \left[DEL\$COSTABS_{itc} + (WEIGHT_{YEAR} - WEIGHT_{BASEYR}) * DEL\$COSTWGT_{itc}\right] \qquad \text{(B-17)}$$

where:

DEL\$COSTABS = The cost of technology *itc*
DEL\$COSTWGT = The weight-based change in cost of technology *itc* (\$/lb)

17) Calculate horsepower, assuming a constant weight to horsepower ratio:

$$HP_{YEAR} = HP_{BASEYR} * \frac{WEIGHT_{YEAR}}{WEIGHT_{BASEYR}} \qquad \text{(B-18)}$$

where:

$HP_{BASEYEAR}$ = The base year average horseposer for the considered vehicle class

18) Calculate the horsepower adjustment factor:

$$ADJHP = PERFFACT * \left[\left(\frac{INCOME_{YEAR}}{INCOME_{YEAR-1}} \right)^{0.9} * \left(\frac{PRICE_{YEAR-1}}{PRICE_{YEAR}} \right)^{0.9} * \left(\frac{FE_{YEAR}}{FE_{YEAR-1}} \right)^{0.2} * \left(\frac{FUELCOST_{YEAR-1}}{FUELCOST_{YEAR}} \right)^{0.2} - 1 \right] \quad \text{(B-19)}$$

where:

ADJHP = The fractional change in horspower from the previous year within a given vehicle class
INCOME = Household income
PRICE = Vehicle price
FE = Vehicle fuel economy
FUELCOST = Fuel price

19) Calculate current year horsepower, summing incremental changes from the initial year:

$$HP_{YEAR} = HP_{YEAR} * \left(1 + \sum_{1990}^{YEAR} ADJHP \right) \quad \text{(B-20)}$$

20) Calculate fractional change in fuel economy due to horsepower change:

$$\begin{aligned} ADJFE &= -0.22 * ADJHP - 0.560 * ADJHP^2 \quad ; \quad ADJHP \geq 0 \\ ADJFE &= -0.22 * ADJHP + 0.560 * ADJHP^2 \quad ; \quad ADJHP < 0 \end{aligned} \quad \text{(B-21)}$$

where:

ADJFE = The fuel economy adjustment factor

21) Calculate the adjusted fuel economy:

$$FE = FE * (1 + ADJFE) \quad \text{(B-22)}$$

22) Calculate the vehicle price, adjusted for the change in performance:

$$PRICE = PRICE + ADJHP * VALUEPERF \quad \text{(B-23)}$$

This subroutine is called from subroutine FEMCALC in order to check whether new technologies have superseded older ones. Affected technologies are grouped in a hierarchy, and market shares are adjusted so that the sum does not exceed the maximum market penetration of the group.

1) Calculate aggregate market share of superseding technologies:

$$TOT\$MKT = \sum_{ino=1}^{numSsup} ACTUAL\$MKT_{ino} \qquad \textbf{(B-24)}$$

where:

TOT$MKT = The total market share of the considered group of technologies
ino = The index identifying the technologies in the superseding group
numSsup = The number of technologies in the superseding group

2) Establish the maximum market share for the group:

$$MAX\$SHARE = MAX\,(MKT\$MAX_{ino}) \qquad \textbf{(B-25)}$$

--where:

MKT$MAX = The maximum market share for the considered technology, exogenously set
MAX$SHARE = The maximum market share of the group, *ino*

3) If the aggregate market share (TOT$MKT) is greater than the maximum share (MAX$SHARE), reduce the market shares of those technologies which are lower in the hierarchy:

a) Calculate the reduction in market share of a superseded technology, ensuring that the decrement does not exceed that technology's total share:

$$DEL\$MKT = MIN\big((TOT\$MKT - MAX\$SHARE),\ ACTUAL\$MKT_{isno}\big) \qquad \textbf{(B-26)}$$

where:

DEL$MKT = The amount of the superseded technology's market share to be removed
isno = An index indicating the superseded technology

b) Adjust total market share to reflect this decrement

$$TOT\$MKT = TOT\$MKT - DEL\$MKT \tag{B-27}$$

c) Adjust the market share of the superseded technology to reflect the decrement

$$ACTUAL\$MKT_{isno} = ACTUAL\$MKT_{isno} - DEL\$MKT \tag{B-28}$$

These values are returned to the preceding subroutine.

FUEL ECONOMY MODEL Subroutine CMKSCALC

1) Calculate incremental change in class market share ratio:

a) For all vehicles except luxury cars:

$$DIFF\$LN = A * \ln\left(\frac{YEAR}{1990}\right) + B * \ln\left(\frac{FUELCOST_{YEAR}}{FUELCOST_{1990}}\right) + C * \ln\left(\frac{INCOME_{YEAR} - \$13{,}000}{INCOME_{1990} - \$13{,}000}\right) \tag{B-29}$$

where:

DIFFSLN = The increment from the base year (1990) of the log of the market share ratio

b) For luxury cars:

$$DIFF\$LN = A * \ln\left(\frac{YEAR}{1990}\right) + B * \ln\left(\frac{FUELCOST_{YEAR}}{FUELCOST_{1990}}\right) + C * \ln\left(\frac{INCOME_{YEAR}}{INCOME_{1990}}\right) \tag{B-30}$$

2) Solve for the log-share ratio:

$$RATIO\$LN = DIFF\$LN + \ln\left(\frac{CLASS\$SHARE_{1990}}{1 - CLASS\$SHARE_{1990}}\right) \tag{B-31}$$

where:

RATIO$LN = Log of the market share ratio of the considered vehicle class

3) Solve for the class market share:

$$CMKS = \frac{EXP\ (RATIO\$LN)}{1 + EXP\ (RATIO\$LN)} \tag{B-32}$$

where:

CMKS = Class market share, subsequently reassigned to the appropriate vehicle class and group, $CLASS\$SHARE_{icl,igp}$

4) Normalize so that shares total 100% within each CAFE group:

$$CLASS\$SHARE_{icl,igp,YEAR} = \frac{CLASS\$SHARE_{icl,igp,YEAR}}{\sum_{icl=1}^{7} CLASS\$SHARE_{icl,igp,YEAR}} \tag{B-33}$$

FUEL ECONOMY MODEL — Subroutine CAFECALC

1) Calculate the Corporate Average Fuel Economy for each of the four CAFE groups:

$$CAFE_{icl,igp,YEAR} = \frac{\sum_{icl=1}^{7} CLASS\$SHARE_{icl,igp,YEAR}}{\sum_{icl=1}^{7} \frac{CLASS\$SHARE_{icl,igp,YEAR}}{FE_{icl,igp,YEAR}}} \tag{B-34}$$

where:

icl = FEM vehicle size class index (7)

igp = CAFE group index: 1 = domestic car, 2 = import car, 3 = domestic light truck, 4 = import light truck

This subroutine maps vehicle sales and fuel economy generated for the seven size classes considered in the Fuel Economy Model (FEM) into the six vehicle size classes used in subsequent sectors.

1) Determine the number of Light Truck sales which are classified as LDT's:

$$T\_LDT\_MAC_N = MC\_SQDTRUCKS_N * LT10K * \left[(LT2A4 * LT2A4LDV) + (LTOSU * LTOSULDV) \right] \quad (35)$$

where:

T_LDT_MAC = Total LDT's (under 8,500 pounds), as estimated by the Macro Module
MC_SQDTRUCKS = Total Light Truck sales (under 14,000 pounds), from Macro
LT10K = Fraction of these trucks under 10,000 pounds
LT2A4 = Fraction of light trucks with a 2-axle, 4-tire configuration
LT2A4LDV = Fraction of these trucks less than 8,500 pounds
LTOSU = Fraction of light trucks with other axle configurations
LTOSULDV = Fraction of these trucks less than 8,500 pounds

2) Calculate total LDV sales:

$$T\_LDV\_MAC_N = MC\_SQTRCARS_N + T\_LDT\_MAC_N \quad (36)$$

where:

T_LDV_MAC = Total car and adjusted light truck sales
MC-SQTRCARS = Total car sales, from the Macro Module

3) Allocate LDV sales between cars and light trucks:

$$TMC\_SQTRCARS_N = T\_LDV\_MAC_N * (1 - CARLTSHR)$$
$$and \quad (37)$$
$$TMC\_SQDTRUCKS_N = T\_LDV\_MAC_N * CARLTSHR$$

where:

TMC_SQTRCARS = Total sales of new cars

TMC_SQDTRUCKS = Total sales of new light trucks

CARLTSHR = Allocation factor representing LDT fraction of LDV sales (Appendix F, Attachment 8)

4) Map vehicle sales from seven size classes to six:

$$MAPSALE_{igp,icl,osc,N} = NVS7SC_{igp,icl,N} * MAP_{igp,icl,osc} \quad \text{(B-38)}$$

where:

MAPSALE = Disaggregate vehicle sales

NVS7SC = New vehicle sales within the seven FEM size classes, calculated in subroutine TSIZE

MAP = Array of mapping constants, which converts FEM to ORNL size classes

osc = ORNL size class index (6)

N = Time period index (1990 = 1)

5) Sum across sales within each size class:

$$TOTNVS7 = \sum_{icl=1}^{7} MAPSALE_{igp,icl,osc,N} \quad \text{(B-39)}$$

where:

TOTNVS7 = Total new vehicle sales within the six ORNL size classes

6) Create a mapping share:

$$MAPSHR_{igp,icl,osc,N} = \frac{MAPSALE_{igp,icl,osc,N}}{TOTNVS7_{igp,osc,N}} \quad \text{(B-40)}$$

where:

MAPSHR = Sales shares within the disaggregate array

7) Multiply MPG by mapped sales share:

$$FEMPG_{igp,osc,N} = \sum_{icl=1}^{7} FE_{icl,igp,YEAR} * MAPSHR_{igp,icl,osc,N} \quad \text{(B-41)}$$

where:

FEMPG = Average fuel economy by six ORNL size classes

FE = Average fuel economy by seven FEM size classes

$YEAR$ = Year index ($YEAR = N+1$)

8) Create benchmark factors for each CAFE group *igp*, held constant after 1992:

$$BENCHMPG_{igp,osc} = \frac{ORNLMPG_{igp,osc}}{FEMPG_{igp,osc,N=3}} \tag{B-42}$$

where:

BENCHMPG = MPG benchmark factors to ensure congruence with most recent data from ORNL

ORNLMPG = Most recent (1992) fuel economy data from ORNL

9) Apply the benchmark factor to each size class, combining domestic and imported vehicles:

$$FESIXC_{osc,N} = \sum_{igp=1}^{2} FEMPG_{igp,osc,N} * BENCHMPG_{igp,osc} * ORNLSHR_{igp,osc}$$

$$FESIXT_{osc,N} = \sum_{igm=3}^{4} FEMPG_{igp,osc,N} * BENCHMPG_{igp,osc,} * ORNLSHR_{igp,osc} \tag{B-43}$$

where:

FESIXC = Fuel economy for cars within six size classes

FESIXT = Fuel economy for light trucks within six size classes

REGIONAL SALES MODEL — Subroutine TSIZE

1) Estimate non-fleet, non-commercial sales of cars and light-trucks within each of the seven size classes considered by FEM (subsequently passed to subroutine FEMSIZE):

a) For cars, igp = 1,2:

$$NVS7SC_{igp,icl,N} = CLASS\$SHARE_{icl,igp,YEAR} * TMC\_SQTRCARS_N * \left(1 - FLTCRAT_{1990}\right) * SALESHR_{igp,N} \tag{B-44}$$

where:

NVS7SC = New vehicle sales in the original seven FEM size classes, by CAFE group *igp*
TMC_SQTRCARS = Total new car sales (supplied by the MACRO module)
CLASS$SHARE = The market share for each automobile class, from FEM
FLTCRAT = Fraction of new cars purchased by fleets
SALESHR = Fraction of vehicle sales which are domestic/imported

b) For light trucks, $igp = 3,4$:

$$NVS7SC_{igp,icl,N} = CLASS\$SHARE_{icl,igp,YEAR} * TMC\_SQDTRUCKS_N * \left(1 - (FLTTRAT_{1990} + COMTSHR)\right) * SALESHR_{igp,N} \tag{B-45}$$

where:

TMC_SQDTRUCKS = Total new light truck sales (from the MACRO module)
FLTTRAT = Fraction of new light trucks purchased by fleets
COMTSHR = Fraction of new light trucks dedicated to commercial freight

2) Redistribute car and truck sales among six size classes, combining import and domestic:

a) For cars:

$$NCSTSCC_{osc,N} = \sum_{igp=1}^{2} \sum_{icl=1}^{7} \left(NVS7SC_{igp,icl,N}\right) * MAP_{igp,icl,osc} \tag{B-46}$$

where:

NCSTSCC = Total new car sales by size class *osc*
MAP = Array of constants which map sales from seven to six size classes

b) For light trucks:

$$NLTSTSCC_{osc,N} = \sum_{igp=3}^{4} \sum_{icl=1}^{7} \left(NVS7SC_{igp,icl,N}\right) * MAP_{igp,icl,osc} \tag{B-47}$$

where:

NLTSTSCC = Total new light truck sales by size class *osc*

3) Calculate the market shares of cars and light trucks by size class:

$$PASSHRR_{osc,N} = \frac{NCSTSCC_{osc,N}}{\sum_{osc=1}^{6} NCSTSCC_{osc,N}} \tag{B-48}$$

and:

$$LTSHRR_{osc,N} = \frac{NLTSTSCC_{osc,N}}{\sum_{osc=1}^{6} NLTSTSCC_{osc,N}} \tag{B-49}$$

where:

PASSHRR = Non-fleet market shares of automobiles, by size class *osc*
NLTSHRR = Non-fleet market shares of light trucks, by size class *osc*

4) Reassign horsepower estimates to six size classes:

$$HPCAR_{osc,N} = \sum_{igp=1}^{2} \sum_{icl=1}^{7} \left(HP_{icl,igp,YEAR} \right) * SALESHR_{igp} * MAP_{igp,icl,osc} \tag{B-50}$$

and:

$$HPTRUCK_{osc,N} = \sum_{igp=3}^{4} \sum_{icl=1}^{7} \left(HP_{icl,igp,YEAR} \right) * SALESHR_{igp} * MAP_{igp,icl,osc} \tag{B-51}$$

where:

HPCAR = Average horsepower of automobiles, by size class *osc*
HPTRUCK = Average horsepower of light trucks, by size class *osc*
HP = Vehicle horsepower by FEM size class *icl* and CAFE group *igp*
SALESHR = Domestic vs. import market share for automobiles and light trucks, from ORNL

5) Calculate average horsepower of cars and light trucks, by size class *osc*:

$$AHPCAR_{N} = \sum_{osc=1}^{6} HPCAR_{osc,N} * PASSHRR_{osc,N} \tag{B-52}$$

and:

$$AHPTRUCK_N = \sum_{osc=1}^{6} HPTRUCK_{osc,N} * LTSHRR_{osc,N} \quad \text{(B-53)}$$

where:

AHPCAR = Average automobile horsepower
AHPTRUCK = Average light truck horsepower

REGIONAL SALES MODEL

Subroutine TREG

1) Calculate regional shares of fuel demand, and normalize:

$$SEDSHR_{FUEL,REG,T} = \frac{SEDSHR_{FUEL,REG,T-1} * \left(\frac{TMC\_YD_{REG,T}}{TMC\_YD_{REG,T-1}} \right)}{\sum_{REG=1}^{9} SEDSHR_{FUEL,REG,T-1} * \left(\frac{TMC\_YD_{REG,T}}{TMC\_YD_{REG,T-1}} \right)} \quad \text{(B-54)}$$

where:

SEDSHR = Regional share of the consumption of a given fuel in period *T*
TMC_YD = Estimated disposable personal income by region, *REG* (9)
FUEL = Index of fuel type (11)

2) Calculate regional cost of driving per mile:

$$COSTMIR_{REG,T} = 0.1251 * \left(\frac{TPMGTR_{REG,T}}{MPGFLT_{T-1}} \right) \quad \text{(B-55)}$$

where:

COSTMIR = The cost per mile of driving in region *REG*, in $/mile
TPMGTR = The regional price of motor gasoline, in $/MMBTU
MPGFLT = The previous year's stock MPG for non-fleet vehicles
.1251 = A conversion factor for gasoline, in MMBTU/gal

3) Calculate regional income:

$$INCOMER_{REG,T} = \left(\frac{TMC\_YD_{REG,T}}{TMC\_POPAFO_{REG,T}} \right) \qquad \text{(B-56)}$$

where:

INCOMER = Regional per capita disposable income
TMC_POPAFO = Total population in region *REG*

4) Estimate regional driving demand:

$$\begin{aligned} VMT16R_{REG,T} = {} & \rho\, VMT16R_{REG,T-1} + \beta_0 (1-\rho) + \beta_1 \left(COSTMIR_{REG,T} - \rho\, COSTMIR_{REG,T-1} \right) \\ & + \beta_2 \left(INCOMER_{REG,T} - \rho\, INCOMER_{REG,T-1} \right) + \beta_3 \left(PRFEM_T - \rho\, PRFEM_{T-1} \right) \end{aligned} \qquad \text{(B-57)}$$

and:

$$VMTEER_{REG,T} = VMT16R_{REG,T} * TMC\_POP16_{REG,T} * DAF_T \qquad \text{(B-58)}$$

where:

VMT16R = Vehicle-miles traveled per population over 16 years of age
PRFEM = Ratio of female to male driving rates
ρ = Lag factor for the difference equation
VMTEER = Total VMT in region *REG*
TMC_POP16 = Total regional population over the age of 16
DAF = A demographic adjustment factor, to reflect different age groups' driving patterns

5) Calculate regional VMT shares (RSHR):

$$RSHR_{REG,T} = \frac{VMTEER_{REG,T}}{\sum_{REG=1}^{9} VMTEER_{REG,T}} \qquad \text{(B-59)}$$

6) Divide non-fleet car and light truck sales according to regional VMT shares:

$$NCS_{REG,SC,T} = NCSTSCC_{SC,T} * RSHR_{REG,T} \qquad \text{(B-60)}$$

and:

$$NLTS_{REG,SC,T} = NLTSTSCC_{SC,T} * RSHR_{REG,T} \qquad \text{(B-61)}$$

where:

NCS = New car sales, by size class *SC* and region *REG*
NLTS = New light truck sales, by size class and region

ALTERNATIVE FUEL VEHICLE MODEL

Subroutine TALT3

1) Calculate commercial availability by technology:

$$COMAV_{IT,N} = \left[1 + EXP\left(\frac{TT50_{IT} - YEAR}{2}\right)\right]^{-1} \qquad \text{(B-62)}$$

where:

COMAV = The fraction of market demand of a given technology which is commercially available
IT = Index of the sixteen engine technologies considered by the model
TT50 = The exogenously specified year in which 50% of the demand for technology *IT* can be met

2) Calculate the weighted average fuel price for each technology, by region:

$$AFCOST_{IT,IR,N} = \frac{\sum_{FUEL} (RFP_{FUEL,IR,N} * FAVAIL_{FUEL,IR,N})}{\sum_{FUEL} FAVAIL_{FUEL,IR,N}} \qquad \text{(B-63)}$$

where:

AFCOST = Weighted average fuel price, in 1990 cents/MMBTU, for each technology *IT*
RFP = Price of each fuel used by the corresponding technology
FAVAIL = Relative availability of the corresponding fuel

3) Map fuel economy for cars and light trucks from six to three size classes for use in the AFV model:

a) For cars:

$$FEC3SC_{ISC,N} = \left[\frac{\sum_{OSC} \left(\frac{NCSTSCC_{OSC,N}}{FESIXC_{OSC,N}} \right)}{\sum_{OSC} NCSTSCC_{OSC,N}} \right]^{-1} \quad \text{(B-64)}$$

where:

FEC3SC = Automobile fuel economy within the three reduced size classes
NCSTSCC = New car sales within the six size classes *OSC*
FESIXC = New car fuel economy within the six size classes *OSC*
ISC = Index of reduced size classes, mapped as follows for cars: *ISC* = 1, *OSC* = 2, 3; *ISC* = 2, *OSC* = 1, 6; *ISC* = 3, *OSC* = 4, 5

b) For light trucks:

$$FET3SC_{ISC,N} = \left[\frac{\sum_{OSC} \left(\frac{NLTSTSCC_{OSC,N}}{FESIXT_{OSC,N}} \right)}{\sum_{OSC} NLTSTSCC_{OSC,N}} \right]^{-1} \quad \text{(B-65)}$$

where:

FET3SC = Light truck fuel economy within the three reduced size classes
NLTSTSCC = New light truck sales within the six size classes *OSC*
FESIXT = New light truck fuel economy within the six size classes *OSC*
ISC = Index of reduced size classes, mapped as follows for trucks: *ISC* = 1, *OSC* = 1, 3; *ISC* = 2, *OSC* = 2, 5; *ISC* = 3, *OSC* = 4, 6

4) Convert fuel economy from miles per gallon to miles per MMBTU:

$$VEFFACT_{ISC,N} = \frac{FEC3SC_{ISC,N}}{0.125} \quad \text{(B-66)}$$

where:

VEFFACT = Gasoline vehicle fuel economy, used as a baseline

5) Calculate alternative vehicle fuel economy, using gasoline baseline:

$$VEFFBTU_{ISC,IT,N} = VEFF_{ISC,IT,N} * VEFFACT_{ISC,N} \tag{B-67}$$

where:

VEFFBTU = Fuel economy by technology *IT*, in miles per MMBTU
VEFF = Fuel economy of technology *IT*, relative to gasoline baseline

6) Calculate AFV operating cost, by region:

$$COPCOST_{IT,ISC,IR,N} = \frac{AFCOST_{IT,IT,N} * 100}{VEFFBTU_{ISC,IT,N}} \tag{B-68}$$

where:

COPCOST = Regional vehicle operating cost, in 1990$/mile

7) Calculate utility of electric and electric hybrid vehicles (*IT* = 7-10):

$$\begin{aligned} VC3_{IT,IR} = {} & BETACONST_{IT} + BETAVP \cdot VPRICE3_{IS,IT,N} + BETAFC \cdot COPCOST3_{IT,IS,IR,N} \\ & + BETAVR \cdot VRANGE3_{IS,IT,N} + BETAVR2 \cdot VRANGE3^2_{IS,IT,N} + BETAEM \cdot EMISS3_{IS,IT,N} \\ & + BETAEM2 \cdot EMISS3^2_{IS,IT,N} + BETAFA \cdot FAVAIL3_{IT,IR,N} + BETAFA2 \cdot FAVAIL3^2_{IT,IR,N} \end{aligned} \tag{B-69}$$

where:

VC3 = Utility vector for electric vehicles
BETACONST = Constant associated with each considered technology *IT*
COPCOST3 = Fuel operating costs for electric vehicles
VPRICE3 = Price of each considered EV technology in 1990$
VRANGE3 = Vehicle range of the considered EV technology
EMISS3 = EV emissions levels relative to gasoline ICE's
FAVAIL33 = Fuel availability for EV technologies
BETAVP = Coefficient associated with vehicle price
VETAFC = Coefficient associated with fuel cost
BETAVR = Coefficient associated with vehicle range
BETAEM = Coefficient associated with vehicle emissions
BETAFA = Coefficient associated with fuel availability
BETAVR2 = Coefficient associated with the square of vehicle range
BETAEM2 = Coefficient associated with the square of vehicle emissions
BETAFA2 = Coefficient associated with the square of fuel availability

8) Exponentiate utility vector, and adjust by commercial availability factor:

$$EVC3_{IT,IS,IR,N} = EXP\left[VC3_{IT,IS,IR,N}\right] * COMAV_{IT,N} \tag{B-70}$$

where:

EVC3 = Exponentiated value of electric vehicle utility vector

9) Calculate electric vehicle market shares, by region:

$$APSHR33_{IS,IR,IT,N} = \frac{EVC3_{IT,IS,IR,N}}{\sum_{IT=7}^{10} EVC3_{IT,IS,IR,N}} \tag{B-71}$$

where:

APSHR33 = Relative market shares within the electric vehicle group

ALTERNATIVE FUEL VEHICLE MODEL Subroutine TALT2

1) Calculate weighted average characteristics of electric vehicles, and reconfigure technology indices to reflect the compression of four EV technologies into one prototype:

$$\Psi_{IS,IT,IR,N} = \sum_{IT=7}^{10} \Psi_{IS,IT,IR,N} \cdot APSHR33_{IS,IR,IT,N} \tag{B-72}$$

where:

Ψ = VPRICE3, VEMISS3, VRANGE3, COMAV, COPCOST, FAVAIL33, and BETACONST

2) Calculate utility for alternative fuel vehicles (IT = 3-13):

$$\begin{aligned} VC2_{IT,IR} = {} & BETACONST2_{IT} + BETAVP \cdot VPRICE2_{IS,IT,N} + BETAFC \cdot COPCOST2_{IT,IS,IR,N} \\ & + BETAVR \cdot VRANGE2_{IS,IT,N} + BETAVR2 \cdot VRANGE2^2_{IS,IT,N} + BETAEM \cdot EMISS2_{IS,IT,N} \\ & + BETAEM2 \cdot EMISS2^2_{IS,IT,N} + BETAFA \cdot FAVAIL22_{IT,IR,N} + BETAFA2 \cdot FAVAIL22^2_{IT,IR,N} \end{aligned} \tag{B-73}$$

where:

VC2 = Utility vector for alternative vehicles

BETACONST2 = Constant associated with each considered AFV technology

COPCOST2 = Fuel operating costs for alternative vehicles
VPRICE2 = Price of each considered AFV technology in 1990$
VRANGE2 = Vehicle range of the considered AFV technology
EMISS2 = AFV emissions levels relative to gasoline ICE's
FAVAIL22 = Alternative fuel availability

3) Exponentiate utility vector, and adjust by commercial availability factor:

$$EVC2_{IT,IS,IR,N} = EXP\left[VC2_{IT,IS,IR,N}\right] * COMAV_{IT,N} \tag{B-74}$$

where:

EVC2 = Exponentiated value of alternative vehicle utility vector

4) Calculate alternative vehicle market shares, by region:

$$APSHR22_{IS,IR,IT,N} = \frac{EVC2_{IT,IS,IR,N}}{\sum_{IT=3}^{13} EVC2_{IT,IS,IR,N}} \tag{B-75}$$

where:

APSHR22 = Relative market shares within the alternative vehicle group

ALTERNATIVE FUEL VEHICLE MODEL — Subroutine TALT1

1) Calculate weighted average characteristics of alternative vehicles, and reconfigure technology indices to reflect the compression of eleven alternative technologies into one prototype:

$$\Psi_{IS,IT,IR,N} = \sum_{IT=3}^{13} \Psi_{IS,IT,IR,N} \cdot APSHR22_{IS,IR,IT,N} \tag{B-76}$$

where:

Ψ = VPRICE2, VEMISS2, VRANGE2, COMAV, COPCOST2, FAVAIL22, and BETACONST2

2) Calculate utility for all vehicles (IT = 1-3):

$$\begin{aligned} VC1_{IT,IR} = \; & BETACONST1_{IT} + BETAVP \cdot VPRICE1_{IS,IT,N} + BETAFC \cdot COPCOST1_{IT,IS,IR,N} \\ & + BETAVR \cdot VRANGE1_{IS,IT,N} + BETAVR2 \cdot VRANGE1^2_{IS,IT,N} + BETAEM \cdot EMISS1_{IS,IT,N} \\ & + BETAEM2 \cdot EMISS1^2_{IS,IT,N} + BETAFA \cdot FAVAIL11_{IT,IR,N} + BETAFA2 \cdot FAVAIL11^2_{IT,IR,N} \end{aligned} \quad \text{(B-77)}$$

where:

VC1 = Utility vector for conventional and alternative vehicles
BETACONST1 = Constant associated with each considered technology
COPCOST1 = Fuel operating costs for conventional and alternative vehicles
VPRICE1 = Price of each considered technology in 1990$
VRANGE1 = Vehicle range of the considered technology
EMISS1 = Emissions levels relative to gasoline ICE's
FAVAIL11 = Fuel availability

3) Exponentiate utility vector, and adjust by commercial availability factor:

$$EVC1_{IT,IS,IR,N} = EXP\left[VC1_{IT,IS,IR,N}\right] * COMAV_{IT,N} \quad \text{(B-78)}$$

where:

EVC1 = Exponentiated value of vehicle utility vector

4) Calculate vehicle market shares, by region:

$$APSHR11_{IS,IR,IT,N} = \frac{EVC1_{IT,IS,IR,N}}{\sum_{IT=1}^{3} EVC1_{IT,IS,IR,N}} \quad \text{(B-79)}$$

where:

APSHR11 = Relative market shares of conventional and alternative vehicles

5) Expand market share estimates to generate absolute market shares for each of the sixteen conventional and alternative technologies:

a) For conventional vehicles (IT = 16,15; $IT1$ = 1,2):

$$APSHR44_{IS,IR,IT,N} = APSHR11_{IS,IR,IT1,N} * APSHR22_{IS,IR,IT2,N} \quad \text{(B-80)}$$

where:

APSHR44 = Absolute market share of technology IT

b) For non-electric alternative vehicles (IT = 1-6,11-14; $IT1$ = 3; $IT2$ = 5,6,3,4,8-13):

$$APSHR44_{IS,IR,IT,N} = APSHR11_{IS,IR,IT1,N} \quad \text{(B-81)}$$

c) For electric and electric hybrid vehicles (IT = 7-10; $IT1$ = 3; $IT2$ = 7; $IT3$ = 1-4):

$$APSHR44_{IS,IR,IT,N} = APSHR11_{IS,IR,IT1,N} * APSHR22_{IS,IR,IT2,N} * APSHR33_{IS,IR,IT3,N} \quad \text{(B-82)}$$

LIGHT DUTY VEHICLE FLEET MODULE

1) Calculate fleet acquisitions of cars and light trucks:

$$FLTSAL_{VT=1,ITY,T} = FLTCRAT * SQTRCARS_T * FLTCSHR_{ITY}$$

and: (B-83)

$$FLTSAL_{VT=2,ITY,T} = FLTTRAT * SQDTRUCKSL_T * FLTTSHR_{ITY}$$

where:

FLTSAL = Sales to fleets by vehicle and fleet type
FLTCRAT = Fraction of total car sales attributed to fleets
FLTTRAT = Fraction of total truck sales attributed to fleets
SQTRCARS = Total automobile sales in a given year
SQTRUCKSL = Total light truck sales in a given year
FLTCSHR = Fraction of fleet cars purchased by a given fleet type
FLTTSHR = Fraction of fleet trucks purchased by a given fleet type
VT = Index of vehicle type: 1 = cars, 2 = light trucks
ITY = Index of fleet type: 1 = business, 2 = government, 3 = utility

2) Determine total alternative fuel fleet vehicle sales, using either the market-driven or legislatively mandated values :

$$FLTALT_{VT,ITY,T} = MAX\left[\left(FLTSAL_{VT,ITY,T} * FLTAPSHR1_{ITY}\right), EPACT_{VT,ITY,T}\right] \quad \text{(B-84)}$$

where:

FLTALT = Number of AFV's purchased by each fleet type in a given year
FLTAPSHR1 = Fraction of each fleets' purchases which are AFV's, from historical data
EPACT = Legislative mandates for AFV purchases, by fleet type

3) Calculate the difference between total sales and AFV sales (representing conventional sales):

$$FLTCONV_{VT,ITY,T} = FLTSAL_{VT,ITY,T} - FLTALT_{VT,ITY,T} \quad \text{(B-85)}$$

where:

FLTCONV = Fleet purchases of conventional vehicles

4) Distribute fleet purchases among three size classes:

$$FLTSLSCA_{VT,ITY,IS,T} = FLTALT_{VT,ITY,T} * FLTSSHR_{VT,ITY,IS}$$

and: (B-86)

$$FLTSLSCC_{VT,ITY,IS,T} = FLTCONV_{VT,ITY,T} * FLTSSHR_{VT,ITY,IS}$$

where:

FLTSLSCA = Fleet purchases of AFV's, by size class
FLTSLSCC = Fleet purchases of conventional vehicles, by size class
FLTSSHR = Percentage of fleet vehicles in each size class, from historical data
IS = Index of size classes: 1 = small, 2 = medium, 3 = large

5) Disaggregate AFV sales by engine technology:

$$FLTECHSAL_{VT,ITY=1,IS,ITECH,T} = FLTSLSCA_{VT,ITY=1,IS,T} * APSHRFLTB_{VT,ITECH,ITY=1,T}$$

$$FLTECHSAL_{VT,ITY\neq 1,IS,ITECH,T} = FLTSLSCA_{VT,ITY\neq 1,IS,T} * FLTECHSHR_{ITECH,ITY,T}$$ (B-87)

and:

$$FLTECHSAL_{VT,ITY,IS,ITECH=6,T} = FLTSLSCC_{VT,ITY,IS,T}$$

where:

FLTECHSAL = Fleet sales by size, technology, and fleet type
APSHRFLTB = Alternative technology shares for the business fleet
FLTECHSHR = Alternative technology shares for the government and utility fleets
ITECH = Index of engine technologies: 1-5 = alternative fuels (neat), 6 = gasoline

6) Sum sales across size classes:

$$FLTECH_{VT,ITY,ITECH,T} = \sum_{IS=1}^{3} FLTECHSAL_{VT,ITY,IS,ITECH,T}$$ (B-88)

where:

FLTECH = Vehicle purchases by fleet type and technology

7) Calculate survival of older vehicles, and modify vintage array:

$$FLTSTKVN_{VT,ITY,ITECH,IVIN,T} = FLTSTKVN_{VT,ITY,ITECH,IVIN-1,T-1} * SURVFLTT_{VT,IVIN-1}$$

and:

$$FLTSTKVN_{VT,ITY,ITECH,IVIN=1,T} = FLTECH_{VT,ITY,ITECH,T} \tag{B-89}$$

where:

FLTSTKVN = Fleet stock by fleet type, technology, and vintage

SURVFLTT = Survival rate of a given vintage

8) Assign fleet vehicles of retirement vintage to another variable, prior to removal from the fleet:

$$OLDFSTK_{VT,ITY,ITECH,RVINT,T} = FLTSTKVN_{VT,ITY,ITECH,RVINT,T} \tag{B-90}$$

where:

OLDFSTK = Old fleet stocks of given types and vintages, transferred to the private sector

RVINT = Retirement vintage of fleet vehicles: If *VT* = 1, *ITY* = 1,2,3, *RVINT* = 5,6,7; If *VT* = 2, *ITY* = 1,2,3, *RVINT* = 6,7,6

9) Calculate total surviving vehicles, by vehicle, fleet type, and engine technology:

$$TFLTECHSTK_{VT,ITY,ITECH,T} = \sum_{IVIN=1}^{6} FLTSTKVN_{VT,ITY,ITECH,IVIN,T} \tag{B-91}$$

where:

TFLTECHSTK = Total stock within each technology and fleet type

10) Calculate grand total of surviving vehicles:

$$TOTFLTSTK_T = \sum_{VT=1}^{2} \sum_{ITY=1}^{3} \sum_{ITECH=1}^{6} TFLTECHSTK_{VT,ITY,ITECH,T} \tag{B-92}$$

where:

TOTFLTSTK = Total of all surviving fleet vehicles

11) Calculate percentage of fleet stock represented by each of the vehicle, fleet types, and engine technologies:

$$VFSTKPF_{VT,ITY,ITECH,T} = \frac{TFLTECHSTK_{VT,ITY,ITECH,T}}{TOTFLTSTK_T} \tag{B-93}$$

where:

VFSTKPF = Share of fleet stock by vehicle type and technology

LIGHT DUTY VEHICLE FLEET MODULE Subroutine TLEGIS

This subroutine adjusts vehicle sales and market shares to reflect California's legislative mandates on sales of zero-emission vehicles (ZEV's) and ultra-low emission vehicles (ULEV's), which have also been tentatively adopted by New York and Massachusetts.

1) Calculate regional vehicle sales, by technology, within three size classes:

$$VSALES_{IS,IR,IT,N} = \sum_{OSC} APSHR44_{IS,IR,IT,N} * \left(NCS_{IR,OSC,N} + NLTS_{IR,OSC,N}\right) \tag{B-94}$$

where:

VSALES = Total disaggregate vehicle sales
APSHR44 = Absolute market share of new vehicles, by region, size, and technology
IS = Index of reduced size class (1-3)
OSC = Index of original size class (1-6)
NCS = Regional new car sales within corresponding size classes OSC:
$IS = 1, OSC = 2,3;\ IS = 2, OSC = 1,6;\ IS = 3, OSC = 4,5$
NLTS = Regional new light truck sales within corresponding size classes OSC
$IS = 1, OSC = 1,2;\ IS = 2, OSC = 3,4;\ IS = 3, OSC = 5,6$

2) Calculate total regional sales of electric and electric hybrid vehicles:

$$ELECVSAL_{IR,N} = \sum_{IS=1}^{3} \sum_{IT=7}^{10} VSALES_{IS,IR,IT,N} \tag{B-95}$$

where:

ELECVSAL = Regional electric vehicle sales

3) Calculate total vehicle sales across all technologies:

$$VSALEST_{IS,IR,N} = \sum_{IT=1}^{16} VSALES_{IS,IR,IT,N} \tag{B-96}$$

where:

VSALEST = Total regional vehicle sales, by size class

4) Calculate mandated sales of ZEV's and ULEV's by participating state:

$$\begin{aligned} ZEVST_{ST,N} = \big(&TMC\_SQTRCARS_N * STATESHR_{ST,VT=1,N} \\ &+ TMC\_SQDTRUCKSL_N * STATESHR_{ST,VT=2,N}\big) * ZEV_N \\ &\text{and} \\ ULEVST_{ST,N} = \big(&TMC\_SQTRCARS_N * STATESHR_{ST,VT=1,N} \\ &+ TMC\_SQDTRUCKSL_N * STATESHR_{ST,VT=2,N}\big) * ULEV_N \end{aligned} \tag{B-97}$$

where:

ZEVST = State-mandated minimum sales of ZEV's
ULEVST = State-mandated minimum sales of ULEV's
TMC_SQTRCARS = Total car sales, from the MACRO module
TMC_SQDTRUCKSL = Total light truck sales, from the MACRO module
STATESHR = Share of national vehicle sales attributed to a given state
ZEV = State-mandated minimum sales share of ZEV's
ULEV = State-mandated minimum sales share of ULEV's
ST = Index of participating state: CA, MA, NY
VT = Index of vehicle type: 1 = cars, 2 = light trucks

5) If mandated sales exceed actual sales, then adjust actual sales as follows:

a) Evenly distribute mandated sales among three size classes:

$$ZEVSTSC_{ST,IS,N} = \frac{ZEVST_{ST,N}}{3} \tag{B-98}$$

where:

ZEVSTSC = Mandated ZEV sales by size class and state

b) Evenly distribute actual electric vehicle sales among three size classes:

$$ELECVSALSC_{IR,IS,N} = \frac{ELECVSAL_{IR,N}}{3} \qquad \textbf{(B-99)}$$

where:

ELECVSALSC = Regional ZEV sales within corresponding regions

IR = Corresponding regions: ST = CA, MA, NY; IR = 9,1,2

c) Calculate mandated ZEV sales by EV technology (IT = 7-10):

$$AVSALES_{IS,IR,IT,N} = ZEVSTSC_{ST,IS,N} * APSHR33_{IS,IR,IT,N} \qquad \textbf{(B-100)}$$

where:

AVSALES = Regional adjusted vehicle sales by size class

APSHR33 = Relative market shares of electric vehicle technologies

d) Reduce sales of gasoline vehicles (IT = 16) to compensate for increased ZEV sales in the affected regions (IR = 1,2,9):

$$AVSALES_{IS,IR,IT=16,N} = VSALES_{IS,IR,IT=16,N} - \left(ZEVSTSC_{ST,IS,N} - ELECVSALSC_{IR,IS,N}\right) \qquad \textbf{(B-101)}$$

