TRANSPORTATION SECTOR MODEL OF THE NATIONAL ENERGY MODELING SYSTEM

Volume II--Appendices

Part 1

January 1998

Office of Integrated Analysis and Forecasting
Energy Information Administration
U.S. Department of Energy
Washington, DC
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Released for Printing: January 13, 1998
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<th>ITEM</th>
<th>CLASS. (Source)</th>
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<th>EQ #</th>
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<td>Variable</td>
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<td>Fuel economy for cars within six size classes</td>
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<td>FEM vehicle size class index (7)</td>
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<td>ign</td>
<td>Index</td>
<td>CAFE group index: 1 = domestic car, 2 = import car, 3 = domestic light truck, 4 = import light truck</td>
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<td>ino</td>
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<td>MKTSPEN</td>
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<td>Variable</td>
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<td>Time period index (1990 = 1)</td>
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### LIGHT DUTY VEHICLE MODULE: Regional Sales Model

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<th>UNITS</th>
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<th>EQ #</th>
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<td>COMTSHARE</td>
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<td>COSTMIR</td>
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<td>FLTTRAT</td>
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<td>NCS</td>
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### LIGHT DUTY VEHICLE STOCK MODULE

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<td>Total new light truck sales, by technology</td>
<td>Units</td>
<td>TSMOD</td>
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</tr>
<tr>
<td>TECHNLT</td>
<td>Variable</td>
<td>Non-fleet new light truck sales, by technology /T</td>
<td>Units</td>
<td>TMPGAG</td>
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<tr>
<td>TLDVMPG</td>
<td>Variable</td>
<td>Average fuel economy of light-duty vehicles</td>
<td>MPG</td>
<td>TMPGAG</td>
<td>161</td>
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<tr>
<td>TMC_POPAFO</td>
<td>Variable</td>
<td>Total population, from MACRO module</td>
<td>Units</td>
<td>TVMT</td>
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<td>TMC_SQDTRUCKSL</td>
<td>Variable</td>
<td>Total light truck sales, from MACRO module</td>
<td>Units</td>
<td>TFREISMOD</td>
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<td>TMC_YD</td>
<td>Variable</td>
<td>Total disposable personal income, from MACRO module</td>
<td>$</td>
<td>TVMT</td>
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<td>TMPGLDVSTK</td>
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<td>Average MPG by vehicle type /T</td>
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<td>TEMPSTG</td>
<td>Variable</td>
<td>Light truck stock MPG</td>
<td>Miles per gallon</td>
<td>TMPGSTK</td>
<td>135</td>
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<td>TOTMICT</td>
<td>Variable</td>
<td>Total miles driven by cars</td>
<td>Miles</td>
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<td>TOTMITT</td>
<td>Variable</td>
<td>Total miles driven by light trucks</td>
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<td>TPMGTR</td>
<td>Variable</td>
<td>Price of motor gasoline</td>
<td>$ per gallon</td>
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<td>TRFLTMPG</td>
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<td>TRSAL</td>
<td>Variable</td>
<td>Light truck sales for freight</td>
<td>Units</td>
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<td>TRSALTECH</td>
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<td>Light truck sales by technology</td>
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<td>Light truck stock by technology</td>
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<td>TRSTKTOT</td>
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<td>Total light truck stock by technology</td>
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<td>TSTOCKLDV</td>
<td>Variable</td>
<td>Total stock by vehicle type ( VT )</td>
<td>Units</td>
<td>TMPGAG</td>
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<td>TTMPGLDV</td>
<td>Variable</td>
<td>New light truck MPG, by technology ( VT )</td>
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<td>TTMPGSTK</td>
<td>Variable</td>
<td>Light truck stock MPG, by vintage and technology</td>
<td>Miles per gallon</td>
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<td>VDF</td>
<td>Input Data (N)</td>
<td>Vehicle fuel efficiency degradation factor</td>
<td>Percent</td>
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<td>VMTECH</td>
<td>Variable</td>
<td>Personal travel VMT by technology</td>
<td>Vehicle-miles</td>
<td>TVMT</td>
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<td>VMT for personal travel</td>
<td>Vehicle-miles</td>
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<td>VMTLDV</td>
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<td>Total VMT for light duty vehicles</td>
<td>Vehicle-miles</td>
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<td>VSPLDV</td>
<td>Variable</td>
<td>The light duty vehicle shares of each of the sixteen vehicle technologies</td>
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<td>124</td>
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<td>( VT )</td>
<td>Index</td>
<td>Index of vehicle type: 1 = cars, 2 = light trucks</td>
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<td>XLDVMT</td>
<td>Variable</td>
<td>Fractional change of VMT over base year (1990)</td>
<td>Percent</td>
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<td>146</td>
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<td>APSHRS5</td>
<td>Variable</td>
<td>Absolute regional market shares of adjusted vehicle sales</td>
<td>Percent</td>
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<tr>
<td>APSHRFLTB</td>
<td>Variable</td>
<td>Market shares of business fleet by vehicle type and technology</td>
<td>Percent</td>
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<td>106</td>
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<td>APSHRFLTB</td>
<td>Variable</td>
<td>Alternative technology shares for the business fleet</td>
<td>Percent</td>
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<td>84</td>
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<td>APSHRFLTOT</td>
<td>Variable</td>
<td>Aggregate market shares of fleet vehicle technologies</td>
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<td>Market shares of new cars by technology</td>
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<td>104</td>
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<tr>
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<td>Variable</td>
<td>Market shares of new light trucks by technology</td>
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<td>104</td>
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<td>AVSALES</td>
<td>Variable</td>
<td>Regional adjusted vehicle sales by size class</td>
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<td>97</td>
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<td>AVSALEST</td>
<td>Variable</td>
<td>Total regional adjusted vehicle sales by size class</td>
<td>Units</td>
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<td>ELECVSAL</td>
<td>Variable</td>
<td>Regional electric vehicle sales</td>
<td>Units</td>
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<td>ELECVSALSC</td>
<td>Variable</td>
<td>Regional ZEV sales within corresponding regions</td>
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<td>96</td>
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<td>EPACT</td>
<td>Parameter</td>
<td>Legislative mandates for AFV purchases, by fleet type</td>
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<td>81</td>
</tr>
<tr>
<td>FLTALT</td>
<td>Variable</td>
<td>Number of AFV's purchased by each fleet type in a given year</td>
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<td>TFLTSTKS</td>
<td>81</td>
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<tr>
<td>FTLAPSHRI</td>
<td>Input Data</td>
<td>Fraction of each fleets' purchases which are AFV's, from historical data</td>
<td>Percent</td>
<td>TEXOG</td>
<td>81</td>
</tr>
<tr>
<td>FLTCNV</td>
<td>Variable</td>
<td>Fleet purchases of conventional vehicles</td>
<td>Units</td>
<td>TFLTSTKS</td>
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</tr>
<tr>
<td>FLTCRAT</td>
<td>Input Data</td>
<td>Fraction of total car sales attributed to fleets</td>
<td>Percent</td>
<td>TEXOG</td>
<td>80</td>
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<td>FLTCSHR</td>
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<td>Fraction of fleet cars purchased by a given fleet type</td>
<td>Percent</td>
<td>TEXOG</td>
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<tr>
<td>FLTECH</td>
<td>Variable</td>
<td>Vehicle purchases by fleet type and technology</td>
<td>Units</td>
<td>TFLTSTKS</td>
<td>85</td>
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<tr>
<td>FLTECHSAL</td>
<td>Variable</td>
<td>Fleet sales by size, technology, and fleet type</td>
<td>Units</td>
<td>TFLTSTKS</td>
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<tr>
<td>FLTECHSHR</td>
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<td>Alternative technology shares for the government and utility fleets</td>
<td>Percent</td>
<td>TEXOG</td>
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<td>FLTFCLDVBTU</td>
<td>Variable</td>
<td>Fuel consumption by vehicle type and technology</td>
<td>MMBtu</td>
<td>TFLTCONS</td>
<td>117</td>
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<td>FLTFCLDVBTUR</td>
<td>Variable</td>
<td>Regional fuel consumption by fleet vehicles, by technology</td>
<td>MMBtu</td>
<td>TFLTCONS</td>
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<td>FLTLDVVC</td>
<td>Variable</td>
<td>Fuel consumption by technology, vehicle and fleet type</td>
<td>MMBtu</td>
<td>TFLTCONS</td>
<td>116</td>
</tr>
<tr>
<td>FLTMPG</td>
<td>Variable</td>
<td>New fleet vehicle fuel efficiency, by fleet type and engine technology</td>
<td>Miles per Gallon</td>
<td>TFLTMPG</td>
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<tr>
<td>FLTMPGVTOT</td>
<td>Variable</td>
<td>Overall fuel efficiency of new fleet cars and light trucks</td>
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<td>TFLTMPG</td>
<td>112</td>
</tr>
<tr>
<td>FLTSAL</td>
<td>Variable</td>
<td>Sales to fleets by vehicle and fleet type</td>
<td>Units</td>
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<tr>
<td>FLTSLSCA</td>
<td>Variable</td>
<td>Fleet purchases of AFV's, by size class</td>
<td>Units</td>
<td>TFLTSTKS</td>
<td>83</td>
</tr>
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<td>Variable</td>
<td>Fleet purchases of conventional vehicles, by size class</td>
<td>Units</td>
<td>TFLSTSKS</td>
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<td>FLTSSHR</td>
<td>Input Data</td>
<td>Percentage of fleet vehicles in each size class, from historical data</td>
<td>Percent</td>
<td>TEXOG</td>
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<tr>
<td>FLTSTKVN</td>
<td>Variable</td>
<td>Fleet stock by fleet type, technology, and vintage</td>
<td>Units</td>
<td>TFLSTSKS</td>
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<tr>
<td>FLTTOTMPG</td>
<td>Variable</td>
<td>Fleet vehicle average fuel efficiency for cars and light trucks</td>
<td>Miles per</td>
<td>TFLTMPG</td>
<td>115</td>
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<tr>
<td>FLTRAT</td>
<td>Input Data</td>
<td>Fraction of total truck sales attributed to fleets</td>
<td>Percent</td>
<td>TEXOG</td>
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<tr>
<td>FLTSSHR</td>
<td>Input Data</td>
<td>Fraction of fleet trucks purchased by a given fleet type</td>
<td>Percent</td>
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<tr>
<td>FLTVMT</td>
<td>Variable</td>
<td>Total VMT driven by fleet vehicles</td>
<td>Vehicle Miles</td>
<td>TFLTVMTS</td>
<td>108</td>
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<td>FLTVMTECH</td>
<td>Variable</td>
<td>Fleet VMT by technology, vehicle type, and fleet type</td>
<td>Vehicle Miles</td>
<td>TFLTVMTS</td>
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</tr>
<tr>
<td>FLTVMTYR</td>
<td>Variable</td>
<td>Annual miles of travel per vehicle, by vehicle and fleet type</td>
<td>Miles</td>
<td>TFLTVMTS</td>
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<tr>
<td>FMSHC</td>
<td>Variable</td>
<td>The market share of fleet cars, from the AFV model</td>
<td>Percent</td>
<td>TFLTMPG</td>
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<td>FMSHLET</td>
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<td>The market share of fleet light trucks, from the AFV model</td>
<td>Percent</td>
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<td>IR</td>
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<td>Corresponding regions: ST = CA, MA, NY; IR = 9.1.2</td>
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<tr>
<td>IS</td>
<td>Index</td>
<td>Index of size classes: 1 = small, 2 = medium, 3 = large</td>
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<td>ITECH</td>
<td>Index</td>
<td>Index of engine technologies: 1-5 = alternative fuels (neat), 6 = gasoline</td>
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<td>IFF</td>
<td>Index</td>
<td>Index of fleet vehicle technologies, corresponding to IFF = 3,5,7,8,9</td>
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<td>TLEGIS</td>
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<tr>
<td>IITY</td>
<td>Index</td>
<td>Index of fleet type: 1 = business, 2 = government, 3 = utility</td>
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<td>MAXINT</td>
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<td>Maximum IINT index associated with a given vehicle and fleet type</td>
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<td>MPGFLTSTK</td>
<td>Variable</td>
<td>Fleet MPG by vehicle and fleet type, and technology, across vintages</td>
<td>Miles per</td>
<td>TFLTMPG</td>
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<tr>
<td>MPGFSK</td>
<td>Variable</td>
<td>Fleet MPG by vehicle and fleet type, technology, and vintage</td>
<td>Miles per</td>
<td>TFLTMPG</td>
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<td>NAMPG</td>