6) Reassign vehicle sales in unaffected regions ($IR \neq$ 1,2,9):

$$AVSALES_{IS,IR,IT,N} = VSALES_{IS,IR,IT,N} \qquad \textbf{(B-102)}$$

7) Sum adjusted vehicle sales across technologies:

$$AVSALEST_{IS,IR,N} = \sum_{IT=1}^{16} AVSALES_{IS,IR,IT,N} \qquad \textbf{(B-103)}$$

where:

AVSALEST = Total regional adjusted vehicle sales by size class

8) Calculate new absolute market shares for each vehicle technology:

$$APSHR55_{IS,IR,IT,N} = \frac{AVSALES_{IS,IR,IT,N}}{AVSALEST_{IS,IR,N}} \tag{B-104}$$

where:

APSHR55 = Absolute regional market shares of adjusted vehicle sales

9) Reset conventional vehicle market shares so that diesel represents 2.5% of conventional vehicle sales:

$$APSHR55_{IS,IR,IT=15,N} = \sum_{IT=15}^{16} APSHR55_{IS,IR,IT,N} * 0.025$$

and (B-105)

$$APSHR55_{IS,IR,IT=16,N} = \sum_{IT=15}^{16} APSHR55_{IS,IR,IT,N} * 0.975$$

10) Calculate new fleet market shares for use with business fleets:

a) Calculate total vehicle sales by technology:

$$VSALESC16_{IT,N} = \sum_{IR=1}^{9} \sum_{IS=1}^{3} APSHR55_{IS,IR,IT,N} * \left(\sum_{OSC} NCS_{IR,OSC,N} \right)$$

and (B-106)

$$VSALEST16_{IT,N} = \sum_{IR=1}^{9} \sum_{IS=1}^{3} APSHR55_{IS,IR,IT,N} * \left(\sum_{OSC} NLTS_{IR,OSC,N} \right)$$

where:

VSALESC16 = Total new car sales by technology:

$IS = 1,\ OSC = 2,3;\ \ IS = 2,\ OSC = 1,6;\ \ IS = 3,\ OSC = 4,5$

VSALEST16 = Total new light truck sales by technology

$IS = 1,\ OSC = 1,3;\ \ IS = 2,\ OSC = 2,5;\ \ IS = 3,\ OSC = 4,6$

b) Calculate market shares by technology:

$$APSHRNC_{IT,N} = \frac{VSALESC16_{IT,N}}{\sum_{IT=1}^{16} VSALESC16_{IT,N}}$$

and (B-107)

$$APSHRNT_{IT,N} = \frac{VSALEST16_{IT,N}}{\sum_{IT=1}^{16} VSALEST16_{IT,N}}$$

where:

APSHRNC = Market shares of new cars by technology

APSHRNT = Market shares of new light trucks by technology

c) Sum market shares for affected fleet technologies:

$$APSHRFLTOT_{VT=1,N} = \sum_{ITF} APSHRNC_{ITF,N}$$

and (B-108)

$$APSHRFLTOT_{VT=2,N} = \sum_{ITF} APSHRNT_{ITF,N}$$

where:

APSHRFLTOT = Aggregate market shares of fleet vehicle technologies

VT = Index of vehicle type: 1 = cars; 2 = light trucks

ITF = Index of fleet vehicle technologies, corresponding to IT = 3,5,7,8,9

d) Normalize business fleet market shares:

$$APSHRFLTB_{VT=1,ITF,N} = \frac{APSHRNC_{IT,N}}{APSHRFLTOT_{VT=1,N}}$$

and (B-109)

$$APSHRFLTB_{VT=2,ITF,N} = \frac{APSHRNT_{IT,N}}{APSHRFLTOT_{VT=2,N}}$$

where:

APSHRFLTB = Market shares of business fleet by vehicle type and technology

11) Reset new car and light truck sales using market shares, mapped from three to six size classes:

$$NCSTECH_{IR,OSC,IT,N} = NCS_{IR,OSC,N} * APSHR55_{IS,IR,IT,N}$$

and (B-110)

$$NLTECH_{IR,OSC,IT,N} = NLTS_{IR,OSC,N} * APSHR55_{IS,IR,IT,N}$$

where:

NCSTECH = Regional new car sales by technology, within six size classes: OSC = 1-6; IS = 2,1,1,3,3,2

NLTECH = Regional light truck sales by technology, with six size classes: OSC = 1-6; IS = 1,2,1,3,2,3

LIGHT DUTY VEHICLE FLEET MODULE — Subroutine TFLTVMTS

This subroutine calculates VMT for fleets.

1) Use historical data on fleet vehicle travel to estimate total fleet VMT:

$$FLTVMT_T = \sum_{VT=1}^{2} \sum_{ITY=1}^{3} \sum_{ITECH=1}^{6} \left(TFLTECHSTK_{VT,ITY,ITECH,T} * FLTVMTYR_{VT,ITY,T} \right) \tag{B-111}$$

where:

FLTVMT = Total VMT driven by fleet vehicles

FLTVMTYR = Annual miles of travel per vehicle, by vehicle and fleet type

VT = Index of vehicle type: 1 = cars, 2 = light trucks

ITY = Index of fleet type: Business, Government, Utility

$ITECH$ = Index of fleet engine technology, corresponding to IT = 3,5,9,7,8

2) Disaggregate total VMT by vehicle type and technology:

$$FLVMTECH_{VT,ITY,ITECH,T} = FLVMT_T * VFSTKPF_{VT,ITY,ITECH,T} \tag{B-112}$$

where:

FLTVMTECH = Fleet VMT by technology, vehicle type, and fleet type

VFSTKPF = Share of fleet stock by vehicle type and technology

This subroutine calculates fuel efficiency for the fleet stock

1) Calculate the average efficiencies of the five non-gasoline technologies (*ITECH* = 1-5):

$$FLTMPG_{VT=1,ITY,ITECH} = \left[\sum_{IS=1}^{3} \frac{FMSHC_{ITY,ITECH,IS}}{NAMPG_{IT,IS}} \right]^{-1}$$

and:

$$FLTMPG_{VT=2,ITY,ITECH} = \left[\sum_{IS=1}^{3} \frac{FMSHLT_{ITY,ITECH,IS}}{NAMPG_{IT,IS} * RATIO_{IS}} \right]^{-1} \qquad \text{(B-113)}$$

where:

FLTMPG = New fleet vehicle fuel efficiency, by fleet type and engine technology
FMSHC = The market share of fleet cars, from the AFV model
FMSHLT = The market share of fleet light trucks, from the AFV model
NAMPG = New AFV fuel efficiency, from the AFV model
IT = Index which matches technologies in the AFV model to corresponding *ITECH*:
ITECH = 1-5, *IT* = 4,2,7,5,6
IS = Index of reduced size class (1-3)
VT = Index of vehicle type: 1 = cars, 2 = light trucks

2) Calculate the average efficiencies of conventional vehicles:

$$FLTMPG_{VT=1,ITY,ITECH} = \left[\sum_{IS=1}^{3} \frac{FMSHC_{ITY,ITECH,IS}}{FEC3SC_{IS}} \right]^{-1}$$

and:

$$FLTMPG_{VT=2,ITY,ITECH} = \left[\sum_{IS=1}^{3} \frac{FMSHLT_{ITY,ITECH,IS}}{FET3SC_{IS}} \right]^{-1} \qquad \text{(B-114)}$$

where:

FEC3SC = New car MPG, by three size classes, from the FEM model
FET3SC = New light truck MPG, by three size classes, from the FEM model

3) Calculate the average fleet MPG for cars and light trucks:

$$FLTMPGTOT_{VT,T} = \left[\frac{\sum_{IS=1}^{3} \sum_{ITECH=1}^{6} \frac{FLTECH_{VT,IS,ITECH,N}}{FLTMPG_{VT,IS,ITECH,N}}}{\sum_{IS=1}^{3} \sum_{ITECH=1}^{6} FLTECH_{VT,IS,ITECH,N}} \right]^{-1} \tag{B-115}$$

where:

FLTMPGTOT = Overall fuel efficiency of new fleet cars and light trucks

4) Adjust vintage array of fleet stock efficiencies to account for new additions:

$$MPGFSTK_{VT,ITY,ITECH,IVIN,T} = MPGFSTK_{VT,ITY,ITECH,IVIN-1,T-1}$$

and:

$$MPGFSTK_{VT,ITY,ITECH,IVIN=1,T} = FLTMPG_{VT,ITY,ITECH,T} \tag{B-116}$$

where:

MPGFSTK = Fleet MPG by vehicle and fleet type, technology, and vintage

IVIN = Index of fleet vintages

5) Calculate average fuel efficiency by vehicle and fleet type:

$$MPGFLTSTK_{VT,ITY,ITECH,T} = \left[\sum_{IVIN=1}^{MAXVINT} \frac{\left(\frac{FLTSTKVN_{VT,ITY,ITECH,IVIN,T}}{MPGFSTK_{VT,ITY,ITECH,IVIN,T} * VDF_{VT}} \right)}{\left(TFLTECHSTK_{VT,ITY,ITECH,T} \right)} \right]^{-1} \tag{B-117}$$

where:

MPGFLTSTK = Fleet MPG by vehicle and fleet type, and technology, across vintages

MAXVINT = Maximum *IVIN* index associated with a given vehicle and fleet type

VDF = Vehicle degradation factor

TFLTECHSTK = Total fleet stocks by vehicle, fleet type, and technology

6) Calculate overall fleet average MPG for cars and light trucks:

$$FLTTOTMPG_{VT,T} = \left[\sum_{ITY=1}^{3} \sum_{ITECH=1}^{6} \frac{VFSTKPF_{VT,ITY,ITECH,T}}{MPGFLTSTK_{VT,ITY,ITECH,T}} \right]^{-1} \tag{B-118}$$

where:

FLTTOTMPG = Fleet vehicle average fuel efficiency for cars and light trucks

This subroutine calculates fuel consumption of fleet vehicles.

1) Calculate fuel consumption:

$$FLTLDVC_{VT,ITY,ITECH,T} = \frac{FLTVMTECH_{VT,ITY,ITECH,T}}{MPGFLTSTK_{VT,ITY,ITECH,T}} \tag{B-119}$$

where:

FLTLDVC = Fuel consumption by technology, vehicle and fleet type

2) Sum consumption across fleet types, and convert to Btu values:

$$FLTFCLDVBTU_{VT,ITECH,T} = \sum_{ITY=1}^{3} FLTLDVC_{VT,ITY,ITECH,T} * QBTU_{ITECH} \tag{B-120}$$

where:

FLTFCLDVBTU = Fuel consumption, in Btu, by vehicle type and technology

QBTU = Energy content, in Btu/Gal, of the fuel associated with each technology

Consumption by trucks and cars are added, and total consumption is subsequently divided among regions:

$$FLTFCLDVBTUR_{IR,ITECH,T} = \sum_{VT=1}^{2} FLTFCLDVBTU_{VT,ITECH,T} * RSHR_{IR,T} \tag{B-121}$$

where:

FLTFCLDVBTUR = Regional fuel consumption by fleet vehicles, by technology

RSHR = Regional VMT shares, from the Regional Sales Module

1) Calculate LCT sales:

$$LT\_CLTT_N = MC\_SQDTRUCKSL_N * LT10K * 1e^{6} \tag{B-122}$$

where:

LT_CLTT_N = Sales of light trucks less than 10,000 pounds
$MC\_SQTRUCKSL_N$ = Total sales of light trucks, from the Macro Model
LT10K = Fraction of Light Duty Trucks with a gross vehicle weight of less than 10,000 pounds

2) Divide LCT sales between 2-axle, 4-tire and other single-unit (OSU) trucks:

$$\begin{gathered} CLTSAL2A4T_N = LT\_CLTT_N * LT2A4 \\ \text{and} \\ CLTSALOSU_N = LT\_CLTT_N * LTOSU \end{gathered} \tag{B-123}$$

where:

LT2A4 = Fraction of new light trucks of the 2-axle, 4 tire configuration
LTOSU = Fraction of new light trucks of other configuration

3) Divide sales of both truck types into pickup and non-pickup styles for trucks between 8,500 and 10,000 pounds:

$$\begin{gathered} CLTSAL2A4TS_{istyl,N} = CLTSAL2A4T_N * LT2A4CLT_{istyl} \\ \text{and} \\ CLTSALOSUS_{istyl,N} = CLTSALOSU_N * LTOSUCLT_{istyl} \end{gathered} \tag{B-124}$$

where:

$LT2A4CLT_{istyl}$ = Fraction of 2-axle, 4-tire trucks between 8.5 and 10 thousand pounds, by style
$LTOSUCLT_{istyl}$ = Fraction of other single unit trucks between 8.5 and 10 thousand pounds, by style
istyl = Index of truck style: 1 = pickup, 2 = other

4) Allocate sales among the aggegate major-use groups:

$$CLTSAL_{is,istyl,isic,N} = CLTSAL2A4TS_{istyl,N} * CLTSICSHR_{is,istyl,isic} \quad for\ is = 1$$

$$and \qquad \text{(B-125)}$$

$$CLTSAL_{is,istyl,isic,N} = CLTSALOSUS_{istyl,N} * CLTSICSHR_{is,istyl,isic} \quad for\ is = 2$$

where:

CLTSICSHR = Share of LCT sales allocated to each major-use group, by truck type and style

is = Index of truck type: 1 = 2-axle, 4-tire; 2 = other single-unit truck

isic = Index of major use group: 1 = Agriculture; 2 = Mining; 3 = Construction; 4 = Trade: 5 = Utilities; 6 = Personal

5) Update LCT stocks to reflect survival curve and sales:

$$CLTSTK_{is,istyl,isic,N} = CLTSTK_{is,istyl,isic,N-1} * SURVCLT_{is} + CLTSAL_{is,istyl,isic,N} \qquad \text{(B-126)}$$

where:

CLTSTK = Light commercial truck stock

SURVCLT = Percentage of previous year's stock which gets carried over, by truck type

LIGHT COMMERCIAL TRUCK MODEL Subroutine TCLTVMT

6) Estimate the VMT demand for LCT's, by sector:

$$CLTVMT_{is,istyl,isic,N} = CLTVMT_{is,istyl,isic,N-1} * \left[\frac{CLTSIC_{isic,N}}{CLTSIC_{isic,N-1}} \right] \qquad \text{(B-127)}$$

where:

$CLTSIC_{isic}$ = Aggregate measures of industrial output for sectors 1-5; level of personal travel demand for sector 6.

7) Estimate new LCT fuel economy, assuming that growth from baseline (1992) values parallels that of other light-duty trucks:

$$NCLTMPG_{is,istyl,istc,N} = NCLTMPG_{is,istyl,istc,N-1} * \left[\frac{MPGT_N}{MPGT_{N-1}} \right] \quad \text{(B-128)}$$

where:

MPGT = Light-duty truck miles per gallon (gasoline technology), from the LDV Stock Module

8) Incorporate new LCT estimates into existing stock:

$$CLTMPG_{is,istyl,istc,N} = \left[\frac{\left\{ \left(\frac{CLTSTK_{is,istyl,istc,N-1} * SURVCLT_{is}}{CLTMPG_{is,istyl,istc,N-1}} \right) + \left(\frac{CLTSAL_{is,istyl,istc,N-1}}{NCLTMPG_{is,istyl,istc,N-1}} \right) * LTDFRFG_N \right\}}{CLTSTK_{is,istyl,istc,N}} \right]^{-1} \quad \text{(B-129)}$$

where:

CLTMPG = Stock MPG of light commercial trucks, by truck type and style

LTDFRFG = Scaling factor, associated with the increased use of reformulated gasoline

9) Calculate aggregate sales-weighted new LCT MPG:

$$NCLTMPGT_N = \left[\sum_{is} \sum_{istyl} \sum_{istc} \left\{ \frac{\left(\frac{CLTSAL_{is,istyl,istc,N}}{\sum_{is} \sum_{istyl} \sum_{istc} CLTSAL_{is,istyl,istc,N}} \right)}{NCLTMPG_{is,istyl,istc,N}} \right\} \right]^{-1} \quad \text{(B-130)}$$

10) Calculate VMT-weighted stock average MPG for light commercial trucks:

$$CLTMPGT_N = \left[\sum_{is} \sum_{istyl} \sum_{istc} \left\{ \frac{\left(\frac{CLTVMT_{is,istyl,istc,N}}{\sum_{is} \sum_{istyl} \sum_{istc} CLTVMT_{is,istyl,istc,N} * 1e^9} \right)}{CLTMPG_{is,istyl,istc,N}} \right\} \right]^{-1} \quad \text{(B-131)}$$

11) Calculate fuel consumption in gallons and Btu's for each truck type, style, and major-use category:

$$CLTGAL_{is,istyl,istc,N} = \frac{CLTVMT_{is,istyl,istc,N}}{CLTMPG_{is,istyl,istc,N}}$$

and (B-132)

$$CLTBTU_{is,istyl,istc,N} = CLTGAL_{is,istyl,istc,N} * \frac{5.253}{42}$$

12) Calculate total Btu consumption by light commercial trucks, by summing over the indices:

$$CLTBTUT_N = \sum_{is} \sum_{istyl} \sum_{istc} CLTBTU_{is,istyl,istc,N} \qquad \text{(B-133)}$$

LIGHT DUTY VEHICLE STOCK ACCOUNTING MODEL Subroutine TSMOD

1) Sum across size classes and regions to obtain vehicle sales by technology:

$$TECHNCS_{IT,T} = \sum_{OSC=1}^{6} \sum_{IR=1}^{9} NCSTECH_{IR,OSC,IT,T}$$

and: (B-134)

$$TECHNLT_{IT,T} = \sum_{OSC=1}^{6} \sum_{IR=1}^{9} NLTECH_{IR,OSC,IT,T}$$

where:

TECHNCS = Total new car sales, by technology
TECHNLT = Total new light truck sales, by technology
NCSTECH = New car sales, by region, size class, and technology, from the AFV Module
NLTECH = New light truck sales, by region, size class, and technology
OSC = Index of size class (1-6)
IR = Index of region (1-9)
IT = Index of vehicle technology (1-16)

2) These variables are assigned to the first vintages of the automobile and light truck stock arrays, and the population of subsequent vintages are calculated:

a) For $VINT = 2\text{-}9$:

$$PASSTK_{IT,VINT,T} = PASSTK_{IT,VINT-1,T-1} * SSURVP_{VINT-1}$$

and: (B-135)

$$LTSTK_{IT,VINT,T} = LTSTK_{IT,VINT-1,T-1} * SSURVLT_{VINT-1}$$

b) For $VINT = 10$:

$$PASSTK_{IT,VINT=10,T} = \left(PASSTK_{IT,VINT=9,T-1} * SSURVP_{VINT=9}\right) + \left(PASSTK_{IT,VINT=10,T-1} * SSURVP_{VINT=10}\right)$$

and: (B-136)

$$LTSTK_{IT,VINT=10,T} = \left(LTSTK_{IT,VINT=9,T-1} * SSURVLT_{VINT=10}\right) + \left(LTSTK_{IT,VINT=10,T-1} * SSURVLT_{VINT=10}\right)$$

where:

PASSTK = Surviving automobile stock, by technology and vintage
LTSTK = Surviving light truck stock, by technology and vintage
SSURVP = Fraction of a given vintage's automobiles which survive
SSURVLT = Fraction of a given vintage's light trucks which survive
VINT = Index of vehicle vintage (1-10)

3) Add retired fleet vehicles to the appropriate vintage of the non-fleet population:

$$PASSTK_{IT,TVINT} = PASSTK_{IT,TVINT} + OLDFSTK_{VT=1,TYPE,ITECH,TVINT}$$

and: (B-137)

$$LTSTK_{IT,TVINT} = LTSTK_{IT,TVINT} + OLDFSTK_{VT=2,TYPE,ITECH,TVINT}$$

where:

OLTFSTK = Number of fleet vehicles rolled over into corresponding private categories
TVINT = Transition vintage: vintage at which vehicles of a given type are transferred
TYPE = Type of fleet vehicle: Business, Government, or Utility
ITECH = Index for the six fleet vehicle technologies: mapped to corresponding *IT* index

4) Sum over vintages and technologies to obtain total stocks of cars and light trucks:

$$STKCAR_T = \sum_{VINT=1}^{10} \sum_{IT=1}^{16} PASSTK_{IT,VINT,T}$$

and: (B-138)

$$STKTR_T = \sum_{VINT=1}^{10} \sum_{IT=1}^{16} LTSTK_{IT,VINT,T}$$

where:

STKCAR = Total stock of non-fleet automobiles in year T

STKTR = Total stock of non-fleet light trucks in year T

5) Calculate LDV shares of each technology:

$$VSPLDV_{IT,T} = \frac{\sum_{VINT=1}^{10} \left(PASSTK_{IT,VINT,T} + LTSTK_{IT,VINT,T}\right)}{STKCAR_T + STKTR_T} \tag{B-139}$$

where:

VSPLDV = The light duty vehicle shares of each of the sixteen vehicle technologies

LIGHT DUTY VEHICLE STOCK ACCOUNTING MODEL Subroutine TMPGSTK

1) Map non-gasoline vehicle sales from six to three size classes (IT = 1-15):

$$NCS3A_{IS,IT,T} = \sum_{OSC} \sum_{IR=1}^{9} NCSTECH_{IR,OSC,IT,T}$$

and

$$NLT3A_{IS,IT,T} = \sum_{OSC} \sum_{IR=1}^{9} NLTECH_{IR,OSC,IT,T} \tag{B-140}$$

where:

NCS3A = New car sales by reduced size class and engine technology:
$IS = 1, OSC = 1,6;\ IS = 2, OSC = 2,3;\ IS = 3, OSC = 4,5$

NLT3A = New light truck sales by reduced size class and technolgy:
$IS = 1, OSC = 1,3;\ IS = 2. OSC = 2,5;\ IS = 3, OSC = 4,6$

NCSTECH = New car sales by region, technology, and six size classes

NLTECH = New light truck sales by region, technology, and six size classes

2) Calculate total regional sales of vehicles by reduced size class:

$$NCSR_{IR,IS,T} = \sum_{OSC} NCS_{IR,OSC,T}$$

and (B-141)

$$NLTSR_{IR,IS,T} = \sum_{OSC} NLTS_{IR,OSC,T}$$

where:

NCSR = Regional new car sales by reduced size class

NLTSR = Regional new light truck sales by reduced size class

3) Sum across regions:

$$NCS3SC_{IS,T} = \sum_{IR=1}^{9} NCSR_{IR,IS,T}$$

and (B-142)

$$NLTS3SC_{IS,T} = \sum_{IR=1}^{9} NLTSR_{IR,IS,T}$$

where:

NCS3SC = Total new car sales by reduced size class

NLTS3SC = Total new light truck sales by reduced size class

4) Sum conventional vehicle sales across regions:

$$NNCSCA_{OSC,T} = \sum_{IR=1}^{9} NCSTECH_{IR,OSC,IT=16,T}$$

and (B-143)

$$NNLTCA_{OSC,T} = \sum_{IR=1}^{9} NLTECH_{IR,OSC,IT=16,T}$$

where:

NNCSCA = New conventional car sales by six size classes

NNLTCA = New conventional light truck sales by six size classes

5) Calculate average MPG within reduced size classes:

$$AMPGC_{IS,T} = \sum_{OSC} \frac{NCMPG_{VT=1,OSC,T}}{2}$$

and (B-144)

$$AMPGT_{IS,T} = \sum_{OSC} \frac{NCMPG_{VT=2,OSC,T}}{2}$$

where:

AMPGC = Average new car MPG mapped from six to three size classes:
$IS = 1, OSC = 2,3;\ IS = 2, OSC = 1,6;\ IS = 3, OSC = 4,5$

AMPGT = Average new truck MPG mapped from six to three size classes:
$IS = 1, OSC = 1,3;\ IS = 2, OSC = 2,5;\ IS = 3, OSC = 4,6$

VT = Index of vehicle type: 1 = cars, 2 = light trucks

6) Calculate ratio of truck to car MPG by size class:

$$RATIO_{IS,T} = \frac{AMPGT_{IS,T}}{AMPGC_{IS,T}} \qquad \text{(B-145)}$$

where:

RATIO = Light truck MPG adjustment factor

7) Calculate the average efficiencies of the fifteen non-gasoline technologies:

$$MPGC_{IT,T} = \left[\frac{\displaystyle\sum_{IS=1}^{3} \frac{NCS3A_{IS,IT,T}}{NAMPG_{IT,IS,T}}}{\displaystyle\sum_{IS=1}^{3} NCS3A_{IS,IT,T}} \right]^{-1}$$

and: (B-146)

$$MPGT_{IT,T} = \left[\frac{\displaystyle\sum_{IS=1}^{3} \frac{NLT3A_{IS,IT,T}}{NAMPG_{IT,IS,T} * RATIO_{IS,T}}}{\displaystyle\sum_{IS=1}^{3} NLT3A_{IS,IT,T}} \right]^{-1}$$

where:

MPGC = New car fuel efficiency, by engine technology

MPGT = New light truck fuel efficiency, by engine technology

NAMPG = New AFV fuel efficiency, from the AFV model

8) Calculate new vehicle MPG for gasoline ICE's ($IT = 16$):

$$MPGC_{IT=16,T} = \left[\frac{\sum_{OSC=1}^{6} \frac{NNCSCA_{OSC,T}}{NCMPG_{OSC,T}}}{\sum_{OSC=1}^{6} NNCSCA_{OSC,T}} \right]^{-1}$$

and:

$$MPGT_{IT=16,T} = \left[\frac{\sum_{OSC=1}^{6} \frac{NNLTCA_{OSC,T}}{NLTMPG_{OSC,T}}}{\sum_{OSC=1}^{6} NNLTCA_{OSC,T}} \right]^{-1} \qquad \text{(B-147)}$$

where:

NCMPG = New car MPG, from the FEM model

NLTMPG = New light truck MPG, from the FEM model

9) Calculate average fuel efficiency across all technologies for cars and light trucks:

$$ANCMPG_{T} = \left[\sum_{IT=1}^{16} \frac{APSHRNC_{IT,T}}{MPGC_{IT,T}} \right]^{-1}$$

and:

$$ANTMPG_{T} = \left[\sum_{IT=1}^{16} \frac{APSHRNT_{IT,T}}{MPGT_{IT,T}} \right]^{-1} \qquad \text{(B-148)}$$

where:

ANCMPG = Average new car MPG

ANTMPG = Average new light truck MPG

APSHRNC = Absolute market share of new cars, by technology, from the AFV model

APSHRNT = Absolute market share of new light trucks, by technology, from the AFV model

10) Calculate total miles driven by each type of vehicle:

$$TOTMICT_T = \sum_{IT=1}^{16} \sum_{IV=1}^{10} PASSTK_{IT,IV,T} * PVMT_{IV}$$

and: (B-149)

$$TOTMITT_T = \sum_{IT=1}^{16} \sum_{IV=1}^{10} LTSTK_{IT,IV,T} * LVMT_{IV}$$

where:

TOTMICT = Total miles driven by cars
TOTMITT = Total miles driven by light trucks
PVMT = Average automobile VMT, by vintage, from RTECS
LVMT = Average light truck VMT, by vintage, from RTECS

11) Calculate total energy consumption:

$$CMPGT_T = \sum_{IT=1}^{16} \sum_{IV=1}^{10} \frac{PASSTK_{IT,IV,T} * PVMT_{IV}}{CMPGSTK_{IT,IV,T} * VDF_{VT=1}}$$

and: (B-150)

$$TMPGT_T = \sum_{IT=1}^{16} \sum_{IV=1}^{10} \frac{LTSTK_{IT,IV,T} * LVMT_{IV}}{TTMPGSTK_{IT,IV,T} * VDF_{VT=2}}$$

where:

CMPGT = Automobile stock MPG
TMPGT = Light truck stock MPG
CMPGSTK = Automobile stock MPG, by vintage and technology
TTMPGSTK = Light truck stock MPG, by vintage and technology
VDF = Vehicle fuel efficiency degradation factor: $VT = 1$ for cars, $VT = 2$ for trucks

12) Calculate stock fuel efficiency:

$$SCMPG_T = \frac{TOTMICT_T}{CMPGT_T}$$

and: (B-151)

$$STMPG_T = \frac{TOTMITT_T}{TMPGT_T}$$

where:

SCMPG = Stock MPG for automobiles
STMPG = Stock MPG for light trucks

13) Calculate average fuel efficiency of light duty vehicles:

$$MPGFLT_T = \frac{TOTMICT_T + TOTMITT_T}{CMPGT_T + TMPGT_T} \quad \text{(B-152)}$$

where:

MPGFLT = Stock MPG for all light duty vehicles

14) Calculate average fuel efficiency by technology:

$$MPGTECH_{IT,X} = \frac{\sum_{IV=1}^{10} \frac{PASSTK_{IT,IV,T} * PVMT_{IV}}{CMPGSTK_{IT,IV,T} * VDF_{VT=1}} + \sum_{IV=1}^{10} \frac{LTSTK_{IT,IV,T} * LVMT_{IV}}{TTMPGSTK_{IT,IV,T} * VDF_{VT=2}}}{TOTMICT_T + TOTMITT_T} \quad \text{(B-153)}$$

where:

MPGTECH = Average stock MPG by technology

1) Calculate the cost of driving per mile:

$$COSTMI_T = \frac{TPMGTR_T * 0.125}{MPGFLT_T} \qquad \text{(B-154)}$$

where:

COSTMI = Cost of driving per mile
TPMGTR = Price of motor gasoline
MPGFLT = Fuel economy of the automobile fleet
0.125 = Conversion factor for gasoline, in MMBtu/gallon

2) Calculate per capita income:

$$INCOME_T = \frac{TMC\_YD_T}{TMC\_POPAFO_T} \qquad \text{(B-155)}$$

where:

INCOME = Per capita disposable personal income
TMC_YD = Total disposable personal income, from MACRO module
TMC_POPAFO = Total population, from MACRO module

3) Calculate unadjusted VMT per capita:

$$\begin{aligned} VMT16_T = {} & RHO \cdot VMTPC_{T-1} + ALPHA\,(1 - RHO) \\ & - BETAPE\,(COSTMI_T - RHO \cdot COSTMI_{T-1}) \\ & + BETAIE\,(INCOME_T - RHO \cdot INCOME_{T-1}) \\ & + BETADEM\,(PrFem_T - RHO \cdot PrFem_{T-1}) \end{aligned} \qquad \text{(B-156)}$$

where:

VMT16 = Per capita VMT for persons 16 and older
ALPHA = Constant parameter for the VMT difference equation
BETAPE = Parameter associated with the cost of driving
BETAIE = Parameter associated with disposable persoal income
BETADEM = Parameter associated with demographic influences

PrFem = Ratio of per capita female driving to per capita male driving.
RHO = Lag factor, estimated using the Cochrane-Orcutt iterative procedure to be 0.72.

4) Calculate adjusted VMT per capita:

$$ADJVMTPC_T = VMT16_T \cdot DAF_T \tag{B-157}$$

where:

ADJVMTPC = Demographically-adjusted per capita VMT
DAF = Demographic adjustment factor

5) Calculate total VMT:

$$VMTLDV_T = ADJVMTPC_T * TMC\_POP16_T \tag{B-158}$$

where:

VMTLDV = Total VMT for light duty vehicles

6) Calculate net VMT, subtracting off fleet and light truck freight VMT:

$$VMTEE_T = VMTLDV_T - \left(FLTVMT_T + FVMTSC_{IS=1,T}\right) \tag{B-159}$$

where:

VMTEE = VMT for personal travel
FLTVMT = Fleet VMT
FVMTSC = Freight VMT by size class

7) Calculate VMT by technology:

$$VMTECH_{IT,T} = VMTEE_T * VSPLDV_{IT,T} \tag{B-160}$$

where:

VMTECH = Personal travel VMT by technology
VSPLDV = Sales shares of vehicles by technology

8) Calculate fractional change of VMT:

$$XLDVMT_T = \frac{VMTEE_T}{VMTEE_{T=1}} \tag{B-161}$$

where:

XLDVMT = Fractional change of VMT over base year (1990)

VEHICLE MILES TRAVELED MODEL Subroutine TFREISMOD

1) Calculate light truck sales dedicated to freight:

$$TRSAL_T = 0.408427 * TMC\_SQDTRUCKSL_T \tag{B-162}$$

where:

TRSAL = Light truck sales for freight
TMC_SQDTRUCKSL = Total light truck sales, from MACRO module

2) Calculate sales by technology:

$$TRSALTECH_{IT,T} = TRSAL_T * FLVMTSHR_{IS=1,IT,T} \tag{B-163}$$

where:

TRSALTECH = Light truck sales by technology
FLVMTSHR = VMT-weighted shares by size class and technology

3) Add to vintage array and adjust stock survival:

$$\begin{gathered} TRSTKTECH_{IT,IV=1,T} = TRSALTECH_{IT,T} \\ TRSTKTECH_{IT,IV,T} = TRSTKTECH_{IT,IV-1,T-1} * SSURVLT_{IV-1} \quad ; \quad IV = 2-9 \\ \text{and} \\ TRSTKTECH_{IT,IV=10,T} = \left(TRSTKTECH_{IT,IV=9,T-1} * SSURVLT_{IV=9}\right) \\ + \left(TRSTKTECH_{IT,IV=10,T-1} * SSURVLT_{IV=10}\right) \end{gathered} \tag{B-164}$$

where:

TRSTKTECH = Light truck stock by technology

SSURVLT = Array of survival rates for light trucks

4) Sum over vintages:

$$TRSTKTOT_{IT,T} = \sum_{IV=1}^{10} TRSTKTECH_{IT,IV,T} \tag{B-165}$$

where:

TRSTKTOT = Total light truck stock by technology

5) Sum over technologies:

$$TRSTK_{T} = \sum_{IT=1}^{5} TRSTKTOT_{IT,T} \tag{B-166}$$

where:

TRSTK = Total light truck stock

6) Calculate average MPG for light trucks:

$$TRFLTMPG_{T} = \left[\frac{\sum_{IT=1}^{5} \left(\frac{TRSTKTOT_{IT,T}}{FMPG_{IS=1,IT,T}} \right)}{\sum_{IT=1}^{5} TRSTKTOT_{IT,T}} \right]^{-1} \tag{B-167}$$

where:

TRFLTMPG = Average light truck MPG

This subroutine calculates aggregate fuel efficiencies for cars and light trucks.

1) Sum fleet vehicle sales over size class:

$$FLTECHSALT_{VT,ITY,ITECH,T} = \sum_{IS=1}^{3} FLTECHSAL_{VT,ITY,IS,ITECH,T} \qquad \text{(B-168)}$$

where:

FLTECHSALT = Vehicle purchases by fleet type and technolgy
FLTECHSAL = Fleet sales by size, technology, and fleet type
VT = Index of vehicle type: 1 = cars. 2 = light trucks
$ITECH$ = Index of engine technology (1-6)
ITY = Index of fleet type: Business, Government, Utility
IS = Index of size class (1-3)

2) Calculate new vehicle MPG:

$$FLTMPGNEW_{VT,ITECH,T} = \left[\frac{\sum_{ITY=1}^{3} \frac{FLTECHSALT_{VT,ITY,ITECH,T}}{FLTMPG_{VT,ITY,ITECH,T}}}{\sum_{ITY=1}^{3} FLTECHSALT_{VT,ITY,ITECH,T}} \right]^{-1} \qquad \text{(B-169)}$$

where:

FLTMPGNEW = New fleet vehicle MPG by vehicle type and technology
FLTMPG = Fleet vehicle MPG by vehicle type. size class, and technology

3) Sum fleet stock across fleet types:

$$FLTSTOCK_{VT,ITECH,T} = \sum_{ITY=1}^{3} FLTECHSTK_{VT,ITY,ITECH,T} \qquad \text{(B-170)}$$

where:

FLTSTOCK = Total fleet vehicle stock. by technology
FLTECHSTK = Total fleet vehicle stock, by technology and fleet type

4) Calculate average MPG of fleet and non-fleet vehicles, by technology:

a) For cars:

$$CCMPGLDV_{IT,T} = \left[\frac{\left(\dfrac{TECHNCS_{IT,T}}{MPGC_{IT,T}} \right) + \left(\dfrac{FLTSTOCK_{VT=1,ITECH,T}}{FLTMPGNEW_{VT=1,ITECH,T}} \right)}{TECHNCS_{IT,T} + FLTSTOCK_{VT=1,ITECH,T}} \right]^{-1} \tag{B-171}$$

where:

CCMPGLDV = New car MPG, by technology *IT*
IT = Index of vehicle technology (1-16)
ITECH = Index of fleet vehicle technologies which correspond to the *IT* index
TECHNCS = Non-fleet new car sales, by technology *IT*
MPGC = New car MPG, by technology *IT*
FLTSTOCK = New fleet stock, by vehicle type and technology *ITECH*
FLTMPGNEW = New fleet vehicle MPG, by vehicle type and technology *ITECH*

b) For light trucks:

$$TTMPGLDV_{IT,T} = \left[\frac{\left(\dfrac{TECHNLT_{IT,T}}{MPGT_{IT,T}} \right) + \left(\dfrac{FLTSTOCK_{VT=2,ITECH,T}}{FLTMPGNEW_{VT=2,ITECH,T}} \right)}{TECHNLT_{IT,T} + FLTSTOCK_{VT=2,ITECH,T}} \right]^{-1} \tag{B-172}$$

where:

TTMPGLDV = New light truck MPG, by technology *IT*
TECHNLT = Non-fleet new light truck sales, by technology *IT*
MPGT = New light truck MPG, by technology *IT*

5) Calculate total stock by vehicle type and technology:

$$STOCKLDV_{VT,IT2,T} = STKCT_{VT,IT,T} + FLTSTOCK_{VT,ITECH,T} \tag{B-173}$$

where:

STOCKLDV = Total stock of fleet and non-fleet vehicles, by technology
STKCT = Stock of non-fleet vehicles, by technology
IT = Index of vehicle technology (1-16)
IT2 = Reassigned indices of vehicle technology *IT2* = 1-16; *IT* = 16,15,1-14

$ITECH$ = Index of fleet technologies which map to corresponding IT and $IT2$ as follows:
$IT2$ = 1,3,5,7,8,9; IT = 16,1,3,5,6,7; $ITECH$ = 6,1,2,3,4,5

6) Calculate total stock across technologies:

$$TSTOCKLDV_{VT,T} = \sum_{IT2=1}^{16} STOCKLDV_{VT,IT2,T} \tag{B-174}$$

where:

TSTOCKLDV = Total stock by vehicle type VT

7) Calculate average MPG of cars and light trucks:

$$TMPGLDVSTK_{VT=1,T} = \left[\frac{\sum_{IT2=1}^{16} \left(\frac{STOCKLDV_{VT=1,IT2,T}}{CCMPGLDV_{IT2,T}} \right)}{\sum_{IT2=1}^{16} STOCKLDV_{VT=1,IT2,T}} \right]^{-1}$$

and (B-175)

$$TMPGLDVSTK_{VT=2,T} = \left[\frac{\sum_{IT2=1}^{16} \left(\frac{STOCKLDV_{VT=2,IT2,T}}{TTMPGLDV_{IT2,T}} \right)}{\sum_{IT2=1}^{16} STOCKLDV_{VT=2,IT2,T}} \right]^{-1}$$

where:

TMPGLDVSTK = Average MPG by vehicle type VT

8) Calculate overall average MPG of light-duty vehicle fleet:

$$TLDVMPG_{T} = \left[\frac{\sum_{VT=1}^{2} \left(\frac{TSTOCKLDV_{VT,T}}{TMPGLDVSTK_{VT,T}} \right)}{\sum_{VT=1}^{2} TSTOCKLDV_{VT,T}} \right]^{-1} \tag{B-176}$$

where:

TLDVMPG = Average fuel economy of light-duty vehicles

HIGHWAY FREIGHT MODEL Subroutine TFREI

Estimate New Truck Fuel Economies

1) Calculate the average fuel price over the previous three years:

$$AVGPRC_{T,FUEL} = \frac{(PRICE_{T,FUEL} + PRICE_{T-1,FUEL} + PRICE_{T-2,FUEL})}{3} \quad \textbf{(B-177)}$$

where:

T = Index referring to model run year; where $T = 0,...,23$
$FUEL$ = Index referring to fuel type, where $FUEL = 1$ refers to diesel, $FUEL = 2$ refers to gasoline. $FUEL = 3$ refers to LPG and $FUEL = 4$ refers to CNG
AVGPRC = Average price of fuel $FUEL$ over three year period, in \$ per MBtu
PRICE = Price of each fuel, in \$ per MBtu

2) If the technology has not yet entered market and the average price is greater than the technology's trigger price, the technology enters the market during the current year:

$$\begin{gathered} For\ TECH = 6,...,16 \\ If \quad AVGPRC_{T,FUEL} \geq TRIGPRC_{SC,FUEL,TECH} \\ \downarrow \\ INITYR_{SC,FUEL,TECH} = T \end{gathered} \quad \textbf{(B-178)}$$

where:

$TECH$ = Index referring to fuel-saving technologies, where $TECH = 1,...,5$ refers to currently available technologies and $TECH = 6,...,16$ refers to future technologies
SC = Index referring to truck size class, where $SC = 2$ refers to medium trucks and $SC = 3$ refers to heavy trucks
INITYR = Year in which technology $TECH$ enters market
TRIGPRC = Exogenously determined fuel price at which technology $TECH$ becomes economically viable

3) If a future technology enters market in the current year, coefficients for the logistic market penetration curve are determined:

$$COEFT_{SC,FUEL,TECH} = \frac{\ln(0.01)}{\left[\frac{CYCLE_{SC,FUEL,TECH}}{2}\right]}$$

and

$$MIDYR_{SC,FUEL,TECH} = INITYR_{SC,FUEL,TECH} + \left[\frac{CYCLE_{SC,FUEL,TECH}}{2}\right] \quad \text{(B-179)}$$

where:

COEFT = Endogenously determined logistic market penetration curve parameter
CYCLE = Exogenously determined logistic market penetration curve parameter representing number of years until 99 percent of maximum market penetration
MIDYR = Endogenously determined logistic market penetration curve parameter

4) For each technology which has entered the market, and for existing technologies, the effect of fuel prices on market penetration is determined for the current year:

$$PREFF_{T,SC,FUEL,TECH} = 1 + PRCVAR_{SC,FUEL,TECH} \cdot \left[\frac{AVGPRC_{T,FUEL}}{TRIGPRC_{SC,FUEL,TECH}} - 1\right] \quad \text{(B-180)}$$

where:

PREFF = Effect of fuel price on market penetration rates for six fuel-saving technologies
PRCVAR = Exogenously determined fuel price sensitivity parameter for each technology, representing percent increase in technology market share if fuel price exceeds trigger price by 100%

5) For each available technology, including existing technologies, the model determines its share of the available market in the current year:

$$\text{For } TECH = 1,\ldots,5$$

$$TECH_{T,SC,FUEL,TECH} = \min \left\{ PREFF_{T,SC,FUEL,TECH} \cdot \left[BSHRT_{SC,TECH} + \left(ESHRT_{SC,FUEL,TECH} - BSHRT_{SC,TECH} \right) \cdot \left(1 - e^{CONST_{SC,TECH} + COEFT_{SC,TECH} \cdot T} \right) \right] , 1 \right\} \tag{B-181}$$

$$\text{For } TECH = 6,\ldots,16$$

$$TECHSHR_{T,SC,FUEL,TECH} = \min \left\{ PREFF_{T,SC,FUEL,TECH} \cdot \frac{ESHRT_{SC,FUEL,TECH}}{1 + e^{COEFT_{SC,FUEL,TECH} \cdot \left(T - MDTR_{SC,FUEL,TECH} \right)}} , 1 \right\}$$

where:

- TECHSHR = Market share of fuel-saving technology *TECH* for size class *SC* and fuel type *FUEL*
- CONST = Exogenously determined market penetration curve parameter for existing technologies
- COEFT = Market penetration curve parameter; exogenous for existing technologies, endogenous for future technologies
- BSHRT = Exogenously determined market penetration curve parameter representing market share of existing technology *TECH* in 1992
- ESHRT = Exogenously determined market penetration curve parameter representing final market share of technology *TECH* if fuel price were always equal to trigger price

6) If a technology A is superseded by another mutually exclusive technology B at any time during the model run, technology A's market share must be adjusted to reflect the smaller pool of vehicles in its base market:

$$TECHSHR_{T,SC,FUEL,TECH} = \left(1 - SPRSDEFF_{T,SC,FUEL,TECH} \right) \cdot TECHSHR_{T,SC,FUEL,TECH} \tag{B-182}$$

where:

- SPRSDEFF = Superseding effect, equal to the market share of the superseding technology

7) Determine MPG effects:

$$MPGEFF_{T,SC,FUEL} = \prod_{TECH=1}^{16} \left(1 + MPGINCR_{SC,FUEL,TECH} \cdot TECHSHR_{T,SC,FUEL,TECH} \right) \tag{B-183}$$

where:

- MPGEFF = Total effect of all fuel-saving technologies on new truck fuel economy in year *T*
- MPGINCR = Exogenous factor representing percent improvement in fuel economy due to each technology

8) Fuel economy of new medium and heavy trucks can finally be determined:

$$MPG_{T,SC,AGE=0,FUEL} = BASEMPG_{SC,FUEL} \cdot MPGEFF_{T,SC,FUEL} \tag{B-184}$$

where:

BASEMPG = Fuel economy of new medium and heavy trucks with no fuel-saving technologies

Determine the Share of Each Fuel Type in Current Year's Class of New Trucks

9) Calculate the fuel cost per mile for trucks of each size class and fuel type:

$$FCOST_{T,SC,FUEL} = \frac{AVGPRC_{T,FUEL}}{MPG_{T,SC,FUEL}} \cdot HTRATE \tag{B-185}$$

where:

FCOST = Fuel cost of driving a truck of fuel type *FUEL*, in dollars per mile
HTRATE = Heat rate of gasoline, in million Btu per gallon

10) Calculate the fuel cost of driving diesel trucks relative to AFVs:

$$RCOST_{T,SC,FUEL} = 1 - \left[\frac{FCOST_{T,SC,FUEL}}{FCOST_{T,SC,FUEL=1}} - 1\right] \cdot PRCDIFFVAR_{SC,FUEL} \tag{B-186}$$

where:

RCOST = Fuel cost per mile of diesel relative to LPG and CNG
PRCDIFFVAR = Exogenously determined parameter representing inherent variation in AFV market share due to difference in fuel prices

11) Determine the market penetration curve parameters during a user-specified trigger year:

$$COEFAFV_{SC,FUEL,FLT} = \frac{\ln(0.01)}{\left[\frac{CYCAFV_{SC,FUEL,FLT}}{2}\right]}$$

$$and \tag{B-187}$$

$$MYRAFV_{SC,FUEL,FLT} = TRYRAFV_{SC,FUEL,FLT} + \frac{CYCAFV_{SC,FUEL,FLT}}{2}$$

where:

FLT = Index referring to fleet type, where $FLT = 1$ refers to trucks in fleets of nine or less and $FLT = 2$ refers to trucks in fleets of ten or more

COEFAFV = Endogenously determined logistic market penetration curve parameter

CYCAFV = Exogenously determined logistic market penetration curve parameter representing number of years until maximum market penetration

MYRAFV = Logistic market penetration curve parameter representing "halfway point" to maximum market penetration

TRYRAFV = Exogenously determined year in which each alternative fuel begins to increase in market share, due to EPACT or other factors

12) The AFV market trend is determined through a logistic function:

$$MPATH_{T,SC,FUEL,FLT} = RCOST_{T,SC,FUEL} \cdot \left[BSHRF_{SC,FUEL,FLT} + \frac{ESHRF_{SC,FUEL,FLT} - BSHRF_{SC,FUEL,FLT}}{1 + e^{COEFAFV_{SC,FUEL,FLT} \cdot (T - MYRAFV_{SC,FUEL,FLT})}} \right] \quad \text{(B-188)}$$

where:

BSHRF = Base year (1992) market share of each fuel type

ESHRF = Exogenously determined final market share of each fuel type

13) Forecast the share of diesel in conventional truck sales:

$$MPATH_{T,SC,FUEL=1,FLT} = BSHRF_{SC,FUEL,FLT} + \left[ESHRF_{SC,FUEL,FLT} - BSHRF_{SC,FUEL,FLT} \right] \cdot \left(1 - e^{CONSD_{SC,FLT} + COEFT_{SC,FLT} \cdot T} \right) \quad \text{(B-189)}$$

where:

CONSD = Exogenously determined market penetration curve parameter for diesel trucks

COEFD = Exogenously determined market penetration curve parameter for diesel trucks

14) The actual AFV market share is thus calculated as the maximum of historical and forecast shares:

$$FSHR_{T,SEC,SC,FUEL=3,4,FLT} = \max \left[BSEC_{SEC,SC,FUEL,FLT} , MPATH_{T,SC,FUEL,FLT} \right] \quad \text{(B-190)}$$

where:

BSEC = Exogenously determined base year (1992) share of alternative fuels in truck purchases

15) Diesel market share is calculated as the forecast share of diesel in conventional truck sales multiplied by the share occupied by conventional trucks:

$$FSHR_{T,SEC,SC,FUEL=1,FLT} = \left(1 - \sum_{FUEL=3}^{4} FSHR_{T,SEC,SC,FUEL,FLT}\right) \cdot \left(\min\left[MPATH_{T,SC,FUEL,FLT} \cdot BSECD_{SEC,SC,FLT}, 1\right]\right) \quad \text{(B-191)}$$

where:

BSECD = Exogenously determined parameter representing tendency of each sector to purchase diesel trucks

16) The remainder of truck purchases are assumed to be gasoline:

$$FSHR_{T,SEC,SC,FUEL=2,FLT} = 1 - \sum_{FUEL=1,3,4} FSHR_{T,SEC,SC,FUEL,FLT} \quad \text{(B-192)}$$

Determine Composition of Existing Truck Stock

17) Scrappage rates are applied to the current truck population:

$$TRKSTK_{T,SEC,SC,AGE,FUEL,FLT} = TRKSTK_{T-1,SEC,SC,AGE-1,FUEL,FLT} \cdot \left(1 - SCRAP_{SC,AGE-1}\right) \quad \text{(B-193)}$$

where:

TRKSTK = Stock of trucks in year T

SCRAP = Exogenously determined factor which consists of the percentage of trucks of each age which are scrapped each year

18) A number of trucks are transferred in each year from fleets of ten or more to fleets of nine or less. Transfers of conventional trucks are based on exogenously determined transfer rates:

$$TRF1_{T,SEC,SC,AGE,FUEL} = TRFRATE_{SC,AGE} \cdot TRKSTK_{T,SEC,SC,AGE,FUEL,FLT=2} \quad \text{(B-194)}$$

where:

TRF1 = Number of trucks transferred from fleet to non-fleet populations, if no restrictions are placed on the transfer of alternative-fuel trucks

TRFRATE = Exogenously determined parameter representing the percentage of trucks of each vintage to be transferred from fleets to non-fleets in each year

19) Restricted AFV transfers are calculated as follows:

$$TRF2_{T,SEC,SC,AGE,FUEL=3,4} = FSHR_{T,SEC,SC,FUEL,FLT=1} \cdot TRFRATE_{SC,AGE} \cdot \sum_{FUEL=1}^{4} TRKSTK_{T,SEC,SC,AGE,FUEL,FLT=1} \quad \text{(B-195)}$$

where:

TRF2 = Number of trucks transferred from fleet to non-fleet populations, if the fuel mix of fleet transfers is exactly the same as the fuel mix of new non-fleet purchases

20) Actual fleet transfers are then defined as the unrestricted fleet transfers as calculated in *TRF1* for conventional trucks, and the minimum of unrestricted and restricted transfers for AFVs:

$$TRF_{T,SEC,SC,AGE,FUEL=1,2} = TRF1_{T,SEC,SC,AGE,FUEL,FLT}$$

$$and \quad \text{(B-196)}$$

$$TRF_{T,SEC,SC,AGE,FUEL=3,4} = \min\left[TRF1_{T,SEC,SC,AGE,FUEL}, TRF2_{T,SEC,SC,AGE,FUEL}\right]$$

where:

TRF = Total number of trucks transferred from fleet to non-fleet populations

21) Allocate fleet transfers based on each sector's share of the total non-fleet truck population of each vintage of trucks:

$$TRFSHR_{T,SC,SEC} = \frac{\sum_{FUEL=1}^{4} \sum_{AGE=1}^{11} sUSUMTRKSTK_{T,SEC,SC,AGE,FUEL,FLT=1}}{\sum_{FUEL=1}^{4} \sum_{AGE=1}^{11} \sum_{SEC=1}^{12} TRKSTK_{T,SEC,SC,AGE,FUEL,FLT=1}} \quad \text{(B-197)}$$

where:

TRFSHR = Share of fleet transfers which goes to each sector

22) The new existing population of trucks is simply the existing population (after scrappage) modified by fleet transfers:

$$TRKSTK_{T,SEC,SC,AGE,FUEL,FLT=2} = TRKSTK_{T,SEC,SC,AGE,FUEL,FLT=2} - TRF_{T,SEC,SC,AGE,FUEL}$$

$$and \quad \text{(B-198)}$$

$$TRKSTK_{T,SEC,SC,AGE,FUEL,FLT=1} = TRKSTK_{T,SEC,SC,AGE,FUEL,FLT=1} + TRFSHR_{T,SEC,SC} \cdot \sum_{SEC=1}^{12} TRF_{T,SEC,SC,AGE,FUEL}$$

Calculate Purchases of New Trucks

23) Calculate index of average annual VMT per truck:

$$VMTTREND_{T,SC} = \frac{BSHRV_{SC} + \left(ESHRV_{SC} - BSHRV_{SC}\right) \cdot \left(1 - e^{CONSV_{SC} + COEFV_{SC} \cdot T}\right)}{BSHRV_{SC} + \left(ESHRV_{SC} - BSHRV_{SC}\right) \cdot \left(1 - e^{CONSV_{SC} + COEFV_{SC} \cdot 1992}\right)} \quad \text{(B-199)}$$

where:

VMTTREND = Index of average annual VMT per truck, where 1992 = 1
BSHRV = Exogenously determined VMT per vehicle increase factor representing minimum annual vehicle mileage
ESHRV = Exogenously determined VMT per vehicle increase factor representing maximum annual vehicle mileage
CONSV = Exogenously determined exponential VMT per vehicle increase factor
COEFV = Exogenously determined exponential VMT per vehicle increase factor

24) Calculate VMT per truck in each year:

$$ANNVMT_{T,SEC,SC,AGE,FUEL} = ANNVMTBASE_{T,SEC,SC,AGE,FUEL} \cdot VMTTREND_{T,SC} \quad \text{(B-200)}$$

where:

ANNVMT = Average annual VMT per vehicle by sector, size class, truck age and fuel type
ANNVMTBASE = Base year average annual VMT per vehicle by sector, size class, truck age and fuel type

25) Determine the VMT which can be provided by the current population of trucks in each sector:

$$VMTOLD_{T,SEC} = \sum_{FLT=1}^{2} \sum_{FUEL=1}^{16} \sum_{AGE=1}^{31} \sum_{SC=1}^{3} TRKSTK_{T,SEC,SC,AGE,FUEL,FLT} \cdot ANNVMT_{SEC,SC,AGE,FUEL} \quad \text{(B-201)}$$

where:

VMTOLD = VMT which can be provided by existing stock of trucks in each sector, after scrappage

26) Calculate the current year FAC as follows:

$$COEFFAC = \ln\left[\frac{9}{(T90 - T50)}\right]$$

$$and$$

$$FACTR_{T,SEC} = AFFACBASE_{SEC} + \frac{1 - FACBASE_{SEC}}{1 + e^{COEFFAC \cdot (T50 - T)}} \tag{B-202}$$

where:

COEFFAC = FAC decay parameter
T90 = User-specified year by which 90% of FAC decay is experienced
T50 = User-specified year by which 50% of FAC decay is experienced
FACTR = "Freight Adjustment Coefficient": factor relating growth in value added of sector *SEC* to growth in demand for freight truck VMT
FACBASE = Base year Freight Adjustment Coefficient

27) Calculate the actual VMT demand in each sector:

$$For\ T = 0$$

$$VMTDMD_{T,SEC} = VMTDMDBASE_{SEC} \cdot FACTR_{SEC} \cdot \frac{OUTPUT_{T,SEC}}{OUTPUT_{T-1,SEC}}$$

$$For\ T = 1-22$$

$$VMTDMD_{T,SEC} = VMTDMD_{T-1,SEC} \cdot FACTR_{SEC} \cdot \frac{OUTPUT_{T,SEC}}{OUTPUT_{T-1,SEC}} \tag{B-203}$$

where:

VMTDMD = Demand for freight travel by sector *SEC*, in year *T*
VMTDMDBASE = Demand for freight travel by sector *SEC*, in year 0
FACTR = "Freight Adjustment Coefficient": exogenously determined factor relating growth in value added of sector *SEC* to growth in demand for freight truck VMT

28) Calculate perceived VMT growth:

$$PVMTGROWTH_{T,SEC} = 0.5 \cdot \left[\frac{OUTPUT_{T,SEC}}{OUTPUT_{T-1,SEC}} - 1\right] + 0.5 \cdot \left[\frac{OUTPUT_{T-1,SEC}}{OUTPUT_{T-2,SEC}} - 1\right] \tag{B-204}$$

where:

PVMTGROWTH = Growth rate with which perceived demand for freight travel in year T is forecast by freight companies

29) Calculate perceived baselineVMT demand:

$$For\ T = 0$$

$$PVMTBASE_{T,SC} = 0.5 \cdot VMTDMDBASE_{SEC}$$

$$For\ T = 1-22 \tag{B-205}$$

$$PVMTBASE_{T,SC} = 0.5 \cdot VMTDMD_{T,SEC} + 0.25 \cdot VMTDMD_{T-1,SEC}$$

where:

PVMTBASE = Baseline from which perceived demand for freight travel in year T is calculated.