<td>Variable</td>
<td>New AFV fuel efficiency, from the AFV model</td>
<td>Miles per</td>
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<tr>
<td>NCSTECH</td>
<td>Variable</td>
<td>Regional new car sales by technology, within six size classes: OSC = 1-6; IS = 2.1.1.3.3.2</td>
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<td>TLEGIS</td>
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<tr>
<td>NLTECH</td>
<td>Variable</td>
<td>Regional light truck sales by technology, with six size classes: OSC = 1-6; IS = 1.2.1.3.3.3</td>
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<td>TLEGIS</td>
<td>107</td>
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<td>OLDFSTK</td>
<td>Variable</td>
<td>Old fleet stocks of given types and vintages, transferred to the private sector</td>
<td>Units</td>
<td>TFLTSTKS</td>
<td>87</td>
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<td>QBTU</td>
<td>Input Data (I)</td>
<td>Energy content of the fuel associated with each technology</td>
<td>Btu/Gal</td>
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<td>RSHR</td>
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<td>Regional VMT shares, from the Regional Sales Module</td>
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<td>TREG</td>
<td>118</td>
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<td>Index of participating state: CA, MA, NY</td>
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<td>STATESHR</td>
<td>Variable</td>
<td>Share of national vehicle sales attributed to a given state</td>
<td>Percent</td>
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<td>SURVFLTT</td>
<td>Input Data (G)</td>
<td>Survival rate of a given vintage</td>
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<tr>
<td>TFLTECHSTK</td>
<td>Variable</td>
<td>Total stock within each technology and fleet type</td>
<td>Units</td>
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<tr>
<td>TMC_SQDTRUCKSL</td>
<td>Variable</td>
<td>Total light truck sales in a given year</td>
<td>Units</td>
<td>TMAC</td>
<td>80</td>
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<td>TMC_SOTRCARS</td>
<td>Variable</td>
<td>Total automobile sales in a given year</td>
<td>Units</td>
<td>TMAC</td>
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<td>TOTFLTSTK</td>
<td>Variable</td>
<td>Total of all surviving fleet vehicles</td>
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<td>TFLTSTKS</td>
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<td>ULEV</td>
<td>Data Input (J)</td>
<td>State-mandated minimum sales share of ULEV's</td>
<td>Percent</td>
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<td>94</td>
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<td>ULEVST</td>
<td>Variable</td>
<td>State-mandated minimum sales of ULEV's</td>
<td>Units</td>
<td>TLEGIS</td>
<td>94</td>
</tr>
<tr>
<td>VFSTKPF</td>
<td>Variable</td>
<td>Share of fleet stock by vehicle type and technology</td>
<td>Percent</td>
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<td>90</td>
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<tr>
<td>VSALES</td>
<td>Variable</td>
<td>Total disaggregate vehicle sales</td>
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<td>VSALESC16</td>
<td>Variable</td>
<td>Total new car sales by technology: IS = 1, OSC = 2.3; IS = 2, OSC = 1.6; IS = 3, OSC = 4.5</td>
<td>Units</td>
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<tr>
<td>VSALEST</td>
<td>Variable</td>
<td>Total regional vehicle sales, by size class</td>
<td>Units</td>
<td>TLEGIS</td>
<td>93</td>
</tr>
<tr>
<td>VSALEST16</td>
<td>Variable</td>
<td>Total new light truck sales by technology: IS = 1, OSC = 1.3; IS = 2, OSC = 2.5; IS = 3, OSC = 4.6</td>
<td>Units</td>
<td>TLEGIS</td>
<td>103</td>
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<td>IS</td>
<td>Index</td>
<td>Index of vehicle type: 1 = cars, 2 = light trucks</td>
<td>—</td>
<td>TFLTSTKS</td>
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<td>ZEV</td>
<td>Data Input (J)</td>
<td>State-mandated minimum sales of ZEV's</td>
<td>Percent</td>
<td>TLEGIS</td>
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<td>ZEVST</td>
<td>Variable</td>
<td>State-mandated minimum sales share of ZEV's</td>
<td>Units</td>
<td>TLEGIS</td>
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<tr>
<td>ZEVSTSC</td>
<td>Variable</td>
<td>Mandated ZEV sales by size class and state</td>
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<tbody>
<tr>
<td>DFRT</td>
<td>Parameter (O)</td>
<td>Fraction of freight ton-miles transported on dedicated carriers.</td>
<td>Percent</td>
<td>TAIRT</td>
<td>199</td>
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<td>Parameter (O)</td>
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<tr>
<td>EQSM</td>
<td>Input Data (O)</td>
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<tr>
<td>LFDOM</td>
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<td>LFINTER</td>
<td>Parameter (O)</td>
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<tr>
<td>OPCST</td>
<td>Input Data (O)</td>
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<td>PCTINT</td>
<td>Parameter (O)</td>
<td>Proportionality factor relating international to domestic travel levels.</td>
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<tr>
<td>RPMB</td>
<td>Variable</td>
<td>Revenue passenger miles of domestic travel for business purposes.</td>
<td>Passenger Miles</td>
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<tr>
<td>RPMBPC</td>
<td>Variable</td>
<td>Per capita domestic RPM for business travellers.</td>
<td>Miles per Capita</td>
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<tr>
<td>RPMD</td>
<td>Variable</td>
<td>Total domestic revenue passenger miles.</td>
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<td>RPMI</td>
<td>Variable</td>
<td>Revenue passenger miles of international travel.</td>
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<tr>
<td>RPMIPC</td>
<td>Variable</td>
<td>Per capita international RPM</td>
<td>Miles per Capita</td>
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<tr>
<td>RPMMP</td>
<td>Variable</td>
<td>Revenue passenger miles of domestic travel for personal purposes.</td>
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<tr>
<td>RPMMPPC</td>
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<td>Per capita domestic RPM for personal travel.</td>
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<td>RKT</td>
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<td>Revenue ton miles of cargo.</td>
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<td>Variable</td>
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<td>Variable</td>
<td>Real gross domestic product</td>
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<td>TMC_POPAFO</td>
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<td>ASMP</td>
<td>Variable</td>
<td>The available seat-miles per plane, by type</td>
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<td>User-specified rate of passenger shifts between aircraft types</td>
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<tr>
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<tr>
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<td>OIJETR</td>
<td>Variable</td>
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<tr>
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<td>Parameter (P)</td>
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<tr>
<td>SEAT</td>
<td>Input Data (P)</td>
<td>Average number of seats per aircraft, by type.</td>
<td>Seats per Aircraft</td>
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<tr>
<td>SMFRCN</td>
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<td>Fraction of seat-mile demand on narrow-body planes</td>
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<tr>
<td>SMFRCN</td>
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<tr>
<td>SMPGT</td>
<td>Variable</td>
<td>Overall fleet average seat-miles per gallon</td>
<td>SMPG</td>
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<tr>
<td>SMSURV</td>
<td>Variable</td>
<td>Surviving travel capacity by body type.</td>
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<td>Parameter (P)</td>
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<tr>
<td>STKOLD</td>
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<td>Fraction of planes older than one year, by aircraft type</td>
<td>Percent</td>
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<td>TPJFGAL</td>
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<td>Price of jet fuel</td>
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<td>TPN</td>
<td>Variable</td>
<td>Binary variable (0,1) which tests whether current fuel price exceeds the considered technology's trigger price</td>
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<tr>
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<tr>
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<td>XAIREFF</td>
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<tr>
<td>FAC</td>
<td>Input Data</td>
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<td>FBENCH</td>
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<tr>
<td>FMPG</td>
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<td>Value of output of each industry in base year dollars.</td>
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<td>RTMT</td>
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<td>Total rail freight traffic, by industry</td>
<td>Ton Miles</td>
<td>TRAIL</td>
<td>180</td>
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<tr>
<td>RTMTT</td>
<td>Variable</td>
<td>Total rail ton-miles traveled</td>
<td>Ton Miles</td>
<td>TRAIL</td>
<td>181</td>
</tr>
<tr>
<td>SEDSHR</td>
<td>Parameter (K)</td>
<td>Regional shares of shipping fuel demand</td>
<td>Percent</td>
<td>TFREI</td>
<td>179</td>
</tr>
<tr>
<td>SFD</td>
<td>Variable</td>
<td>Domestic freighter energy demand, by fuel</td>
<td>MMBtu</td>
<td>TSHIP</td>
<td>189</td>
</tr>
<tr>
<td>SFDBENCH</td>
<td>Parameter (I)</td>
<td>Benchmark factor to ensure congruence with 1990 data</td>
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<td>188</td>
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<tr>
<td>SFDT</td>
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<td>MMBtu</td>
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<tr>
<td>SFSHARE</td>
<td>Parameter (B)</td>
<td>Domestic shipping fuel allocation factor</td>
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<tr>
<td>SUMFVMT</td>
<td>Variable</td>
<td>Total freight VMT for the second size class for use in TMISC</td>
<td>Vehicle Miles</td>
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</tr>
<tr>
<td>TBETA1</td>
<td>Parameter</td>
<td>Base rate of fuel economy growth, by size class</td>
<td>Percent</td>
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<td>174</td>
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<tr>
<td>TBETA2</td>
<td>Parameter</td>
<td>Fuel-price sensitive rate of fuel economy growth, by size class</td>
<td>Percent</td>
<td>TFREI</td>
<td>174</td>
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<td>TECH</td>
<td>Index</td>
<td>Index of engine technology (1-5)</td>
<td>—</td>
<td>TFREI</td>
<td>—</td>
</tr>
<tr>
<td>TMC_YD</td>
<td>Variable</td>
<td>Disposable personal income, from the MACRO module</td>
<td>$</td>
<td>TFREI</td>
<td>165</td>
</tr>
<tr>
<td>TPMGTR</td>
<td>Variable</td>
<td>Price of motor gasoline used for highway transport</td>
<td>$ per Gallon</td>
<td>TFREI</td>
<td>174</td>
</tr>
<tr>
<td>TQFREIR</td>
<td>Variable</td>
<td>Total regional truck fuel consumption for each technology</td>
<td>MMBtu</td>
<td>TFREI</td>
<td>179</td>
</tr>
<tr>
<td>TQFREIRSC</td>
<td>Variable</td>
<td>Total regional freight energy demand by technology and size class</td>
<td>MMBtu</td>
<td>TFREI</td>
<td>179</td>
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<tr>
<td>TQISHIPR</td>
<td>Variable</td>
<td>Total regional energy demand by international freighters</td>
<td>MMBtu</td>
<td>TSHIP</td>
<td>193</td>
</tr>
<tr>
<td>TQRAIL</td>
<td>Variable</td>
<td>Total demand for each fuel by rail freight sector in year T</td>
<td>MMBtu</td>
<td>TRAIL</td>
<td>183</td>
</tr>
<tr>
<td>TQRAILR</td>
<td>Variable</td>
<td>Total regional rail fuel consumption for each technology</td>
<td>MMBtu</td>
<td>TRAIL</td>
<td>184</td>
</tr>
<tr>
<td>TQRAILT</td>
<td>Variable</td>
<td>Total energy consumption by freight trains in year T</td>
<td>MMBtu</td>
<td>TRAIL</td>
<td>182</td>
</tr>
<tr>
<td>TQSHIPR</td>
<td>Variable</td>
<td>Total regional energy demand by domestic freighters, by fuel type</td>
<td>MMBtu</td>
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<td>TRSCSHR</td>
<td>Input Data (B)</td>
<td>Travel share distribution factors, held constant</td>
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<td>168</td>
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<tr>
<td>TSIC</td>
<td>Variable</td>
<td>Value of output of industry $I$, in base year (1990) dollars</td>
<td>$</td>
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<td>162</td>
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<tr>
<td>TSIC90</td>
<td>Input Data (I)</td>
<td>Base year value of industrial output</td>
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<td>TYD8290</td>
<td>Input Data (I)</td>
<td>Base year disposable personal income</td>
<td>$</td>
<td>TFREI</td>
<td>165</td>
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<tr>
<td>XFREFF</td>
<td>Variable</td>
<td>Fuel economy improvement over base year</td>
<td>Percent</td>
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<tr>
<td>XRAIL</td>
<td>Variable</td>
<td>Growth in rail travel from base year</td>
<td>Percent</td>
<td>TRAIL</td>
<td>185</td>
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<tr>
<td>XRAILEFF</td>
<td>Variable</td>
<td>Growth in rail efficiency from base year</td>
<td>Percent</td>
<td>TRAIL</td>
<td>185</td>
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<tr>
<td>XSHIP</td>
<td>Variable</td>
<td>Growth in ship travel from base year</td>
<td>Percent</td>
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<td>194</td>
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<tr>
<td>XSHIPEFF</td>
<td>Variable</td>
<td>Growth in ship efficiency from base year</td>
<td>Percent</td>
<td>TSHIP</td>
<td>194</td>
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<tr>
<td>XTOTVMT</td>
<td>Variable</td>
<td>Fractional growth in freight VMT over base year</td>
<td>Percent</td>
<td>TFREI</td>
<td>167</td>
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### MISCELLANEOUS ENERGY DEMAND MODULE

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

<table>
<thead>
<tr>
<th>ITEM</th>
<th>CLASS.</th>
<th>DESCRIPTION</th>
<th>UNITS</th>
<th>SUBROUTINE</th>
<th>EQ #</th>
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</thead>
<tbody>
<tr>
<td>TMEFF89</td>
<td>Input Data (B)</td>
<td>Base-year Btu per vehicle-mile, by mass transit mode</td>
<td>Btu per vehicle mile</td>
<td>TMISC</td>
<td>231</td>
</tr>
<tr>
<td>TMEFFL</td>
<td>Variable</td>
<td>Btu per passenger-mile, by mass transit mode</td>
<td>Btu per passenger mile</td>
<td>TMISC</td>
<td>231</td>
</tr>
<tr>
<td>TMFD</td>
<td>Variable</td>
<td>Total mass-transit fuel consumption by mode</td>
<td>Gallons</td>
<td>TMISC</td>
<td>232</td>
</tr>
<tr>
<td>TMOD</td>
<td>Variable</td>
<td>Passenger-miles traveled, by mode</td>
<td>Passenger miles</td>
<td>TMISC</td>
<td>230</td>
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<tr>
<td>TMLOAD89</td>
<td>Data Input (B)</td>
<td>Average passengers per vehicle, by mode, held constant at 1989 values (1=LDVs)</td>
<td>Units</td>
<td>TMISC</td>
<td>230</td>
</tr>
<tr>
<td>TYPE</td>
<td>Index</td>
<td>Vehicle type. from the Freight Module: 1 = Mid-size trucks. 2 = Rail</td>
<td>—</td>
<td>TFREI</td>
<td>231</td>
</tr>
<tr>
<td>VMTEE</td>
<td>Variable</td>
<td>LDV vehicle-miles traveled, from the VMT module</td>
<td>Vehicle miles</td>
<td>TVMT</td>
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</tr>
<tr>
<td>ITEM</td>
<td>CLASS</td>
<td>DESCRIPTION</td>
<td>UNITS</td>
<td>SUBROUTINE</td>
<td>EQ #</td>
</tr>
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<td>------------------------------------------------------------------------------</td>
<td>------------</td>
<td>------------</td>
<td>------</td>
</tr>
<tr>
<td>EFACT</td>
<td>Parameter (M)</td>
<td>Emissions factor relating measures of travel to pollutant emissions</td>
<td>—</td>
<td>TEMISS</td>
<td>240</td>
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<tr>
<td>EMISS</td>
<td>Variable</td>
<td>Regional emissions of a given pollutant, by mode of travel</td>
<td>Tons per year</td>
<td>TEMISS</td>
<td>240</td>
</tr>
<tr>
<td>IE</td>
<td>Index</td>
<td>Index of pollutants: 1 = SO₂, 2 = NOₓ, 3 = C, 4 = CO₂, 5 = CO, 6 = VOC</td>
<td>—</td>
<td>TEMISS</td>
<td>240</td>
</tr>
<tr>
<td>IM</td>
<td>Index</td>
<td>Index of travel mode: references individual vehicle types used in the preceding modules</td>
<td>—</td>
<td>TEMISS</td>
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<tr>
<td>IR</td>
<td>Index</td>
<td>Index identifying census region</td>
<td>—</td>
<td>TEMISS</td>
<td>240</td>
</tr>
<tr>
<td>U</td>
<td>Variable</td>
<td>Measure of travel demand, by mode: units in VMT for highway travel, gallons of fuel consumption for other modes</td>
<td>—</td>
<td>TEMISS</td>
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### SOURCES OF DATA INPUTS AND PARAMETERS USED IN THE NEMS TRANSPORTATION MODEL

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<tr>
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<th>SOURCE</th>
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Table A-2. Light Duty Vehicle Market Classes

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<tr>
<th>CLASS</th>
<th>DEFINITION</th>
<th>EXAMPLE MODEL</th>
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<tr>
<td><strong>AUTOMOBILES</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minicompact</td>
<td>Interior passenger volume &lt; 79 ft³</td>
<td>Geo Metro, Toyota Paseo (no domestic cars)</td>
</tr>
<tr>
<td>Subcompact</td>
<td>Passenger volume between 79 ft³ and 89 ft³</td>
<td>Nissan Sentra, Honda Civic, GM Saturn, Ford Escort</td>
</tr>
<tr>
<td>Sports</td>
<td>Two door high performance cars costing less than $25,000</td>
<td>VW Corrado, Honda Prelude, Chevy Camaro, Ford Mustang</td>
</tr>
<tr>
<td>Compact</td>
<td>Passenger volume between 89 and 95 ft³</td>
<td>Honda Accord, Toyota Camry, Ford Tempo, Pontiac Grand Am</td>
</tr>
<tr>
<td>Intermediate</td>
<td>Passenger volume between 96 and 105 ft³</td>
<td>Nissan Maxima, Ford Taurus, Chevy Lumina</td>
</tr>
<tr>
<td>Large</td>
<td>Passenger volume &gt;105 ft³</td>
<td>Ford Crown Victoria, Pontiac Bonneville (no imports)</td>
</tr>
<tr>
<td>Luxury</td>
<td>Cars over $25,000</td>
<td>Lincoln Continental, Cadillac, all Mercedes, Lexus LS400</td>
</tr>
<tr>
<td><strong>LIGHT TRUCKS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compact Pickup</td>
<td>Trucks with inertia weight between 2750 and 4000 lbs.</td>
<td>All import trucks, Ford Ranger, GM S-10/15</td>
</tr>
<tr>
<td>Compact Van</td>
<td>Vans with inertia weight between 3000 and 4250 lbs.</td>
<td>All import vans, Plymouth, Voyager, Ford Aerostar</td>
</tr>
<tr>
<td>Compact Utility</td>
<td>Utility vehicles with inertia weight between 3000 and 4250 lbs.</td>
<td>Nissan Pathfinder, Toyota SR-5, Ford Bronco II, Jeep Cherokee</td>
</tr>
<tr>
<td>Standard Pickup</td>
<td>Trucks with inertia weight over 4000 lbs.</td>
<td>GM C-10, Ford F-150 (no imports)</td>
</tr>
<tr>
<td>Standard Van</td>
<td>Vans with inertia weight over 4250 lbs.</td>
<td>GM C15 van, Ford E-150 (no imports)</td>
</tr>
<tr>
<td>Standard Utility</td>
<td>Utility vehicles with inertia weight over 4250 lbs.</td>
<td>Toyota Land Cruiser, GM Suburban, Ford Blazer</td>
</tr>
<tr>
<td>Mini-truck</td>
<td>Utility/trucks below 2750 lbs. inertia weight</td>
<td>Suzuki Samurai (no domestics)</td>
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</table>