30) Calculate perceived VMT demand:

$$PVMTBASE_{T,SEC} = 0.5 \cdot VMTDMT_{T-1,SEC} + 0.25 \cdot VMTDMD_{T-2,SEC}$$

$$and \tag{B-206}$$

$$VMTDMD_{T,SEC} = 0.25 \cdot VMTDMD_{T,SEC} + PVMTBASE_{T,SEC} \cdot \left(1 + PVMTGROWTH_{T,SEC}\right) \cdot FACTR_{SE}$$

where:

PVMTBASE = Baseline from which perceived demand for freight travel in year T is forecast by freight companies

PVMTDMD = Perceived demand for freight travel in year T

31) Calculate perceived unmet VMT demand, which is provided by purchasing new trucks:

$$PVMTUNMET_{T,SEC} = PVMTDMT_{T,SEC} - VMTOLD_{T,SEC} \tag{B-207}$$

where:

PVMTUNMET = Difference between perceived VMT demand and demand which can be met by existing stock of trucks

32) Allocate unmet VMT demand among size classes and fleet types by means of constant size class and fleet type allocation factors.

$$PVMT_{T,SEC,SC,FLT=1} = MAX\left[PVMTUNMET_{T,SEC} \cdot VMTSCFAC_{SEC,SC} \cdot \left(1 - FLTSHR_{SEC,SC}\right), 0\right]$$
$$and \tag{B-208}$$
$$PVMT_{T,SEC,SC,FLT=2} = MAX\left[PVMTUNMET_{T,SEC} \cdot VMTSCFAC_{SEC,SC} \cdot FLTSHR_{SEC,SC}, 0\right]$$

where:

PVMT = Perceived demand for freight travel by new trucks of size class *SC* and fleet type *FLT* in sector *SEC*

VMTSCFAC = Exogenously determined parameter representing percentage of new truck sales which go to each size class *SC* in sector *SEC*

FLTSHR = Exogenous parameter representing percentage of new truck sales of each size class *SC* which go to fleets of ten or more in sector *SEC*

33) Calculate a fuel technology-weighted average annual VMT per vehicle of the current year's class of new fleet and non-fleet trucks:

$$PVN_{T,SEC,SC,FLT} = \sum_{FUEL=1}^{4} FSHR_{T,SEC,SC,FUEL,FLT} \cdot ANNVMT_{T,SEC,SC,AGE=0,FUEL} \tag{B-209}$$

where:

AGE = 0 refers to new trucks

PVN = Annual VMT per vehicle for new trucks in year *T*

34) Truck purchases are finally calculated as the perceived unmet VMT demand divided by VMT per truck, weighted by fuel type:

$$TRKSTK_{T,SEC,SC,AGE=0,FUEL,FLT} = \left[\frac{PVMT_{T,SEC,SC,FLT}}{PVN_{T,SEC,SC,FLT}}\right] \cdot FSHR_{T,SEC,SC,FUEL,FLT} \tag{B-210}$$

Calculate Fuel Consumption

35) Allocate actual VMT demand among truck types:

$$VMT_{T,SEC,SC,AGE,FUEL,FLT} = TRKSTK_{T,SEC,SC,AGE,FUEL,FLT} * ANNVMT_{T,SEC,SC,AGE,FUEL} * \left[\frac{\sum_{SEC=1}^{12} VMTDMD_{T,SEC}}{\sum_{SEC=1}^{12} PVMTDMD_{T,SEC}} \right] \quad \text{(B-211)}$$

where:

VMT = Actual VMT by trucks of each type in year T

36) Reduce the light-duty vehicle degradation calculated in FEM to reflect the higher percentage of highway miles driven by freight trucks:

$$MPGDEGFAC_{T,SC} = \frac{1 - \left[\left(1 - MPGDEGFAC_{T,LDV}\right) * \frac{URBANSHR_{SC}}{URBSHRLDV} \right]}{1 - \left[\left(1 - MPGDEGFAC_{T=0,LDV}\right) * \frac{URBANSHR_{SC}}{URBSHRLDV} \right]} \quad \text{(B-212)}$$

where:

$MPGDEGFAC_{LDV}$ = Fuel economy degradation factor, from LDV Module
MPGDEGFAC = Fuel economy degradation factor for freight trucks
URBANSHR = % of miles driven in urban areas by trucks of each size class in base year (1992)
URBSHRLDV = % of miles driven in urban areas by LDVs in base year (1992)

37) Calculate fuel consumption, in gallons of gasoline equivalent:

$$FUEL_{T,SEC,SC,AGE,FUEL,FLT} = \frac{VMT_{T,SEC,SC,AGE,FUEL,FLT}}{MPG_{T,SEC,SC,AGE,FUEL} * MPGDEGFAC_{T,SC}} \quad \text{(B-213)}$$

where:

FUEL = Total freight truck fuel consumption by sector, size class and fuel type in year T, in gallons of gasoline equivalent
$MPGDEGFAC_{T,SC}$ = Fuel economy degredation factor, overwritten in the code by 0.99.

38) Converting from gasoline equivalent to trillion Btu:

$$TRIL_{T,SEC,SC,FUEL,FLT} = \sum_{AGE=0}^{11} FUEL_{T,SEC,SC,AGE,FUEL,FLT} \cdot HTRATE \cdot 10^{-6} \quad \text{(B-214)}$$

where:

TRIL = Total fleet truck fuel consumption by sector, size class and fuel type in year T, in trillion Btu

Roll Truck Population and Fuel Economy

39) Calculate new fuel economies of trucks which are ten years old or older:

$$MPG_{T+1,SC,SGE=10,FUEL} = \frac{\sum_{FLT=1}^{2} \sum_{AGE=10}^{11} \sum_{SEC=1}^{12} VMT_{T,SEC,SC,AGE,FUEL,FLT}}{\sum_{FLT=1}^{2} \sum_{AGE=10}^{11} \sum_{SEC=1}^{12} FUEL_{T,SEC,SC,AGE,FUEL,FLT}} \quad \text{(B-215)}$$

where:

AGE = 10 refers to trucks in the tenth vintage, i.e., trucks which are ten years old during model run year t

AGE = 11 refers to trucks in the eleventh vintage, i.e., trucks which are eleven years old or older during model run year t

$T+1$ = refers to the next model run year

40) Collapse the last two vintages of trucks into one:

$$TRKSTK_{T,SEC,SC,AGE=10,FUEL,FLT} = TRKSTK_{T,SEC,SC,AGE=10,FUEL,FLT} + TRKSTK_{T,SEC,SC,AGE=11,FUEL,FLT} \quad \text{(B-216)}$$

RAIL FREIGHT MODEL Subroutine TRAIL

1) Calcutate ton-miles traveled for rail. by industry:

$$RTMT_{I,T} = RTMT_{I,T_0} \cdot FAC_{I,MODE} \cdot \left[\frac{TSIC_{I,T}}{TSIC_{I,T_0}}\right] \quad \text{(B-217)}$$

where:

RTMT = Rail ton-miles traveled, by industry I

$MODE$ = Index of freight mode: truck, rail, marine

TSIC = Value of industrial output, by industry

I = Index of NEMS industrial category

FAC = Freight adjustment coefficient, by industry and mode

2) Sum across industries:

$$RTMTT_T = \sum_{I=1}^{10} RTMT_{I,T} \tag{B-218}$$

where:

RTMTT = Total rail ton-miles traveled

3) Estimate energy consumption by rail:

$$TQRAILT_T = FERAIL_T \cdot RTMTT_T \tag{B-219}$$

where:

TQRAILT = Total energy demand by rail

FERAIL = Rail efficiency coefficient, in Btu/ton-mile

4) Increment rail demand for specific fuels:

$$TQRAIL_{IF,T} = TQRAIL_{IF,T-1} \cdot \left(\frac{TQRAILT_T}{TQRAILT_{T-1}} \right) \tag{B-220}$$

where:

TQRAIL = Rail demand, by fuel IF

IF = Index of fuel type

5) Divide into regions:

$$TQRAILR_{IF,IR,T} = TQRAIL_{IF,T} * SEDSHR_{IF,IR,T} \tag{B-221}$$

where:

TQRAILR = Regional demand by fuel type
SEDSHR = Regional shares of fuel demand, from SEDS
IR = Index of census region (1-9)

6) Calculate fractional change in rail travel and fuel efficiency:

$$XRAIL_T = \frac{RTMTT_T}{RTMTT_{T-1}}$$

and (B-222)

$$XRAILEFF_T = \frac{FERAIL_{T-1}}{FERAIL_T}$$

where:

XRAIL = Growth in rail travel from base year
XRAILEFF = Growth in rail efficiency from base year

WATERBORNE FREIGHT MODEL Subroutine TSHIP

1) Calcutate ton-miles traveled for domestic shipping, by industry:

$$STMT_{I,T} = STMT_{I,T_0} \cdot FAC_{I,MODE} \cdot \left[\frac{TSIC_{I,T}}{TSIC_{I,T_0}}\right] \qquad \text{(B-223)}$$

where:

STMT = Ship ton-miles traveled, by industry I

2) Sum across industries:

$$STMTT_T = \sum_{I=1}^{10} STMT_{I,T} \qquad \text{(B-224)}$$

where:

STMTT = Total ship ton-miles traveled

3) Estimate energy consumption by ship:

$$SFDT_T = FESHIP_T * STMTT_T * SFDBENCH \tag{B-225}$$

where:

SFDT = Total energy demand by ship
FESHIP = Ship efficiency coefficient, in Btu/ton-mile
SFDBENCH = Benchmark factor to ensure congruence with 1990 data

4) Allocate energy demand among specific fuels:

$$SFD_{IF,T} = SFDT_T * SFSHARE_{IF} \tag{B-226}$$

where:

SFD = Domestic ship energy demand, by fuel *IF*
SFSHARE = Constant allocation share for domestic shipping, by fuel

5) Divide into regions:

$$TQSHIPR_{IF,IR,T} = SFD_{IF,T} * SEDSHR_{IF,IR,T} \tag{B-227}$$

where:

TQSHIPR = Regional ship demand by fuel type
SEDSHR = Regional shares of fuel demand, from SEDS

6) Calculate international shipping fuel demand:

$$ISFDT_T = ISFDT_{T-1} + \left[\frac{GROSST_T}{GROSST_{T-1}} - 1 \right] * 0.5 * ISFDT_{T-1} \tag{B-228}$$

where:

ISFDT = Total international shipping fuel demand
GROSST = Value of gross trade (imports – exports)

7) Allocate among the considered fuels:

$$ISFD_{IF,T} = ISFDT_T \cdot ISFSHARE_{IF} \tag{B-229}$$

where:

ISFD = International ship energy demand, by fuel *IF*

ISFSAHRE = Constant allocation share for international shipping, by fuel

8) Divide into regions:

$$TQISHIPR_{IF,IR,T} = ISFD_{IF,T} * SEDSHR_{IF,IR,T} \tag{B-230}$$

where:

TQISHIPR = Regional international shipping demand by fuel type

9) Calculate fractional change in domestic ship travel and fuel efficiency:

$$XSHIP_T = \frac{STMTT_T}{STMTT_{T=1}} \quad \text{and} \quad XSHIPEFF_T = \frac{FESHIP_T}{FESHIP_{T=1}} \tag{B-231}$$

where:

XSHIP = Growth in ship travel from base year

XSHIPEFF = Growth in ship efficiency from base year

AIR TRAVEL MODULE

AIR TRAVEL DEMAND MODEL — Subroutine TAIRT

1) Calculate the cost of flying:

$$YIELD_T = 9.73 + .794\ TPJFTR_T \qquad \text{(B-232)}$$

where:

YIELD = Cost of air travel, expressed in cents per RPM
TPJFTR = Price of jet fuel, in dollars per million Btu

2) Calculate the revenue passenger-miles per capita for each type of travel:

a) For business travel:

$$RPMBPC_T = 89.70 + .029\left(\frac{TMC\_GDP_T}{TMC\_POPAFO_T}\right) - 16.04\ YIELD_T \qquad \text{(B-233)}$$

b) For personal travel:

$$RPMPPC_T = -481.84 + .083\left(\frac{TMC\_YD_T}{TMC\_POPAFO_T}\right) - 18.68\ YIELD_T \qquad \text{(B-234)}$$

c) For international travel:

$$RPMIPC_T = PCTINT_T \cdot (RPMBPC_T + RPMPPC_T) \qquad \text{(B-235)}$$

where:

RPMBPC = Per capita revenue passenger miles for business travel
RPMPPC = Per capita revenue passenger miles for personal travel
RPMIPC = Per capita revenue passenger miles for international travel
TMC_GDP = Gross domestic product, from MACRO module
TMC_YD = Disposable personal income, from MACRO module
TMC_POPAFO = Total domestic population, from MACRO module
PCTINT = Proportionality factor relating international to domestic travel levels

3) Calculate the revenue ton-miles (RTM) of air freight:

$$RTM_T = \left(-14{,}556 + 19.81\ TMC\_EXDN92_T + 3.49\ TMC\_GDP_T\right) \cdot DFRT_T \tag{B-236}$$

where:

TMC_EXDN92 = Value of merchandise exports, from MACRO module
DFRT = Fraction of freight ton-miles transported by dedicated carriers

4) Calculate total revenue passenger-miles flown for each category of travel:

a) For business travel:

$$RPMB_T = RPMBPC_T \cdot TMC\_POPAFO_T \tag{B-237}$$

b) For personal travel:

$$RPMP_T = RPMPPC_T \cdot TMC\_POPAFO_T \cdot DI_T \tag{B-238}$$

c) For international travel:

$$RPMI_T = RPMIPC_T \cdot TMC\_POPAFO_T \tag{B-239}$$

where:

RPMB = Revenue passenger miles for business travel
RPMP = Revenue passenger miles for personal travel
RPMI = Revenue passenger miles for international travel
DI = Demographic adjustment index, reflecting the public's propensity to fly

5) Calculate total domestic air travel:

$$RPMD_T = RPMB_T + RPMP_T \tag{B-240}$$

where:

RPMD = Total domestic air travel

6) Calculate the total demand for available seat-miles:

$$ASMDEMD_T = \left(\frac{RPMD_T}{LFDOM_T}\right) + \left(\frac{RPMI_T}{2 * LFINTER_T}\right) + (RTM_T \cdot EQSM) \tag{B-241}$$

where:

ASMDEMD = Total demand for available seat-miles

LFDOM = Load factor for domestic travel

LFINTER = Load factor for international travel

EQSM = Equivalent seat-miles conversion factor; used to transform freight RTM's

AIRCRAFT FLEET EFFICIENCY MODEL — Subroutine TAIREFF

1) Calculate available seat-miles per plane, by aircraft type:

$$ASMP_{IT,T} = AIRHRS_{IT,T} * AVSPD_{IT,T} * SEAT_{IT,T} \qquad \text{(B-242)}$$

where:

ASMP = The available seat-miles per plane, by type.

AIRHRS = The average number of airborne hours per aircraft.

AVSPD = The average flight speed.

SEAT = The average number of seats per aircraft.

IT = Index of aircraft type: 1 = narrow body, 2 = wide body

2) Calculate fraction of seat-mile demand accomodated by narrow-body aircraft:

$$\begin{aligned} SMFRACN_T &= \left[\left(\frac{ASMDEMD_{IT=1,T-1}}{SMDEMD_{T-1}}\right) + DELTA \cdot \left(\frac{ASMDEMD_{IT=2,T-1}}{SMDEMD_{T-1}}\right)\right] \;;\; DELTA \geq 0 \\ &= \left[\left(\frac{ASMDEMD_{IT=1,T-1}}{SMDEMD_{T-1}}\right) \cdot (1 + DELTA)\right] \;;\; DELTA < 0 \end{aligned} \qquad \text{(B-243)}$$

where:

SMFRACN = Fraction of seat-mile demand on narrow-body planes

ASMDEMD = Demand for available seat-miles, by aircraft type

DELTA = User-specified rate of passenger shifts between aircraft types

3) Calculate current seat-miles demanded by aircraft type:

$$ASMDEMD_{IT=1,T} = SMDEMD_T * SMFRACN_T$$

and (B-244)

$$ASDEMD_{IT=2,T} = SMDEMD_T * \left(1.0 - SMFRACN_T\right)$$

4) Calculate survival rates of aircraft:

$$SURVPCT_{IVINT} = \left[1 + EXP\left(SURVK * (T50 - IVINT) \right) \right]^{-1}$$

and (B-245)

$$SSURVPCT_{IVINT} = \frac{SURVPCT_{IVINT}}{SURVPCT_{IVINT-1}}$$

where:

SURVPCT = Survival rate of planes of a given vintage *IVINT*
SSURVPCT = Marginal survival rate of planes of a given vintage
IVINT = Index of aircraft vintage
SURVK = User-specified proportionality constant
T50 = User-specified vintage at which stock survival is 50%

5) Calculate surviving seat-miles from previous year:

$$SMSURV_{IT,T} = \sum_{IVINT=2}^{60} NPCHSE_{IT,IVINT-1,T-1} * SSURVPCT_{IVINT} * ASMP_{IT,T} \quad \text{(B-246)}$$

where:

SMSURV = Surviving available seat-miles, by aircraft type
NPCHSE = Surviving aircraft stock, by vintage and aircraft type

6) Calculate new aircraft purchases:

$$NPCHSE_{IT,IVINT=1,T} = \left[\frac{ASMDEMD_{IT,T} - SMSURV_{IT,T}}{ASMP_{IT,T}} \right] \quad \text{(B-247)}$$

7) Adjust array of aircraft stocks by vintage:

$$NPCHSE_{IT,IVINT,T} = NPCHSE_{IT,IVINT-1,T-1} * SSURVPCT_{IVINT} \quad ; \quad IVINT = 2 - 60 \quad \text{(B-248)}$$

8) Calculate aircraft stock across vintages:

$$NSURV_{IT,T} = \sum_{IVINT=1}^{60} NPCHSE_{IT,IVINT,T} \quad \text{(B-249)}$$

where:

NSURV = Number of surviving aircraft, by type

9) Calculate fraction of current year stock which is old ($IVINT > 1$):

$$STKOLD_{IT,T} = \frac{\left(NSURV_{IT,T} - NPCHSE_{IT,IVINT=1,T}\right)}{NSURV_{IT,T}} \qquad \text{(B-250)}$$

where:

STKOLD = Fraction of planes older than one year, by aircraft type

10) Calculate effect of technology improvements:

a) Calculate time effect:

$$TIMEFX_{IFX,T} = TIMEFX_{IFX,T-1} + \left(TIMECONST * TPN_{IFX} * TYRN_{IFX}\right) \qquad \text{(B-251)}$$

where:

TIMEFX = Factor reflecting the length of time an aircraft technology improvement has been commercially viable

IFX = Index of technology improvements (1-6)

TIMECONST = User-specified scaling constant, reflecting the importance of the passage of time

TPN = Binary variable (0,1) which tests whether current fuel price exceeds the considered techology's trigger price

TYRN = Binary variable which tests whether current year exceeds the considered technology's year of introduction

b) Calculate the cost effect:

$$COSTFX_{IFX,T} = 10 * \left(\frac{TPJFGAL_T - TRAGPRICE_{IFX}}{TPJFGAL_T}\right) * TPN_{IFX} * TYRN_{IFX} * TPZ_{IFX} \qquad \text{(B-252)}$$

where:

COSTFX = Factor reflecting the magnitude of the difference between the price of jet fuel and the trigger price of the considered technology

TPJFGAL = Price of jet fuel

TRIGPRICE = Price of jet fuel above which the considered technology is assumed to be commercially viable

TPZ = Binary variable which tests whether implementation of the considered technology is dependent on fuel price

c) Calculate the total effect:

$$TOTALFX_{IFX,T} = TIMEFX_{IFX,T} + COSTFX_{IFX,T} - BASECONST \qquad \textbf{(B-253)}$$

where:

TOTALFX = Overall effect of fuel price and time on implementation of technology *IFX*

BASECONST = Baseline constant, used to anchor the technology penetration curve

d) Calculate the penetration of new technologies:

$$TECHFRAC_{IFX,T} = \left[1 + EXP\left(-TOTALFX_{IFX,T}\right) \right]^{-1} \qquad \textbf{(B-254)}$$

where:

TECHFRAC = Fration of new aircraft purchases which incorporate a given technology

11) Calculate fractional fuel efficiency improvement for new aircraft, by type:

$$FRACIMP_{IT=1,T} = 1.0 + EFFIMP_{IFX=1} * \left(TECHFRAC_{IFX=1,T} - TECHFRAC_{IFX=2,T}\right) + \sum_{IFX=2}^{6} EFFIMP_{IFX} * TECHFRAC_{IFX,T}$$

and

$$FRACIMP_{IT=2,T} = 1.0 + \sum_{IFX=1}^{6} EFFIMP_{IFX} * TECHFRAC_{IFX,T} \;; \quad IFX \neq 2 \qquad \textbf{(B-255)}$$

where:

FRACIMP = Fractional improvement over base year (1990) fuel efficiency, by type

EFFIMP = Fractional improvement associated with a given technology

12) Ensure that technical improvements provide at least as much efficiency gain as average growth in remainder of air fleet:

$$NEWSMPG_{IT,T} = MAX\left[\left(FRACIMP_{IT,T} * SMPG_{IT,T-1}\right),\ \left((1.0 + \mathrm{P}_{IT,T}) * SMPGIT,T-1 * 1.05\right)\right] \qquad \textbf{(B-256)}$$

where:

NEWSMPG = Average seat-miles per gallon of new aircraft purchases

SMPG = Surviving fleet average seat-miles per gallon, by aircraft type

RHO = Average historic rate of growth of fuel efficiency

13) Calculate average fuel economy of aircraft fleet, by type:

$$SMPG_{IT,T} = \left[\left(\frac{STKOLD_{IT,T}}{\left(1 + RHO_{IT}\right) \cdot \left(SMPG_{IT,T-1}\right)}\right) + \left(\frac{1 - STKOLD_{IT,T}}{NEWSMPG_{IT,T}}\right)\right]^{-1} \quad \text{(B-257)}$$