National Energy Modeling System
Transportation Model Demand Sector Documentation Report
Table A-3. Maximum Light Duty Vehicle Market Penetration Parameters

<table>
<thead>
<tr>
<th>Old Market Share</th>
<th>New PMAX (Automobiles)</th>
<th>New PMAX (Light Trucks)</th>
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<tr>
<td>≤ 1%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>1.1-2%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>2.1-3%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>3.1-6%</td>
<td>12%</td>
<td>10%</td>
</tr>
<tr>
<td>6.1-10%</td>
<td>28%</td>
<td>22%</td>
</tr>
<tr>
<td>10.1-12%</td>
<td>32%</td>
<td>26%</td>
</tr>
<tr>
<td>12.1-14%</td>
<td>36%</td>
<td>30%</td>
</tr>
<tr>
<td>14.1-17%</td>
<td>41%</td>
<td>35%</td>
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<tr>
<td>17.1-20%</td>
<td>47%</td>
<td>40%</td>
</tr>
<tr>
<td>20.1-24%</td>
<td>53%</td>
<td>47%</td>
</tr>
<tr>
<td>24.1-27%</td>
<td>56%</td>
<td>50%</td>
</tr>
<tr>
<td>27.1-31%</td>
<td>60%</td>
<td>54%</td>
</tr>
<tr>
<td>31.1-35%</td>
<td>64%</td>
<td>58%</td>
</tr>
<tr>
<td>35.1-40%</td>
<td>68%</td>
<td>62%</td>
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<tr>
<td>40.1-45%</td>
<td>73%</td>
<td>67%</td>
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<tr>
<td>45.1-53%</td>
<td>78%</td>
<td>73%</td>
</tr>
<tr>
<td>53.1-62%</td>
<td>83%</td>
<td>79%</td>
</tr>
<tr>
<td>62.1-73%</td>
<td>88%</td>
<td>85%</td>
</tr>
<tr>
<td>73.1-85%</td>
<td>94%</td>
<td>92%</td>
</tr>
<tr>
<td>85.1-100%</td>
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<td>100%</td>
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### Table A-4. Aircraft Fleet Efficiency Model Adjustment Factors

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<th>DFRT</th>
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<tr>
<td>1979</td>
<td>0.974</td>
<td>0.27</td>
<td>0.509</td>
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<tr>
<td>1980</td>
<td>0.976</td>
<td>0.32</td>
<td>0.523</td>
</tr>
<tr>
<td>1981</td>
<td>0.978</td>
<td>0.30</td>
<td>0.514</td>
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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).
1) Calculate the fuel cost slope, used to linearly extrapolate expected fuel cost over the desired payback period:

\[
PSLOPE = \frac{\text{MAX} \left( 0, \frac{\text{FUEL}_{\text{YEAR-3}} \text{FUEL}_{\text{YEAR-5}}}{2} \right)}{2} \tag{B-1}
\]

where:

- PSLOPE = The fuel cost slope
- FUEL\text{\textsc{cost}} = 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):

\[
\text{PRICE}\text{\textsc{ex}}_i = PSLOPE \times (i+2) + FUEL_{\text{YEAR-3}} \tag{B-2}
\]

where:

- PRICE\text{\textsc{ex}}_i = The expected price of fuel

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

\[
\text{FUELSAVE}_{ic} = \sum_{t=1}^{\text{PAYBACK}} \text{VMT}_t \times \left( \frac{1}{\text{FE}_{ic,\text{YEAR-1}}} \times \frac{1}{(1 + \text{DELSFE}_{ic} \times \text{FE}_{ic,\text{YEAR-1}})} \right) \times \text{PRICE}\text{\textsc{ex}}_t \times (1 + \text{DISCOUNT})^{-t} \tag{B-3}
\]

where:

- \(ic\) = The index representing the technology under consideration
- FE = The fuel economy of technology \(ic\)
- DELSFE = The fractional change in fuel economy associated with technology \(ic\)
- PAYBACK = The user-specified payback period
- DISCOUNT = The user-specified discount rate
4) Calculate the cost of technology \( itc \):

\[
TECHCOST_{itc} = DELCOSTABS_{itc} - \left( \frac{DELSWGT_{itc} \cdot \text{WEIGHT}_{BASE}}{DELSWGT_{itc} \cdot \text{WEIGHT}_{BASE}} \right)
\]  

where:

\( DELCOSTABS \) = The fixed dollar cost of technology \( itc \)  
\( DELCOSTWGT \) = The weight-based change in cost (\$/lb)  
\( DELSWGWT \) = The fractional change in weight associated with technology \( itc \)  
\( \text{WEIGHT} \) = The original vehicle weight

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

\[
VALS\text{PERF}_{itc} = \frac{\text{VALUEPERF}_{itc}}{\text{INCOME}_{\text{TEAR}} - \frac{\text{FE}_{\text{TEAR-1}} \cdot (1 + \text{DELSF}_E_{itc})}{\text{FE}_{\text{TEAR-1}}} \cdot \frac{\text{FUELCO}_{\text{TEAR-1}}}{\text{PRICESEX}_{itc}} \cdot \text{DELSHP}_{itc}}
\]  

where:

\( VALS\text{PERF} \) = The dollar value of performance of technology \( itc \)  
\( \text{VALUEPERF} \) = The value associated with an incremental change in performance  
\( \text{DELSHP} \) = The fractional change in horsepower of technology \( itc \)  
\( \text{PRICESEX} \) = The expected price of fuel  
\( \text{FUELCO} \) = The actual price of fuel (in the previous year)

6) Calculate the cost effectiveness of technology \( itc \):

\[
\text{COSTEFFECT}_{itc} = \frac{\text{FUELSAVE}_{itc} - \text{TECHCOST}_{itc} - \frac{\text{VALUEPERF}_{itc}}{\text{TECHCOST}_{itc}} \cdot (\text{REGCOST} \cdot \text{FE}_{\text{TEAR-1}} \cdot \text{DELSF}_E_{itc})}{\text{ABS}(\text{TECHCOST}_{itc})}
\]  

where:

\( \text{COSTEFFECT} \) = A unitless measure of cost effectiveness  
\( \text{REGCOST} \) = A factor representing regulatory pressure to increase fuel economy  
\( \text{TECHCOST} \) = The cost of the considered technology  
\( \text{VALS\text{PERF}} \) = The performance value associated with technology \( itc \)
7) Calculate the preliminary economic market share of technology $i$: 

$$ACTUALSMKT_{i} = MMAX_{i} \times PMAX_{i} \times \left(1 + e^{-2 \times COSTEFFECT_{i}}\right)$$

where:

- $ACTUALSMKT_{i}$: The economic share, prior to consideration of engineering or regulatory constraints. The subsequent adjusted value is stored in the variable MKTSPEN.
- $MMAX_{i}$: The maximum market share for technology $i$, obtained from MKTSMAX.
- $PMAX_{i}$: 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:

$$ACTUALSMKT_{i} = \max \left( MKTSPEN_{\text{Y}ear-1}, \, ACTUALSMKT_{i} \right)$$

where:

- $MKTSPEN_{\text{Y}ear-1}$: The previous year's market share of technology $i$.

9) Apply mandatory constraints:

$$ACTUALSMKT_{i} = \max \left( ACTUALSMKT_{i}, \, MANDMKSH_{i} \right)$$

where:

- $MANDMKSH_{i}$: The minimum market share of technology $i$ required by legislative mandate.

10) Apply required engineering constraints (following a call to the subsequent subroutine NOTESUPER):

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

$$REQSMKT = \min \left( \sum_{req} ACTUALSMKT_{req}, \, 1.0 \right)$$

where:

- $REQSMKT$ = The total market share of those technologies which are required for the implementation of technology $i$, indicating that technology's maximum share.
b) Compare \( \text{REQS MKT} \) to the market share of technology referred to by the engineering note, \( \text{ACTUALSMKT}_{itc} \), selecting the smaller share:

\[
\text{ACTUALSMKT}_{itc} = \min \left( \text{ACTUALSMKT}_{itc}, \text{REQS MKT} \right) \quad (B-11)
\]

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

\[
\text{MKTSPEN}_{itc,igp,icl,year} = \text{ACTUALSMKT}_{itc} \quad (B-12)
\]

where:

\( \text{MKTSPEN} \) = The market penetration of technology \( itc \) by vehicle group \( igp \) and vehicle class \( icl \)

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

\[
\text{FE}_{YEAR} = \text{FE}_{YEAR} + \left( \text{MKTSPEN}_{itc1,icl,year} - \text{MKTSPEN}_{itc1,icl,year-1} \right) \times \left( \text{MKTSPEN}_{itc2,icl,year} - \text{MKTSPEN}_{itc2,icl,year-1} \right) \times \text{SYNRSDEL}_{itc1,itc2} \quad (B-13)
\]

where:

\( itc1 \) = First synergistic technology
\( itc2 \) = Second synergistic technology
\( \text{SYNRSDEL} \) = The synergistic effect of the two technologies on fuel economy

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

\[
\text{DELTASMKT}_{itc} = \text{MKTSPEN}_{itc,icl,year} - \text{MKTSPEN}_{itc,icl,year-1} \quad (B-14)
\]

where:

\( \text{DELTASMKT}_{itc} \) = The change in market share for technology \( itc \)
14) Calculate current fuel economy for the considered vehicle class:

\[ \text{FE}_{\text{YEAR}} = \text{FE}_{\text{YEAR}-1} + \sum_{i=1}^{\text{NUMTECH}} \text{FE}_{\text{YEAR}-1} \times \Delta \text{TAS}\text{MT}_{itc} \times \Delta \text{SFE}_{ite} \]  

(B-15)

where:

\[ \Delta \text{SFE}_{ite} = \text{The fractional change in fuel economy attributed to technology } itc \]

15) Calculate average vehicle weight for the considered class:

\[ \text{WEIGHT}_{\text{YEAR}} = \text{WEIGHT}_{\text{YEAR}-1} + \sum_{i=1}^{\text{NUMTECH}} \Delta \text{TAS}\text{MT}_{itc} \times \left[ \Delta \text{SWGT}_{\text{ABS}}_{itc} + \left( \text{WEIGHT}_{\text{BASEYEAR}} - \text{WEIGHT}_{\text{BASEYEAR}} \right) \times \Delta \text{SWGTWGT}_{itc} \right] \]  

(B-16)

where:

\[ \Delta \text{SWGT}_{\text{ABS}}_{itc} = \text{The change in weight (lbs) associated with technology } itc \]
\[ \Delta \text{SWGTWGT}_{itc} = \text{The fractional change in vehicle weight due to technology } itc \]
\[ \text{WEIGHT}_{\text{BASEYEAR}} = \text{The base year vehicle weight, absent the considered technology} \]

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

\[ \text{PRICE}_{\text{YEAR}} = \text{PRICE}_{\text{YEAR}-1} + \sum_{i=1}^{\text{NUMTECH}} \Delta \text{TAS}\text{MT}_{itc} \times \left[ \Delta \text{SCOST}_{\text{ABS}}_{itc} + \left( \text{WEIGHT}_{\text{YEAR}} - \text{WEIGHT}_{\text{BASEYEAR}} \right) \times \Delta \text{SCOSTWGT}_{itc} \right] \]  

(B-17)

where:

\[ \Delta \text{SCOST}_{\text{ABS}}_{itc} = \text{The cost of technology } itc \]
\[ \Delta \text{SCOSTWGT}_{itc} = \text{The weight-based change in cost of technology } itc \text{ (S/lb)} \]

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

\[ \text{HP}_{\text{YEAR}} = \text{HP}_{\text{BASEYEAR}} \times \frac{\text{WEIGHT}_{\text{YEAR}}}{\text{WEIGHT}_{\text{BASEYEAR}}} \]  

(B-18)

where:

\[ \text{HP}_{\text{BASEYEAR}} = \text{The base year average horsepower for the considered vehicle class} \]
18) Calculate the horsepower adjustment factor:

\[
ADJHP = \text{PERFFACT} \times \left( \frac{\text{INCOME}_\text{YEAR}}{\text{INCOME}_\text{YEAR-1}} \right)^{0.9} \times \left( \frac{\text{PRICE}_\text{YEAR}}{\text{PRICE}_\text{YEAR-1}} \right)^{0.9} \times \left( \frac{\text{FE}_\text{YEAR}}{\text{FE}_\text{YEAR-1}} \right)^{0.2} \times \left( \frac{\text{FUELCOST}_\text{YEAR-1}}{\text{FUELCOST}_\text{YEAR}} \right)^{0.2} - 1
\]  

(B-19)

where:

\( ADJHP = \) The fractional change in horsepower from the previous year within a given vehicle class

\( \text{INCOME} = \) Household income

\( \text{PRICE} = \) Vehicle price

\( \text{FE} = \) Vehicle fuel economy

\( \text{FUELCOST} = \) Fuel price

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

\[
\text{HP}_\text{YEAR} = \text{HP}_\text{YEAR} \times \left( 1 + \sum_{1990}^{\text{YEAR}} ADJHP \right)
\]  

(B-20)

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

\[
\text{ADJFE} = -0.22 \times ADJHP - 0.560 \times ADJHP^2 ; \quad ADJHP \geq 0
\]

\[
\text{ADJFE} = -0.22 \times ADJHP + 0.560 \times ADJHP^2 ; \quad ADJHP < 0
\]  

(B-21)

where:

\( \text{ADJFE} = \) The fuel economy adjustment factor

21) Calculate the adjusted fuel economy:

\[
\text{FE} = \text{FE} \times (1 + \text{ADJFE})
\]  

(B-22)

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

\[
\text{PRICE} = \text{PRICE} + ADJHP \times \text{VALUEPERF}
\]  

(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:

\[
TOTSMKT = \sum_{ino=1}^{numSSup} ACTUALSMTK_{ino} \quad (B-24)
\]

where:
- \( TOTSMKT \) = 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:

\[
MAXSHARE = \max (MKTSMAX_{ino}) \quad (B-25)
\]

---where:
- \( MKTSMAX \) = The maximum market share for the considered technology, exogenously set
- \( MAXSHARE \) = The maximum market share of the group, \( ino \)

3) If the aggregate market share (TOTSMKT) is greater than the maximum share (MAXSHARE), 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:

\[
DELSMKT = \min \left( \left( TOTSMKT - MAXSHARE \right), ACTUALSMTK_{ino} \right) \quad (B-26)
\]

where:
- \( DELSMKT \) = The amount of the superseded technology's market share to be removed
- \( ino \) = An index indicating the superseded technology
b) Adjust total market share to reflect this decrement

\[ TOTSMKT = TOTSMKT - DELSMKT \]  \hspace{1cm} \text{(B-27)}

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

\[ ACTUALSMKT_{\text{ino}} = ACTUALSMKT_{\text{ino}} - DELSMKT \]  \hspace{1cm} \text{(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:

\[ DIFFSLN = A \times \ln \left( \frac{YEAR}{1990} \right) + B \times \ln \left( \frac{FUELCOST_{\text{YEAR}}}{FUELCOST_{1990}} \right) + C \times \ln \left( \frac{INCOME_{\text{YEAR}} - $13,000}{INCOME_{1990} - $13,000} \right) \]  \hspace{1cm} \text{(B-29)}

where:

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

b) For luxury cars:

\[ DIFFSLN = A \times \ln \left( \frac{YEAR}{1990} \right) + B \times \ln \left( \frac{FUELCOST_{\text{YEAR}}}{FUELCOST_{1990}} \right) + C \times \ln \left( \frac{INCOME_{\text{YEAR}}}{INCOME_{1990}} \right) \]  \hspace{1cm} \text{(B-30)}

2) Solve for the log-share ratio:

\[ RATIOSLN = DIFFSLN + \ln \left( \frac{CLASSSHARE_{1990}}{1 - CLASSSHARE_{1990}} \right) \]  \hspace{1cm} \text{(B-31)}
where:

\[ \text{RATIOSLN} = \log \text{of the market share ratio of the considered vehicle class} \]

3) Solve for the class market share:

\[ \text{CMKS} = \frac{\exp (\text{RATIOSLN})}{1 + \exp (\text{RATIOSLN})} \]  \hspace{1cm} (B-32)

where:

\[ \text{CMKS} = \text{Class market share, subsequently reassigned to the appropriate vehicle class and group, CLASSSHARE}_{\text{id,gp}} \]

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

\[ \frac{\text{CLASSSHARE}_{\text{id,igp,year}}}{\sum_{\text{id}=1}^{7} \text{CLASSSHARE}_{\text{id,igp,year}}} = \frac{\text{CLASSSHARE}_{\text{id,igp,year}}}{\sum_{\text{id}=1}^{7} \text{CLASSSHARE}_{\text{id,igp,year}}} \]  \hspace{1cm} (B-33)

FUEL ECONOMY MODEL

Subroutine CAFECALC

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

\[ \text{CAFE}_{\text{id,igp,year}} = \frac{\sum_{\text{id}=1}^{7} \text{CLASSSHARE}_{\text{id,igp,year}}}{\sum_{\text{id}=1}^{7} \text{CLASSSHARE}_{\text{id,igp,year}}} \]  \hspace{1cm} (B-34)

where:

\[ \text{id} = \text{FEM vehicle size class index (7)} \]
\[ \text{igp} = \text{CAFE group index: 1 = domestic car, 2 = import car, 3 = domestic light truck, 4 = import light truck} \]
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:

\[
T\_{LDT\_MAC\_N} = MC\_SQDTRUCKS\_N \times LT10K \\
+ \left[ (LT2A4 \times LT2A4LDV) + (LTOSU \times LTOSULDV) \right].
\]  

(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:

\[
T\_{LDV\_MAC\_N} = MC\_SQTRCARS\_N + T\_{LDT\_MAC\_N}.
\] 

(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:

\[
TMC\_SQTRCARS\_N = T\_{LDV\_MAC\_N} \times (1 - CARLTSHR)
\]

\[
\text{and}
\]

\[
TMC\_SQDTRUCKS\_N = T\_{LDV\_MAC\_N} \times CARLTSHR.
\] 

(37)

where:
- \( TMC\_SQTRCARS \) = Total sales of new cars
- \( TMC\_SQDTRUCKS \) = Total sales of new light trucks
RVIC-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:

\[ MAPSALE_{igp,icl,osc,N} = NVS7SC_{igp,icl,N} \times MAP_{igp,icl,osc} \]  \hspace{1cm} (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:

\[ TOTNVS7 = \sum_{icl=1}^{7} MAPSALE_{igp,icl,osc,N} \]  \hspace{1cm} (B-39)

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

6) Create a mapping share:

\[ MAPSHR_{igp,icl,osc,N} = \frac{MAPSALE_{igp,icl,osc,N}}{TOTNVS7_{igp,osc,N}} \]  \hspace{1cm} (B-40)

where:
MAPSHR = Sales shares within the disaggregate array

7) Multiply MPG by mapped sales share:

\[ FEMPG_{igp,osc,N} = \sum_{icl=1}^{7} FE_{icl,igp,TEAR} \times MAPSHR_{igp,icl,osc,N} \]  \hspace{1cm} (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:

\[
BENCHMPG_{igp,osc} = \frac{ORNLMPG_{igp,osc}}{FEMPG_{igp,osc,N+3}}
\]