14) Calculate average fuel economy of aircraft fleet:

$$SMPGT_{T} = \left[\left(\frac{SMFRACN_{T}}{SMPG_{IT=1,T}}\right) + \left(\frac{\left(1 - SMFRACN_{T}\right)}{SMPG_{IT=2,T}}\right)\right]^{-1} \quad \text{(B-258)}$$

where:

SMPGT = Overall fleet average seat-miles per gallon

15) Calculate demand for jet fuel, incrementing by 5% to reflect consumption by private aircraft:

$$JFGAL_{T} = \left(\frac{SMDEMD_{T}}{SMPGT_{T}}\right) * 1.05 \quad \text{(B-259)}$$

where:

JFGAL = Consumption of jet fuel, in gallons

16) Calculate demand for aviation gasoline:

$$AGD_{T} = BASEAGD + GAMMA * EXP\left[-KAPPA * (IYEAR - 1979)\right] \quad \text{(B-260)}$$

where:

AGD = Demand for aviation gasoline, in gallons
BASEAGD = Baseline demand for aviation gasoline
GAMMA = Baseline adjustment factor
KAPPA = Exogenously-specified decay constant
IYEAR = Current year

17) Convert from gallons to Btu:

$$JFBTU_T = JFGAL_T * \left(\frac{5.670\ MMBtu/bbl}{42\ gal/bbl}\right)$$

and (B-261)

$$AGDBTU_T = AGD_T * \left(\frac{5.048\ MMBtu/bbl}{42\ gal/bbl}\right)$$

where:

JFBTU = Jet fuel demand, in Btu
AGDBTU = Aviation gasoline demand, in Btu

18) Regionalize demand:

$$QJETR_{IR,T} = JFBTU_T * SEDSHR_{IF,IR,T}$$

and (B-262)

$$QAGR_{IR,T} = QAGDBTU_T * SEDSHR_{IF,IR,T}$$

where:

QJETR = Regional demand for jet fuel
QAGR = Regional demand for aviation gasoline
SEDSHR = Regional shares of fuel demand, from SEDS

19) Calculate fractional changes in air travel and aircraft efficiency:

$$XAIR_T = \frac{SMDEMD_T}{SMDEMD_{T=1}}$$

and (B-263)

$$XAIREFF_T = \frac{SMPGT_T}{SMPGT_{T=1}}$$

where:

XAIR = Fractional change in air travel from base year
XAIREFF = Fractional change in aircraft fuel efficiency from base year

MISCELLANEOUS TRANSPORTATION ENERGY DEMAND MODULE

MILITARY DEMAND MODEL Subroutine TMISC

Calculate military energy use:

1) Calculate growth in military budget:

$$MILTARGR_T = \frac{TMC\_GRML87_T}{TMC\_GFML87_{T-1}} \tag{B-264}$$

where:

MILTARGR = Fractional growth of military budget
TMC_GRML87 = Military budget, from MACRO module

2) Calculate fuel demand:

$$MFD_{IF,T} = MFD_{IF,T-1} * MILTARGR_T \tag{B-265}$$

where:

MFD = Demand for fuel by military
IF = Index of fuel type

3) Regionalize demand:

$$QMILTR_{IF,IR,T} = MFD_{IF,T} * MILTRSHR_{IF,IR,T} \tag{B-266}$$

where:

QMILTR = Regional military demand for fuel
MILTRSHR = Regional shares of military demand for fuel

Calculate mass-transit consumption:

1) Calculate passenger-miles by mode:

$$TMOD_{IM=1,T} = VMTEE_T * TMLOAD89_{IM=1}$$

and:

$$TMOD_{IM,T} = TMOD_{IM,T-1} * \left[\frac{TMOD_{1,T}}{TMOD_{1,T-1}}\right]^{BETAMS} \tag{B-267}$$

where:

TMOD = Passenger-miles traveled, by mode
VMTEE = LDV vehicle-miles traveled, from the VMT module
TMLOAD89 = Average passengers per vehicle, by mode (1=LDV's)
BETAMS = Coefficient of proportionality, relating mass transit to LDV travel
IM = Index of transportation mode: 1 = LDV's, 2-4 = Buses, 5-7 = Rail

2) Calculate mass transit efficiencies, in Btu per passenger-mile:

$$TMEFFL_{IM,T} = \frac{\left[TMEFF89_{IM} * \left(\frac{FMPG_{TYPE,T}}{FMPG89_{TYPE}}\right)\right]}{TMLOAD89_{IM}} \tag{B-268}$$

where:

TMEFFL = Btu per passenger-mile, by mass transit mode
TMEFF89 = Base-year Btu per vehicle-mile, by mode
FMPG = Fuel efficiency, by vehicle type, from the Freight Module
FMPG89 = Base-year fuel efficiency, by vehicle type, from the Freight Module
TYPE = Vehicle type, from the Freight Module: 1 = Mid-size trucks, 2 = Rail

3) Calculate fuel consumption by mode:

$$TMFD_{IM,T} = TMOD_{IM,T} * TMEFFL_{IM,T} \tag{B-269}$$

where:

TMFD = Total mass-transit fuel consumption by mode

4) Regionalize consumption:

$$QMODR_{IM,IR,T} = TMFD_{IM,T} * \left[\frac{TMC\_POPAFO_{IR,T}}{\sum_{IR=1}^{9} TMC\_POPAFO_{IR,T}} \right] \quad \text{(B-270)}$$

where:

QMODR = Regional consumption of fuel, by mode
TMC_POPAFO = Regional population forecasts, from the Macro Module

RECREATIONAL BOATING DEMAND MODEL — Subroutine TMISC

Calculate recreational boat fuel use:

1) Calculate fuel demand:

$$RECFD_T = RECFD_{T-1} * \left[\frac{TMC\_YD_T}{TMC\_YD_{T-1}} \right]^{BETAREC} \quad \text{(B-271)}$$

where:

RECFD = National recreational boat gasoline consumption in year T
TMC_YD = Total disposable personal income, from the Macro Module
BETAREC = Coefficient of proportionality relating income to fuel demand for boats

2) Regionalize consumption according to population:

$$QRECR_{IR,T} = RECFD_T * \left[\frac{TMC\_POPAFO_{IR,T}}{\sum_{IR=1}^{9} TMC\_POPAFO_{IR,T}} \right] \quad \text{(B-272)}$$

where:

QRECR = Regional fuel consumption by recreational boats in year T

Calculate lubricant demand:

1) Sum freight truck VMT across size classes:

$$FTVMT_T = \sum_{SC=1}^{3} FVMTSC_{SC,T} \qquad \text{(B-273)}$$

where:

FTVMT = Total freight truck VMT
FVMTSC = Freight truck VMT, by size class

2) Calculate total highway travel:

$$HYWAY_T = VMTEE_T + FTVMT_T + FLTVMT_T \qquad \text{(B-274)}$$

where:

HYWAY = Total highway VMT
FLTVMT = Total fleet vehicle VMT, from the Fleet Module

3) Calculate lubricant demand:

$$LUBFD_T = LUBFD_{T-1} * \left[\frac{HYWAY_T}{HYWAY_{T-1}}\right]^{BETALUB} \qquad \text{(B-275)}$$

where:

LUBFD = Total demand for lubricants in year T
BETALUB = Constant of proportionality, relating highway travel to lubricant demand

4) Regionalize lubricant demand:

$$QLUBR_{IR,T} = LUBFD_T * \left[\frac{\left(\left(VMTEE_T + FLTVMT_T\right) * SEDSHR_{IF,IR,T}\right) + \left(FTVMT_T * SEDSHR_{IF,IR,T}\right)}{HYWAY_T}\right] \qquad \text{(B-276)}$$

where:

QLUBR = Regional demand for lubricants in year T, in Btu
SEDSHR = Regional share of fuel consumption, from SEDS
IF = Index of fuel type: gasoline for light-duty vehicles, diesel for freight trucks

VEHICLE EMISSIONS MODULE Subroutine TEMISS

This subroutine calculates the emissions of six airborne pollutants, at every conceivable level of aggregation. A single, representative equation is provided.

1) Calculate disaggregate emissions of airborne pollutants:

$$EMISS_{IE,IM,IR,T} = EFACT_{IE,IM,IR,T} * U_{IM,IR,T} \tag{B-277}$$

where:

EMISS = Regional emissions of a given pollutant, by mode of travel
EFACT = Emissions factor relating measures of travel to pollutant emissions
U = Measure of travel demand, by mode: units in VMT for highway travel, gallons of fuel consumption for other modes
IM = Index of travel mode: references individual vehicle types used in the preceding modules, and may be further subdivided by size class, vehicle technology, and vehicle type
IE = Index of pollutants: 1 = SO_x, 2 = NO_x, 3 = C, 4 = CO_2, 5 = CO, 6 = VOC
IR = Index identifying census region

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Appendix D. Model Abstract

Model Name:

Transportation Sector Model

Model Acronym:

TRAN

Description:

The Transportation Sector Model incorporates an integrated modular design which is based upon economic, engineering, and demographic relationships that model transportation sector energy consumption at the nine Census Division level of detail. The Transportation Sector Model comprises the following components: Light Duty Vehicles, Light Duty Fleet Vehicles, Freight Transport (truck, rail, and marine), Aircraft, Miscellaneous Transport (military, mass transit, and recreational boats), and Transportation Emissions. The model provides sales estimates of 2 conventional and 14 alternative-fuel light duty vehicles, and consumption estimates of 12 main fuels.

Purpose of the Model:

As a component of the National Energy Modeling System integrated forecasting tool, the transportation model generates mid-term forecasts of transportation sector energy consumption. The transportation model facilitates policy analysis of energy markets, technological development, environmental issues, and regulatory development as they impact transportation sector energy consumption.

Most Recent Model Update:

October, 1997.

Part of Another Model?

National Energy Modeling system (NEMS).

Model Interfaces:

Receives inputs from the Electricity Market Module, Oil and Gas Market Module, Renewable Fuels Module, and the Macroeconomic Activity Module.

Official Model Representative:

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Energy Information Administration
Office of Integrated Analysis and Forecasting
Energy Demand and Integration Division
Energy Demand Analysis Branch
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Washington, DC 20585
Telephone: (202) 586-3994

Documentation:

Model Documentation Report: Transportation Sector Model of the National Energy Modeling System, October, 1997.

Archive Media and Installation Manual(s):

The model will be archived on IBM tape compatible with the IBM RS6000 mainframe system upon completion of the NEMS production runs to generate the Annual Energy Outlook 1998.

Energy System Described:

Domestic transportation sector energy consumption.

Coverage:

- Geographic: Nine Census Divisions: New England, Mid Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain, Pacific.
- Time Unit/Frequency: Annual, 1990 through 2010.
- Products: Motor gasoline, aviation gasoline, diesel/distillate, residual oil, electricity, jet fuel, LPG, CNG, methanol, ethanol, hydrogen, lubricants.
- Economic Sectors: Forecasts are produced for personal travel, freight trucks, railroads, domestic and international marine, aviation, mass transit, and military use.

Model Interfaces:

Model outputs are provided to the Integrating Module, which then sends them back to the supply modules.

Model Structure:

Light-duty vehicles are classified according to the six EPA size classes for cars and light trucks. Freight trucks are divided into light-duty, medium-duty and heavy-duty size classes. The air transport module contains both wide- and narrow-body aircraft. Rail transportation is composed of freight rail and three modes of personal rail travel: commuter, intercity and transit. Shipping is divided into domestic and international categories.

Special Feautres:

The Transportation Sector Model has been created to allow the user to change various exogenous and endogenous input levels. The range of policy issues that the transportation model can evaluate are: fuel taxes and subsidies; fuel economy levels by size class; CAFE levels; vehicle pricing policies by size class; demand for vehicle performance within size classes; fleet vehicle sales by technology type; alternative-fuel vehicle sales shares; the Energy Policy Act; Low Emission Vehicle Program; VMT reduction; and greenhouse gas emissions levels.

Modeling Techniques:

The modeling techniques employed in the Transportation Sector Model vary by module: econometrics for passenger travel, aviation, and new vehicle market shares; exogenous engineering and judgement for MPG, aircraft efficiency, and various freight characteristics; and structural for light-duty vehicle and aircraft capital stock estimations.

Computing Environment:

- Hardware Used: IBM RS6000
- Operating System: AIX Version 4.2.1
- Language/Software Used: XL FORTRAN90, Ver 4.0
- Memory Requirement: 9,500 K
- Storage Requirement: 35,000 K
- Estimated Run Time: 15 Seconds
- Special Features: None.

Independent Expert Reviews Conducted:

Independent Expert Review of Transportation Sector Component Design Report, June, 1992, conducted by David L. Greene, Oak Ridge National Laboratory.

Status of Evaluation Efforts by Sponsor:

None.

DOE Input Sources:

- State Energy Data System (SEDS), 1991, May 1993.
- Residential Transportation Energy Consumption Survey (RTECS), 1991, December 1993
- U.S. Department of Energy, Office of Policy, Planning and Analysis, "Assessment of Costs and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation Sector", Technical Report Ten: Alternative Fuel Requirements, 1992.

Non-DOE Input Sources:

- National Energy Accounts
- Federal Highway Administration, Highway Statistics, 1991, 1992
- Department of Transportation Air Travel Statistics
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- Oak Ridge National Laboratory, Energy Data Book: 13, March 1993.
- Oak Ridge National Laboratory, Light-Duty Vehicle MPG and Market Report: Model Year 1992, February, 1992.
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- Bunch, David S., Mark Bradley, Thomas F. Golob, Ryuichi Kitamura, Gareth P. Occhiuzzo, "Demand for Clean-Fuel Personal Vehicles in California: A Discrete-Choice Stated Preference Survey", presented at the Conference on Transportation and Global Climate Change: Long Run Options, Asilomar Conference Center, Pacific Grove, California, August 26, 1991.

Appendix E. Data Quality and Estimation

LIST OF TABLES

Appendix E. Data Quality and Estimation

This appendix presents results of the statistical tests conducted for those componenents of the transportation model which rely on econometric estimations. These components include: The Fuel Economy Model, the Alternative Fuel Vehicle Model, the Vehicle-Miles Traveled Model, and the Air Travel Demand Model. To date, no data quality studies have been conducted in order to validitate the transportation model's input data.

Fuel Economy Model

The methodology employed to assess the influence of macroeconomic and time-dependent variables on the mix of size classes and performance was log-linear regression analysis using historical data on car and light truck sales over the 1979-1990 period. Greater detail is provided in Attachment 1 of Appendix F.

The following equations were used to estimate the class market shares of new vehicle purchases:

<u>All Vehicle Classes Except Luxury Cars:</u>[1]

$$\ln\left(\frac{CLASS\$SHARE_i}{1 - CLASS\$SHARE_i}\right)_{YEAR} - \ln\left(\frac{CLASS\$SHARE_i}{1 - CLASS\$SHARE_i}\right)_{1990} = A * \ln\left(\frac{YEAR}{1990}\right) + B * \ln\left(\frac{FUELCOST_{YEAR}}{FUELCOST_{1990}}\right) + C * \ln\left(\frac{INCOME_{YEAR} - \$13{,}000}{INCOME_{1990} - \$13{,}000}\right) \tag{E-1}$$

where:

CLASSSSHARE$_i$ = The market share of the ith vehicle class
FUELCOST = The price of gasoline
INCOME = Per capita disposable income

[1]Note: Market shares for Mini and Sub-Compact cars are solved jointly. The resulting combined market share is allocated between the two classes based on the original 1990 allocation. Special treatment of these two classes was made necessary by the small sample size in the analysis data sets.

Luxury Cars:

$$\ln\left(\frac{CLASS\$SHARE_t}{1-CLASS\$SHARE_t}\right)_{YEAR} - \ln\left(\frac{CLASS\$SHARE_t}{1-CLASS\$SHARE_t}\right)_{1990} = A * \ln\left(\frac{YEAR}{1990}\right) + B * \ln\left(\frac{FUELCOST_{YEAR}}{FUELCOST_{1990}}\right) + C * \ln\left(\frac{INCOME_{YEAR}}{INCOME_{1990}}\right) \quad \text{(E-2)}$$

The values of the coefficients with their associated T-statistics are provided below in Table E-1.

Table E-1. Regression Results From The Market Share Model

Group	F Val	R^2	Intercept	YEAR	FUELCOST	INCOME
Mini and Subcompact	14.359	0.891	-5.428	0.056 (1.761)	1.33 (1.828)	-0.169 (-1.524)
Sports	11.193	0.808	-2.475	-0.049 (-1.903)	0.26 (.466)	.0068 (.059)
Compact	5.533	0.76	-5.021	0.111 (2.117)	1.332 (1.35)	0.107 (.52)
Intermediate	3.084	0.536	-1.01	-0.051 (-1.742)	-0.213 (-.335)	-0.0017 (-.013)
Large	16.880	0.864	-3.312	-0.119 (-4.754)	0.042 (.077)	0.231 (2.018)
Luxury	18.458	0.939	-3.1	0.126 (2.336)	1.166 (2.704)	0.169 (1.441)
Mini Truck	1.378	0.341	2.268	-0.018 (-.168)	-3.648 (-1.6)	-0.968 (-2.027)
Compact Pickup	19.183	0.916	-8.749	-0.042 (-1.238)	-0.811 (-1.48)	0.174 (1.247)
Compact Van	804.167	0.998	-9.3	0.01 (.352)	0.832 (1.727)	0.307 (3.045)
Compact Utility	274.104	0.994	-7.36	-0.042 (-1.447)	-0.2 (-.396)	0.366 (2.933)
Standard Size Trucks	1.582	0.475	-2.779	-0.056 (-1.523)	0.252 (.307)	0.144 (.846)

Alternative Fuel Vehicle Model

The AFV model uses a multinomial nested logit approach to estimate market shares of sixteen vehicle technologies. Model coefficients are taken from a study sponsored by the California Energy Commission, using a stated preference survey of California residents. The applicability of this study to a nationwide model has not been tested. Market shares are based on the exponentiated value of the consumer utility function, represented as follows:

$$\begin{aligned} VC1_{IT,IR} = \; & CONST_{IT} + \beta_1 VPRI_{IS,IT,N} + \beta_2 COPCOST_{IT,IS,IR,N} \\ & + \beta_3 VRANGE_{IS,IT,N} + \beta_4 VRANGE^2_{IS,IT,N} + \beta_5 EMISS_{IS,IT,N} \\ & + \beta_6 EMISS^2_{IS,IT,N} + \beta_7 FAVAIL_{IT,IR,N} + \beta_8 FAVAIL^2_{IT,IR,N} \end{aligned} \qquad \text{(E-3)}$$

where:

VC1 = Utility vector for conventional and alternative vehicles
CONST = Constant associated with each considered technology *IT*
VPRI = Price of each considered technology in 1990$
VRANGE = Vehicle range of the considered technology
EMISS = Emissions levels relative to gasoline ICE's
FAVAIL = Relative availability of the considered fuel

Model coefficients and relevant T-statistics are provided in Table E-2, on the following page. An extensive description of the data base development process is provided as an attachment in Appendix F.

Table E-2. Alternative Fuel Vehicle Model Coefficients

VARIABLE	COEFFICIENT	T-STATISTIC
VPRI	-.134	10.1
COPCOST	-.190	16.4
VRANGE	2.52	11.4
$VRANGE^2$	-.408	7.4
EMISS	-2.45	7.0
$EMISS^2$	0.855	2.7
FAVAIL	2.96	5.7
$FAVAIL^2$	-1.63	3.5
CONST (Technology-Specific, as Follows)		
Gasoline	0.0	—
Diesel	0.0	—
Ethanol Flex	0.693	6.7
Ethanol Neat	0.0979	0.9
Methanol Flex	0.693	6.7
Methanol Neat	0.0979	0.9
Electric	-.0240	0.1
Electric Hybrid/Large ICE	-.257	1.5
Electric Hybrid/Small ICE	-.257	1.5
Electric Hybrid/Turbine	-.257	1.5
CNG	0.0979	0.9
LPG	0.0979	0.9
Turbine/Gasoline	0.0	—
Turbine/CNG	0.0979	0.9
Fuel Cell/Methanol	0.0979	0.9
Fuel Cell/Hydrogen	0.0979	0.9

Vehicle-Miles Traveled Model

Vehicle-miles traveled is estimated on a per capita basis using a generalized difference equation, estimated using the Cochrane-Orcutt iterative procedure:

$$
\begin{aligned}
VMTPC_T = {} & \rho\, VMTPC_{T-1} + 4.52\,(1-\rho) - 7.50\,(CPM_T - \rho\, CPM_{T-1}) \\
& + 3.6x10^{-4}\,(YPC_T - \rho\, YPC_{T-1}) + 8.36\,(PrFem_T - \rho\, PrFem_{T-1})
\end{aligned}
\tag{E-4}
$$

where:

CPM = The cost of driving a mile
YPC = Disposable personal income per capita
PrFem = The ratio of per capita female driving to per capita male driving.