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:

\[
FESIXC_{osc,N} = \sum_{igp=1}^{2} FEMPG_{igp,osc,N} \times BENCHMPG_{igp,osc} \times ORNLSHR_{igp,osc}
\]

\[
FESIXT_{osc,N} = \sum_{igp=3}^{5} FEMPG_{igp,osc,N} \times BENCHMPG_{igp,osc} \times ORNLSHR_{igp,osc}
\]

where:

- FESIXC = Fuel economy for cars within six size classes
- FESIXT = Fuel economy for light trucks within six size classes

REGIONAL SALES MODEL

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:

\[
NVSTSC_{igp,icl,N} = CLASSSHARE_{icl,igp,YEAR} \times TMC_SQTRCARS_{N} \times (1 - FLTCTRAT_{1990}) \times SALESHR_{igp,N} \]

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)
CLASSSSHARE = The market share for each automobile class, from FEM
FLTTRAT = Fraction of new cars purchased by fleets
SALESHR = Fraction of vehicle sales which are domestic/imported

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

\[ \text{NVS7SC}_{igp,icl,N} = \text{CLASSSSHARE}_{icl,igp,N} \times \text{TMC_SQDTRUCKS}_N \times (1 - (\text{FLTTRAT}_{1990} + \text{COMTSHR})) \times \text{SALESHR}_{igp,N} \]  \hspace{1cm} (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:

\[ \text{NCSTSCC}_{osc,N} = \sum_{igp = 1}^{2} \sum_{icl = 1}^{7} \left( \text{NVS7SC}_{igp,icl,N} \right) \times \text{MAP}_{igp,icl,osc} \]  \hspace{1cm} (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:

\[ \text{NLTSTSCC}_{osc,N} = \sum_{igp = 3}^{4} \sum_{icl = 1}^{7} \left( \text{NVS7SC}_{igp,icl,N} \right) \times \text{MAP}_{igp,icl,osc} \]  \hspace{1cm} (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:
\[
PASSHR_{osc,N} = \frac{NCSTSCC_{osc,N}}{\sum_{osc=1}^{6} NCSTSCC_{osc,N}}
\tag{B-48}
\]

and:
\[
LTSHRR_{osc,N} = \frac{NLTSTSCC_{osc,N}}{\sum_{osc=1}^{6} NLTSTSCC_{osc,N}}
\tag{B-49}
\]

where:
PASSHR = Non-fleet market shares of automobiles, by size class osc
LTSHRR = Non-fleet market shares of light trucks, by size class osc

4) Reassign horsepower estimates to six size classes:
\[
HPCAR_{osc,N} = \sum_{igp=1}^{2} \sum_{icl=1}^{7} (HP_{icl,igp,YEAR}) \times SALESHR_{igp} \times MAP_{igp,icl,osc}
\tag{B-50}
\]

and:
\[
HPTRUCK_{osc,N} = \sum_{igp=3}^{4} \sum_{icl=1}^{7} (HP_{icl,igp,YEAR}) \times SALESHR_{igp} \times MAP_{igp,icl,osc}
\tag{B-51}
\]

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:
\[
AHPCAR_N = \sum_{osc=1}^{6} HPCAR_{osc,N} \times PASSHR_{osc,N}
\tag{B-52}
\]

and:

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where:

$\text{AHPCAR} = \text{Average automobile horsepower}$

$\text{AHPTRUCK} = \text{Average light truck horsepower}$

### REGIONAL SALES MODEL

#### Subroutine TREG

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

$$S_{\text{EDS} \text{SHR}_{F \text{UE}L, R \text{EG}, T}} = \frac{S_{\text{EDS} \text{SHR}_{F \text{UE}L, R \text{EG}, T-1}} * \left( \frac{\text{TMC}_{-} \text{YD}_{R \text{EG}, T}}{\text{TMC}_{-} \text{YD}_{R \text{EG}, T-1}} \right) \sum_{R \text{EG} = 1}^{9} S_{\text{EDS} \text{SHR}_{F \text{UE}L, R \text{EG}, T-1}} * \left( \frac{\text{TMC}_{-} \text{YD}_{R \text{EG}, T}}{\text{TMC}_{-} \text{YD}_{R \text{EG}, T-1}} \right)}$$

#### Subroutine TREG

2) Calculate regional cost of driving per mile:

$$\text{COSTMIR}_{R \text{EG}, T} = 0.1251 * \left( \frac{\text{TPMGTR}_{R \text{EG}, T}}{\text{MPGFLT}_{T-1}} \right)$$

3) Calculate regional income:
\[ \text{INCOMER}_{\text{REG},T} = \left( \frac{\text{TMC}_{\text{YD,REG},T}}{\text{TMC}_{\text{POPAFO,REG},T}} \right) \]  

where:

\( \text{INCOMER} \) = Regional per capita disposable income

\( \text{TMC}_{\text{POPAFO}} \) = Total population in region \( \text{REG} \)

4) Estimate regional driving demand:

\[ \begin{align*}
\text{VMT16R}_{\text{REG},T} &= \rho \text{VMT16R}_{\text{REG},T-1} + \beta_0 (1 - \rho) + \beta_1 (\text{COSTMIR}_{\text{REG},T} - \rho \text{COSTMIR}_{\text{REG},T-1}) \\
&+ \beta_2 (\text{INCOMER}_{\text{REG},T} - \rho \text{INCOMER}_{\text{REG},T-1}) + \beta_3 (\text{PRFEM}_{T} - \rho \text{PRFEM}_{T-1})
\end{align*} \]

and:

\[ \text{VMTEER}_{\text{REG},T} = \text{VMT16R}_{\text{REG},T} \times \text{TMC}_{\text{POP16,REG},T} \times \text{DAF}_{T} \]

where:

\( \text{VMT16R} \) = Vehicle-miles traveled per population over 16 years of age

\( \text{PRFEM} \) = Ratio of female to male driving rates

\( \rho \) = Lag factor for the difference equation

\( \text{VMTEER} \) = Total VMT in region \( \text{REG} \)

\( \text{TMC}_{\text{POP16}} \) = Total regional population over the age of 16

\( \text{DAF} \) = A demographic adjustment factor, to reflect different age groups' driving patterns

5) Calculate regional VMT shares (RSHR):

\[ \text{RSHR}_{\text{REG},T} = \frac{\text{VMTEER}_{\text{REG},T}}{\sum_{\text{REG} = 1}^{9} \text{VMTEER}_{\text{REG},T}} \]
6) Divide non-fleet car and light truck sales according to regional VMT shares:

\[ NCS_{REG,SC,T} = NCSTSCC_{SC,T} \times RSHR_{REG,T} \]  \hspace{1cm} (B-60)

and:

\[ NLTS_{REG,SC,T} = NLTSTSCC_{SC,T} \times RSHR_{REG,T} \]  \hspace{1cm} (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:

\[ COMAV_{IT,N} = \left[ 1 + \exp \left( \frac{TT50_{IT} - YEAR}{2} \right) \right]^{-1} \]  \hspace{1cm} (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:

\[ AFCOST_{IT,IR,N} = \frac{\sum_{FUEL} (RFP_{FUEL,IR,N} \cdot FAVAIL_{FUEL,IR,N})}{\sum_{FUEL} FAVAIL_{FUEL,IR,N}} \]  \hspace{1cm} (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:

\[
FEC3SC_{ISC,N} = \frac{\sum_{OSC} \left( \frac{NCSTSCC_{OSC,N}}{FESIXC_{OSC,N}} \right)}{\sum_{OSC} NCSTSCC_{OSC,N}}^{-1}
\]  
(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:

\[
FET3SC_{ISC,N} = \frac{\sum_{OSC} \left( \frac{NLTSTSCC_{OSC,N}}{FESIXT_{OSC,N}} \right)}{\sum_{OSC} NLTSTSCC_{OSC,N}}^{-1}
\]  
(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:

\[
VEFFACT_{ISC,N} = \frac{FEC3SC_{ISC,N}}{0.125}
\]  
(B-66)

where:

- \(VEFFACT\) = Gasoline vehicle fuel economy, used as a baseline
5) Calculate alternative vehicle fuel economy, using gasoline baseline:

\[ V_{EFFECTU, IT, N} = \frac{V_{EFF, IT, N} \cdot V_{EFFACT, IT, N}}{B_{EFFBTU}} \]  

where:

- \( V_{EFFBTU} \) = Fuel economy by technology \( IT \), in miles per MMBTU
- \( V_{EFF} \) = Fuel economy of technology \( IT \), relative to gasoline baseline

6) Calculate AFV operating cost, by region:

\[ COPCOST_{IT, ISC, RN} = \frac{AFCOST_{IT, ISC, RN} \cdot 100}{V_{EFFBTU, IT, ISC, RN}} \]  

where:

- \( COPCOST \) = Regional vehicle operating cost, in 1990$/mile

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

\[ VC_{IT, RN} = BETA_{CONST, IT} \cdot V_{PRICE3, IT, RN} \cdot V_{FAVIL3, IT, RN} \cdot V_{AVAIL3, IT, RN} \cdot V_{EMISS3, IT, RN} \cdot V_{EMISS3, IT, RN} \]  

where:

- \( VC_{3} \) = Utility vector for electric vehicles
- \( BETA_{CONST} \) = 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
- \( FAVIL3 \) = Fuel availability for EV technologies
- \( BETA_{VP} \) = Coefficient associated with vehicle price
- \( BETA_{FC} \) = Coefficient associated with fuel cost
- \( BETA_{VR} \) = Coefficient associated with vehicle range
- \( BETA_{EM} \) = Coefficient associated with vehicle emissions
- \( BETA_{FA} \) = Coefficient associated with fuel availability
- \( BETA_{VR2} \) = Coefficient associated with the square of vehicle range
- \( BETA_{EM2} \) = Coefficient associated with the square of vehicle emissions
- \( BETA_{FA2} \) = Coefficient associated with the square of fuel availability
8) Exponentiate utility vector, and adjust by commercial availability factor:

\[ EV_{CT,IS,IR,N} = \exp \left[ V_{CT,IS,IR,N} \right] \cdot COMAV_{IT,N} \]  \hspace{1cm} (B-70)

where:

\[ EV_{C3} = \text{Exponentiated value of electric vehicle utility vector} \]