The parameters and relevant T-statistics are provided in Table E-3, below.

Table E-3. Model of VMT per Capita

	ρ	α	CPM92	YPC92	PrFem	Adj. R-Sq
Parameter	0.736	0.28	-.101	2.64 e-04	1.805	0.855
T-Statistic			-4.0	4.0	1.8	

Air Travel Demand Model

This report presents the results of a re-estimation of the four equations comprising the Air Travel Demand Model. This model was originally estimated in 1992, using data from the years following the deregulation of airlines. With the acquisition of five years of additional data (1991-1995), and the revision of major macroeconomic variables, the parameters have been recalculated and are presented, along with the supporting data, on the following pages.

Although various alternative specifications were tested with the updated data sets, three of the four original equations provided results with the highest explanatory power.[2] The single equation which has been altered is that representing average travel costs in the "yield" equation: the non-fuel operating cost has been eliminated as an input due to its relatively static nature over the course of time, and its subsequent lack of explanatory significance.

In all of the regressions, the Durbin-Watson statistic indicates that autocorrelation may be present, but efforts to correct for this using a lagged-dependent variable approach have not provided acceptable results. In conclusion, the suggested model specification represents a simple forecasting tool which is sensitive to aircraft fuel prices and measures of economic activity. With a periodic updating of data and the re-estimation of these equations, the level of confidence in this approach should increase.

[2] For a description of the development of this model, see Appendix B, which reproduces the original report.

Table E-4: Measures of Aviation Activity

Year	RPM Domestic	Business Fraction	RPM Business	RPM Personal	RPM International	International Fraction	RTM
1979	212,701	55%	116,986	95,715	56,498	27%	6,355
1980	204,367	54%	109,336	95,031	65,103	32%	6,541
1981	201,435	52%	104,746	96,689	60,921	30%	6,543
1982	213,631	52%	110,020	103,611	59,894	28%	6,404
1983	232,165	51%	118,404	113,761	61,664	27%	7,017
1984	250,686	48%	120,329	130,357	70,599	28%	7,709
1985	277,836	50%	138,918	138,918	76,986	28%	7,389
1986	307,884	46%	141,627	166,257	76,851	25%	9,306
1987	329,214	48%	158,023	171,191	91,917	28%	11,375
1988	334,290	50%	167,145	167,145	101,492	30%	12,795
1989	335,213	49%	164,254	170,959	111,475	33%	14,409
1990	345,763	48%	165,966	179,797	126,363	37%	14,409
1991	338,085	46%	155,519	182,566	145,213	43%	14,199
1992	354,764	46%	164,467	190,297	138,950	39%	15,114
1993	362,230	48%	173,870	188,360	143,766	40%	16,718
1994	388,399	44%	170,895	217,503	149,096	38%	19,211
1995	403,786	41%	165,552	238,234	154,799	38%	20,699

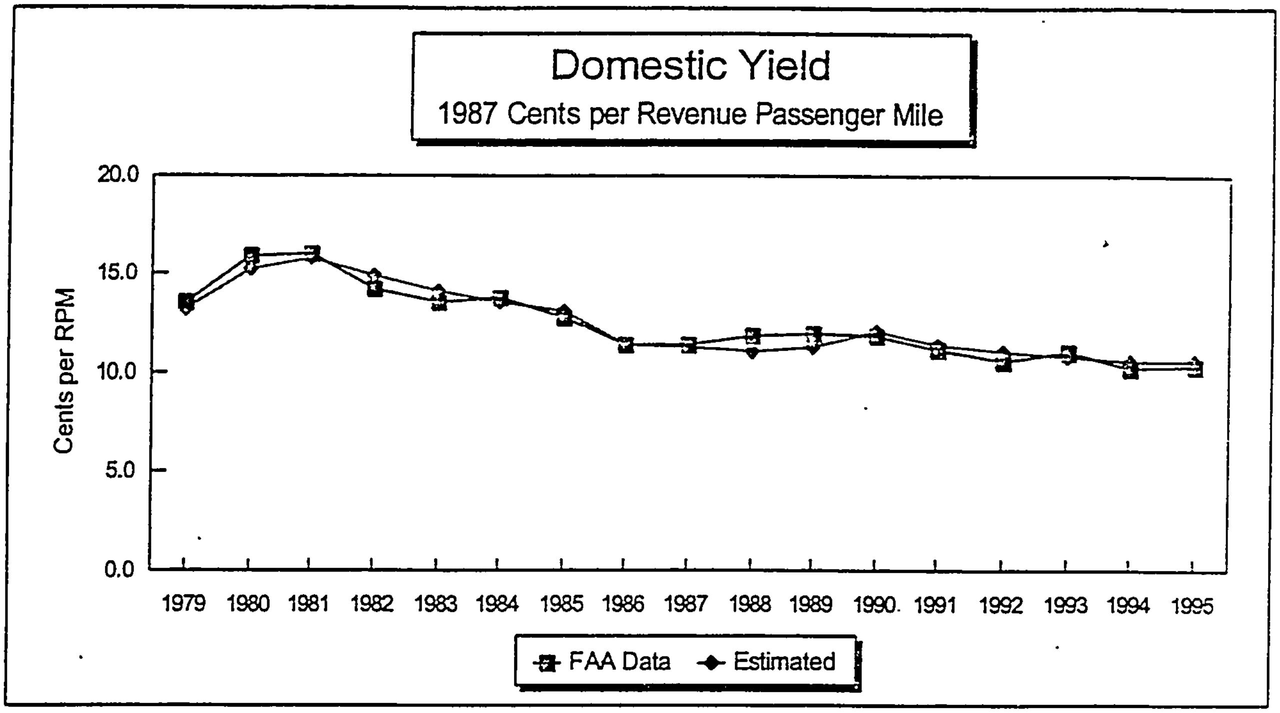
Sources:

(1) **RPM:** U.S. Department of Transportation, Research and Special Projects Administration (RSPA), *Air Carrier Traffic Statistics Monthly, December 1990/1989,* and prior issues. Lines 9, 41.

(2) **Business Fraction:** Air Transport Association of America, *Air Travel Survey,* 1990, Washington D.C.. and telephone conversation 6/5/97.

Table E-5: Measures of Economic Activity

Year	Macroeconomic Inputs					Domestic Revenue			Domestic Jet Fuel Price		
	Tpop	YD92C	GDP92C	EXP92C	GDP Def. 1992=1	Nominial $ (Millions)	Constant $ (1992 $)	YIELD (c/RPM)	Nominial Cents/Gal	Constant 1992 c/Gal	Constant $/MMBtu
1979	224,873	3,354	4,728	212	0.553	18,931	34,232	16.09	56.37	101.94	7.55
1980	227,255	3,373	4,700	237	0.604	23,317	38,604	18.89	86.45	143.14	10.60
1981	229,637	3,452	4,777	235	0.661	25,504	38,584	19.15	102.33	154.80	11.47
1982	231,996	3,483	4,681	214	0.702	25,440	36,239	16.96	96.81	137.91	10.22
1983	234,284	3,580	4,860	207	0.732	27,519	37,594	16.19	88.02	120.24	8.91
1984	236,447	3,842	5,156	224	0.759	31,437	41,419	16.52	84.44	111.25	8.24
1985	238,736	3,959	5,340	232	0.786	33,343	42,421	15.27	80.03	101.82	7.54
1986	241,107	4,087	5,498	244	0.806	33,842	41,988	13.64	54.54	67.67	5.01
1987	243,419	4,154	5,642	271	0.831	37,492	45,117	13.70	54.94	66.11	4.90
1988	246,048	4,318	5,851	321	0.861	41,002	47,621	14.25	52.36	60.81	4.50
1989	248,251	4,404	6,043	362	0.897	43,670	48,685	14.52	59.55	66.39	4.92
1990	250,270	4,485	6,139	392	0.936	46,277	49,441	14.30	76.71	81.96	6.07
1991	253,033	4,486	6,079	419	0.973	44,594	45,820	13.55	66.67	68.50	5.07
1992	255,767	4,614	6,244	449	1.000	45,246	45,246	12.75	61.84	61.84	4.58
1993	258,431	4,667	6,386	465	1.026	49,490	48,236	13.32	58.70	57.21	4.24
1994	261,033	4,778	6,609	512	1.050	50,450	48,067	12.38	54.62	52.04	3.85
1995	263,578	4,946	6,743	566	1.076	53,906	50,115	12.41	54.58	50.74	3.76

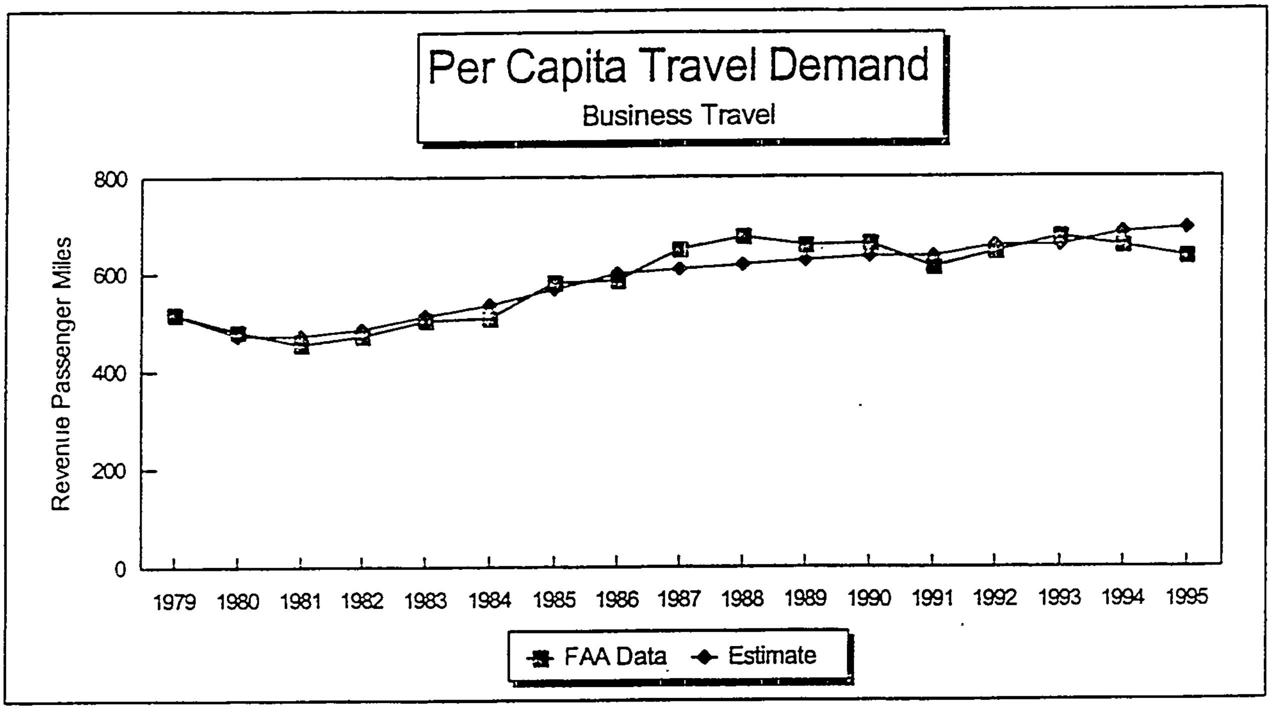


$YIELD = 9.73$	$+ .794\ PJF$	
SE	$.055$	(E-5)
t	14.43	
$Adj.R^2 = .928$	$D\text{-}W = 1.43$	

Sources:

(1) **PJF:** U.S. Department of Transportation, Research and Special Programs Administration (RSPA), *Fuel Cost And Consumption Tables,* annual summaries, 1979-1995.

(2) **YIELD:** Quotient of Passenger Revenue and RPM. **Passenger Revenue:** U.S. Department of Transportation, Research and Special Projects Administration (RSPA), Air Carrier Financial Statistics Quarterly, December 1993/1992, and prior issues, lines 3, 12.

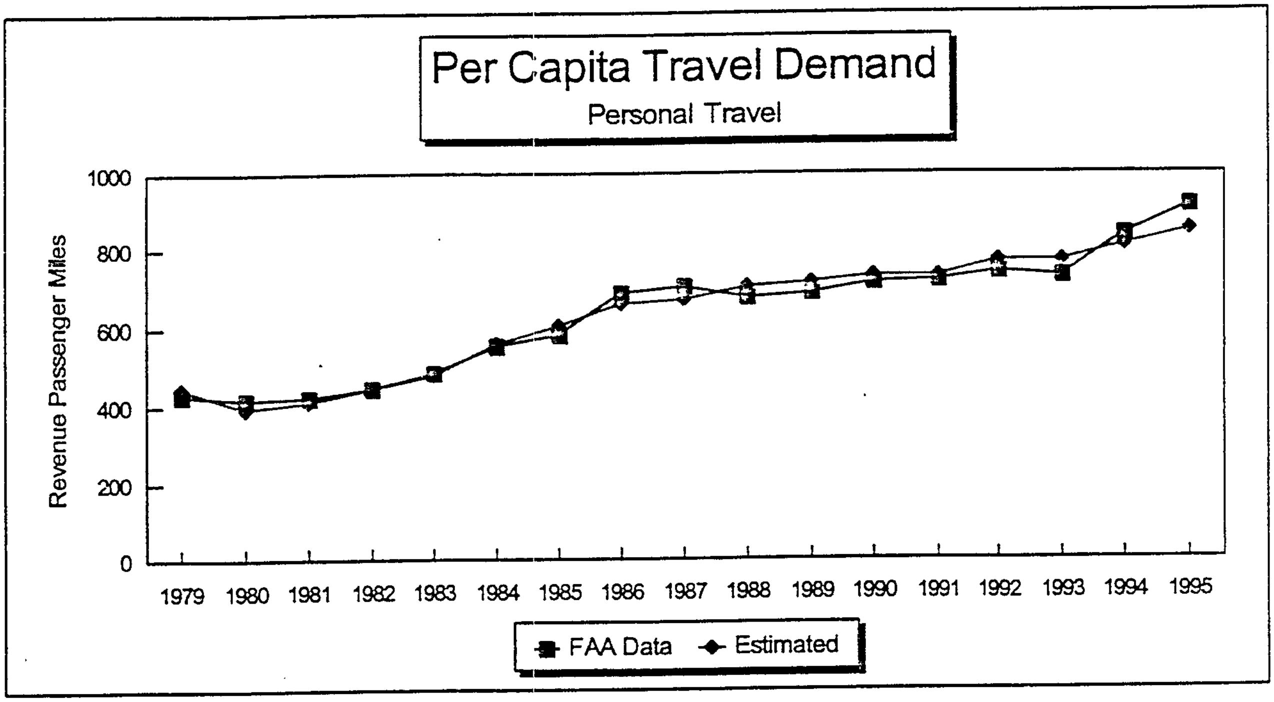


$RPMBPC$ = 89.70	+ .029 $GDPPC92$	− 16.04 $YIELD$	(E-6)
SE	.01	8.2	
t	3.04	−1.35	
$Adj.R^2$ = 0.849		$D\text{-}W$ = 1.15	

Sources:

(1) RPMBPC: Quotient of Business RPM and Population.

(2) GDPPC92: Gross Domestic Product per Capita, in 1992 dollars. From NEMS Macroeconomic Module.



$$RPMPPC = -481.84 + .083\,DPIPC92 - 18.68\,YIELD \tag{E-7}$$

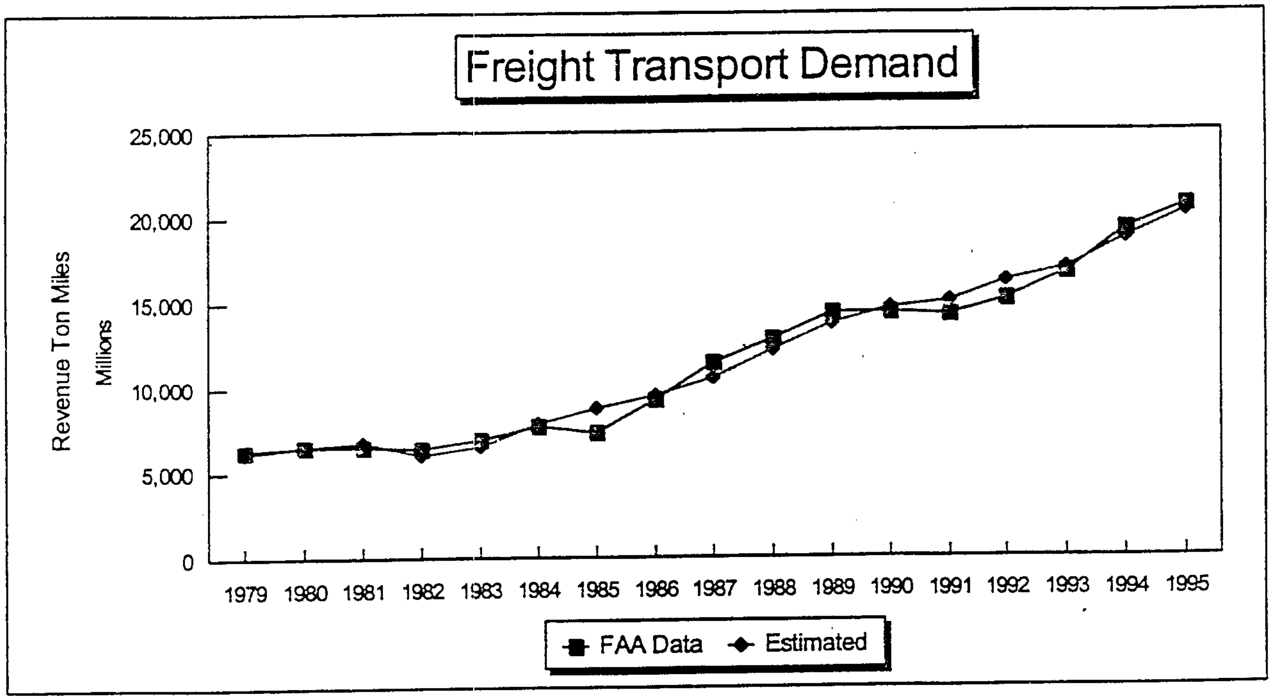
SE	.013	8.40
t	2.35	−2.22

$Adj.R^2 = .96$ $\qquad$ $D\text{-}W = 1.48$

Sources:

(1) **RPMPPC:** Quotient of Personal RPM and Population.

(2) **DPIPC92:** Disposable Personal Income per Capita, in 1992 dollars. From NEMS Macroeconomic Module.



$$RTM = (-14{,}556 + 19.81\,EXP92 + 3.49\,GDP92) \cdot DFRT \qquad \text{(E-8)}$$

SE		4.03	0.675
t		4.91	5.18
$Adj.R^2 = .98$			$D\text{-}W = 1.22$

Sources:

(1) **RTM:** U.S. Department of Transportation, Research and Special Projects Administration (RSPA), *Air Carrier Traffic Statistics Monthly, December 1990/1989,* and prior issues. Lines 18-21, 46.

(2) **EXP92:** Merchandise trade exports, in 1987 dollars, from NEMS Macroeconomic Module (variable name: EXD&N87).

(3) **DFRT:** *Post-hoc* freight adjustment factor, exogenously determined. Represents fraction of freight transported by dedicated carriers.