9) Calculate electric vehicle market shares, by region:

\[ APSHR_{IS,IR,N} = \frac{EV_{CT,IS,IR,N}}{\sum_{IT=1}^{10} EV_{CT,IS,IR,N}} \]  \hspace{1cm} (B-71)

where:

\[ APSHR_{33} = \text{Relative market shares within the electric vehicle group} \]

**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:

\[ \Psi_{IS,IT,IR,N} = \sum_{IT=1}^{10} \Psi_{IS,IT,IR,N} \cdot APSHR_{IS,IR,N} \]  \hspace{1cm} (B-72)

where:

\[ \Psi = \text{VPRICE3, VEMISS3, VRANGE3, COMAV, COPCOST, FAVAIL33, and BETACONST} \]

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

\[ VC_{CT,IR} = \text{BETACONST2}_IT \cdot \text{BETAVP} \cdot V_{PRICE2_{IS,IT,N}} + \text{BETACL} \cdot \text{COPCOST2}_{IT,IS,IR,N} \]

\[ + \text{BETAVR} \cdot V_{RANGE2_{IS,IT,N}} + \text{BETAVR2} \cdot V_{RANGE2_2^{2}_{IS,IT,N}} + \text{BETAEM} \cdot EMISSIONS2_{IS,IT,N} \]  \hspace{1cm} (B-73)

\[ + \text{BETAEM2} \cdot EMISSIONS2^{2}_{IS,IT,N} + \text{BETAF2} \cdot FAVAIL22_{IT,IR,N} + \text{BETAF22} \cdot FAVAIL22^{2}_{IT,IR,N} \]

where:

\[ VC_2 = \text{Utility vector for alternative vehicles} \]

\[ \text{BETACONST2} = \text{Constant associated with each considered AFV technology} \]
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:

\[ EVCT_{I,T,J,S,R,N} = \exp \left( VC_{I,T,J,S,R,N} \right) \cdot COMAV_{T,N} \]  

(B-74)

where:

\[ EVCT = \text{Exponentiated value of alternative vehicle utility vector} \]

4) Calculate alternative vehicle market shares, by region:

\[ APSHR22_{I,S,R,J,N} = \frac{EVC2_{I,T,J,S,R,N}}{\sum_{I,T=3}^{13} EVC2_{I,T,J,S,R,N}} \]  

(B-75)

where:

\[ APSHR22 = \text{Relative market shares within the alternative vehicle group} \]

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:

\[ \Psi_{I,S,T,J,R,N} = \sum_{I,T=3}^{13} \Psi_{I,S,T,J,R,N} \cdot APSHR22_{I,S,R,J,N} \]  

(B-76)

where:

\[ \Psi = VPRICE2, VEMISS2, VRANGE2, COMAV, COPCOST2, FAVAIL22, \text{and BETACONST2} \]
2) Calculate utility for all vehicles $(IT = 1-3)$:

$$VCI_{IT,IS,IR,N} = \beta_{\text{CONST}} + \beta_{\text{AVP}} \cdot \text{VPRICE1}_{IT,IS,IR,N} + \beta_{\text{AVC}} \cdot \text{COPCOST1}_{IT,IS,IR,N}$$

$$+ \beta_{\text{AVR}} \cdot \text{VRANGE1}_{IT,IS,IR,N} + \beta_{\text{AVR2}} \cdot \text{VRANGE1}^2_{IT,IS,IR,N} + \beta_{\text{EMISS1}} \cdot \text{EMISS1}_{IT,IS,IR,N}$$

$$+ \beta_{\text{EMISS2}} \cdot \text{EMISS1}^2_{IT,IS,IR,N} + \beta_{\text{AVFA}} \cdot \text{FAVAIL11}_{IT,IS,IR,N} + \beta_{\text{AVFA2}} \cdot \text{FAVAIL11}^2_{IT,IS,IR,N} \quad (B-77)$$

where:

- $VCI = \text{Utility vector for conventional and alternative vehicles}$
- $\beta_{\text{CONST}} = \text{Constant associated with each considered technology}$
- $\text{COPCOST1} = \text{Fuel operating costs for conventional and alternative vehicles}$
- $\text{VPRICE1} = \text{Price of each considered technology in 1990S}$
- $\text{VRANGE1} = \text{Vehicle range of the considered technology}$
- $\text{EMISS1} = \text{Emissions levels relative to gasoline ICE's}$
- $\text{FAVAIL11} = \text{Fuel availability}$

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

$$EVCI_{IT,IS,IR,N} = \exp \left[ VCI_{IT,IS,IR,N} \right] \cdot \text{COMAV}_{IT,N} \quad (B-78)$$

where:

- $EVCI = \text{Exponentiated value of vehicle utility vector}$

4) Calculate vehicle market shares, by region:

$$\text{APSHR11}_{IS,IR,IT,N} = \frac{EVCI_{IT,IS,IR,N}}{\sum_{IT=1}^{3} EVCI_{IT,IS,IR,N}} \quad (B-79)$$

where:

- $\text{APSHR11} = \text{Relative market shares of conventional and alternative vehicles}$

5) Expand market share estimates to generate absolute market shares for each of the sixteen conventional and alternative technologies:
a) For conventional vehicles \((I_T = 16,15; ITI = 1,2)\):

\[
APSHR_{I_5,I_3,I_T,N}^{44} = APSHR_{I_5,I_3,I_T,1}^{11} \times APSHR_{I_5,I_3,I_T,2}^{22}
\]

\(\text{(B-80)}\)

where:

\(APSHR_{I_5,I_3,I_T}^{44} = \text{Absolute market share of technology } I_T\)

b) For non-electric alternative vehicles \((I_T = 1,6,11,14; ITI = 3; IT2 = 5,6,3,4,8-13)\):

\[
APSHR_{I_5,I_3,I_T,N}^{44} = APSHR_{I_5,I_3,I_T,1}^{11}
\]

\(\text{(B-81)}\)

c) For electric and electric hybrid vehicles \((I_T = 7-10; ITI = 3; IT2 = 7; IT3 = 1-4)\):

\[
APSHR_{I_5,I_3,I_T,N}^{44} = APSHR_{I_5,I_3,I_T,1}^{11} \times APSHR_{I_5,I_3,I_T,2}^{22} \times APSHR_{I_5,I_3,I_T,3}^{33}
\]

\(\text{(B-82)}\)
LIGHT DUTY VEHICLE FLEET MODULE

1) Calculate fleet acquisitions of cars and light trucks:

\[ FLTSAL_{VT,ITY} = FLTCRAT \times SQTRCARS_{ITY} \times FLTCSHR_{ITY} \]

and:

\[ FLTSAL_{VT,ITY} = FLTRAT \times SQTRUCKSL_{ITY} \times FLTTSHR_{ITY} \]

where:

- FLTSAL = Sales to fleets by vehicle and fleet type
- FLTCRAT = Fraction of total car sales attributed to fleets
- FLTRAT = 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:

\[ FLTALT_{VT,ITY} = \max \left[ \left( FLTSAL_{VT,ITY} \times FLTAPSHRI_{ITY} \right), \ EPACT_{VT,ITY} \right] \]

where:

- FLTALT = Number of AFVs purchased by each fleet type in a given year
- FLTAPSHRI = Fraction of each fleet's purchases which are AFVs, 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):

\[ FLTCONV_{VT,ITY} = FLTSAL_{VT,ITY} - FLTALT_{VT,ITY} \]

where:

- FLTCONV = Fleet purchases of conventional vehicles
4) Distribute fleet purchases among three size classes:

\[
FLTSLSCA_{VT,IT,IS,T} = FLTALT_{VT,IT,T} \times FLTSSHR_{VT,IT,IS,T}
\]

and:

\[
FLTSLSCC_{VT,IT,IS,T} = FLTCONV_{VT,IT,T} \times FLTSSHR_{VT,IT,IS,T}
\]

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:

\[
FLTECHSAL_{VT,IT,IS,ITECH,T} = FLTSLSCA_{VT,IT,T} \times APSHRFLTB_{VT,TECH,T+1,T}
\]

and:

\[
FLTECHSAL_{VT,IT,IS,ITECH,T} = FLTSLSCC_{VT,IT,T} \times FLTECHSHR_{ITECH,T,T}
\]

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:

\[
FLTECH_{VT,IT,ITECH,T} = \sum_{IS=1}^{3} FLTECHSAL_{VT,IT,IS,ITECH,T}
\]

where:
- \(FLTECH\) = Vehicle purchases by fleet type and technology
7) Calculate survival of older vehicles, and modify vintage array:

\[ \text{FLTSTKVN}_{VT,ITY,ITECH,IVIN,T} = \text{FLTSTKVN}_{VT,ITY,ITECH,IVIN-1,T-1} \times \text{SURVFLLT}_{VT,IVIN-1} \]

and:

\[ \text{FLTSTKVN}_{VT,ITY,ITECH,IVIN=1,T} = \text{FLTECH}_{VT,ITY,ITECH,T} \]  

where:

- \( \text{FLTSTKVN} \) = Fleet stock by fleet type, technology, and vintage
- \( \text{SURVFLLT} \) = Survival rate of a given vintage

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

\[ \text{OLDFSTK}_{VT,ITY,ITECH,IVIN,T} = \frac{\text{FLTSTKVN}_{VT,ITY,ITECH,IVIN,T}}{\text{RVINT}} \]  

where:

- \( \text{OLDFSTK} \) = Old fleet stocks of given types and vintages, transferred to the private sector
- \( \text{RVINT} \) = Retirement vintage of fleet vehicles: If \( VT = 1 \), \( IITY = 1,2,3 \), \( RVINT = 5,6,7 \); if \( VT = 2 \), \( IITY = 1,2,3 \), \( RVINT = 6,7,6 \)

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

\[ \text{TFLTECHSTK}_{VT,ITY,ITECH,T} = \sum_{IVIN=1}^{5} \text{FLTSTKVN}_{VT,ITY,ITECH,IVIN,T} \]  

where:

- \( \text{TFLTECHSTK} \) = Total stock within each technology and fleet type

10) Calculate grand total of surviving vehicles:

\[ \text{TOTFLTSTK}_{T} = \sum_{VT=1}^{2} \sum_{ITY=1}^{3} \sum_{ITECH=1}^{5} \text{TFLTECHSTK}_{VT,ITY,ITECH,T} \]  

where:

- \( \text{TOTFLTSTK} \) = Total of all surviving fleet vehicles
11) Calculate percentage of fleet stock represented by each of the vehicle, fleet types, and engine technologies:

\[
VFSTKPF_{VT,ITY,TECH,T} = \frac{TFLTECHSTK_{VT,ITY,TECH,T}}{TOTFLTSTK_T} \quad (B-93)
\]

where:

\(VFSTKPF\) = Share of fleet stock by vehicle type and technology

**LIGHT DUTY VEHICLE FLEET MODULE**

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:

\[
VSALES_{IS,IR,IT,N} = \sum_{OSC} APSHR44_{IS,IR,IT,N} \times \left( NCS_{IR,OSC,N} + NLTS_{IR,OSC,N} \right) \quad (B-94)
\]

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:

\[
ELECVSAL_{IR,N} = \sum_{IS=1}^{3} \sum_{IT=7}^{10} VSALES_{IS,IR,IT,N} \quad (B-95)
\]

where:

\(ELECVSAL\) = Regional electric vehicle sales
3) Calculate total vehicle sales across all technologies:

\[ VSALEST_{IS, IR, N} = \sum_{IT=1}^{16} VSALEST_{IS, IR, IT, N} \]  \hspace{1cm} \text{(B-96)}

where:

\[ VSALEST = \text{Total regional vehicle sales, by size class} \]

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

\[ ZEVST_{TN} = \left( \text{TMC}_{SQTRCARS} \times \text{STATESHR}_{ST, VT=2, N} \right) \times ZEV \]
\[ ULEVST_{TN} = \left( \text{TMC}_{SQDTRUCKS} \times \text{STATESHR}_{ST, VT=2, N} \right) \times ULEV \]

where:

\[ ZEVST = \text{State-mandated minimum sales of ZEV's} \]
\[ ULEVST = \text{State-mandated minimum sales of ULEV's} \]
\[ \text{TMC}_{SQTRCARS} = \text{Total car sales, from the MACRO module} \]
\[ \text{TMC}_{SQDTRUCKS} = \text{Total light truck sales, from the MACRO module} \]
\[ \text{STATESHR} = \text{Share of national vehicle sales attributed to a given state} \]
\[ ZEV = \text{State-mandated minimum sales share of ZEV's} \]
\[ ULEV = \text{State-mandated minimum sales share of ULEV's} \]
\[ ST = \text{Index of participating state: CA, MA, NY} \]
\[ VT = \text{Index of vehicle type: 1 = cars, 2 = light trucks} \]

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

a) Evenly distribute mandated sales among three size classes:

\[ ZEVSTSC_{ST, IS, N} = \frac{ZEVST_{ST, N}}{3} \]  \hspace{1cm} \text{(B-98)}

where:

\[ ZEVSTSC = \text{Mandated ZEV sales by size class and state} \]
b) Evenly distribute actual electric vehicle sales among three size classes:

\[
ELECVSALSC_{IR,IS,N} = \frac{ELECVSAI_{IR,N}}{3}
\]  

(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 (\(IT = 7-10\)):

\[
AVSALES_{IS,IR,IT,N} = ZEVSTSC_{ST,IS,N} \times APSHR33_{IS,IR,IT,N}
\]  

(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 (\(IR = 1,2,9\)):

\[
AVSALES_{IS,IR,IT=16,N} = VSALES_{IS,IR,IT=16,N} - (ZEVSTSC_{ST,IS,N} - ELECVSALSC_{IR,IS,N})
\]  

(B-101)

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

\[
AVSALES_{IS,IR,IT,N} = VSALES_{IS,IR,IT,N}
\]  

(B-102)

7) Sum adjusted vehicle sales across technologies:

\[
AVSALEST_{IS,IR,N} = \sum_{IT=1}^{16} AVSALES_{IS,IR,IT,N}
\]  

(B-103)

where:

\(AVSALEST\) = Total regional adjusted vehicle sales by size class
8) Calculate new absolute market shares for each vehicle technology:

\[
APSHR55_{IS,IR,IT,N} = \frac{AVSALES_{IS,IR,IT,N}}{AVSALEST_{IS,IR,N}}
\]  

(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:

\[
APSHR55_{IS,IR,IT=15,N} = \sum_{IT=15}^{16} APSHR55_{IS,IR,IT,N} \times 0.025
\]  

and

\[
APSHR55_{IS,IR,IT=16,N} = \sum_{IT=15}^{16} APSHR55_{IS,IR,IT,N} \times 0.975
\]  

(B-105)

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

a) Calculate total vehicle sales by technology:

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

and

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

(B-106)

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

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

where:

APSHRNC = Market shares of new cars by technology
APSHRNT = Market shares of new light trucks by technology

\(B-107\)

c) Sum market shares for affected fleet technologies:

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

and

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

where:

APSHRFLTOT = Aggregate market shares of fleet vehicle technologies

\(IT = \) Index of vehicle type: 1 = cars; 2 = light trucks

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

\(B-108\)

d) Normalize business fleet market shares:

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

and

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

where:

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

\(B-32\)

Energy Information Administration
NEMS Transportation Demand Model Documentation Report
11) Reset new car and light truck sales using market shares, mapped from three to six size classes:

\[
NCSTECH_{IR,OSC,IT,N} = NCS_{IR,OSC,N} \times APSHR55_{IS,IR,IT,N}
\]

and

\[
NLTECH_{IR,OSC,IT,N} = NLTS_{IR,OSC,N} \times APSHR55_{IS,IR,IT,N}.
\]

where:

\[NCSTECH = \text{Regional new car sales by technology, within six size classes:}\]

\[OSC = 1-6; IS = 2,1,3,3,2\]

\[NLTECH = \text{Regional light truck sales by technology, with six size classes:}\]

\[OSC = 1-6; IS = 1,2,1,3,2,3\]

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:

\[
FLTVMT_T = \sum_{VT=1}^{2} \sum_{ITY=1}^{6} \sum_{ITECH=1}^{6} (TFLTECHSTK_{VT,ITY,ITECH} \times FLTVMTYR_{VT,ITY})
\]

where:

\[FLTVMT = \text{Total VMT driven by fleet vehicles}\]

\[FLTVMTYR = \text{Annual miles of travel per vehicle, by vehicle and fleet type}\]

\[VT = \text{Index of vehicle type: 1 = cars, 2 = light trucks}\]

\[ITY = \text{Index of fleet type: Business, Government, Utility}\]

\[ITECH = \text{Index of fleet engine technology, corresponding to IT = 3,5,9,7,8}\]

2) Disaggregate total VMT by vehicle type and technology:

\[
FLTMTECH_{VT,ITY,ITECH,T} = FLTVMT_T \times VFSTKPF_{VT,ITY,ITECH,T}
\]

where:

\[FLTMTECH = \text{Fleet VMT by technology, vehicle type, and fleet type}\]

\[VFSTKPF = \text{Share of fleet stock by vehicle type and technology}\]
This subroutine calculates fuel efficiency for the fleet stock.

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

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

and:

$$FLTMPG_{VT=2,ITY,ITECH} = \left[ \sum_{IS=1}^{3} \frac{FMSHLT_{ITY,ITECH,IS}}{NAMPG_{ITY,IS} \times RATIO_{IS}} \right]^{-1}$$

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
- $ITY$ = Index which matches technologies in the AFV model to corresponding $ITECH$:
  - $ITECH = 1-5$, $ITY = 4, 7, 5, 6$
- $IS$ = 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:

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

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:

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

(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:

\[
MPGFSTK_{VT,IT,ITECH,IVIN,T} = MPGFSTK_{VT,IT,ITECH,IVIN-1,T-1}
\]

and:

\[
MPGFSTK_{VT,IT,ITECH,IVIN=1,T} = FLTMPG_{VT,IT,ITECH,T}
\]

(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:

\[
MPGFSTK_{VT,IT,ITECH} = \left[ \sum_{IVIN=1}^{\text{MAXIVIN}} \left( \frac{FLSTKYN_{VT,IT,ITECH,IVIN,T}}{MPGFSTK_{VT,IT,ITECH,IVIN,T} \times VDF_{VT}} \right) \left( TFLTECHSTK_{FLT,ITECH,T} \right) \right]^{-1}
\]

(B-117)

where:

\(MPGFSTK = \) Fleet MPG by vehicle and fleet type, and technology, across vintages

\(\text{MAXIVIN} = \) 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:

\[
FLTTOTMPG_{VT,T} = \left[ \sum_{IT = 1}^{3} \sum_{ITECH = 1}^{6} \frac{VFSTKPF_{VT,IT,ITECH,T}}{MPGFSTK_{VT,IT,ITECH,T}} \right]^{-1}
\]

(B-118)

where:

\(FLTTOTMPG = \) Fleet vehicle average fuel efficiency for cars and light trucks
LIGHT DUTY VEHICLE FLEET MODULE

This subroutine calculates fuel consumption of fleet vehicles.

1) Calculate fuel consumption:

\[ FLTLDVC_{VT,JT,ITECH,T} = \frac{FTVMTECH_{VT,JT,TECH,T}}{MPGFLSTK_{VT,JT,TECH,T}} \]  \hspace{1cm} (B-119)

where:

\( FLTLDVC \) = Fuel consumption by technology, vehicle and fleet type

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

\[ FLTFCLDVBTU_{VT,ITECH} = \sum_{JTI=1}^{3} FLTLDVC_{VT,JTI,ITECH,T} \times QBTU_{ITECH} \]  \hspace{1cm} (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:

\[ FLTFCLDVBTUR_{IR,ITECH} = \sum_{VT=1}^{2} FLTFCLDVBTU_{VT,ITECH,T} \times RSHR_{IR,T} \]  \hspace{1cm} (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:

\[ LT\_CLTT_N = MC\_SQTRUCKSL_N \times LT10K \times \times 10^6 \]  

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:

\[ CLTSAL2A4T\_N = LT\_CLTT\_N \times LT2A4 \]

\[ CLTSALOSU\_N = LT\_CLTT\_N \times LTOSU \]

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:

\[ CLTSAL2A4T\_{isyl,N} = CLTSAL2A4T\_N \times LT2A4CLT\_{isyl} \]

\[ CLTSALOSU\_{isyl,N} = CLTSALOSU\_N \times LTOSUCLT\_{isyl} \]

where:

- \( LT2A4CLT\_{isyl} \) = Fraction of 2-axle, 4-tire trucks between 8.5 and 10 thousand pounds, by style
- \( LTOSUCLT\_{isyl} \) = Fraction of other single unit trucks between 8.5 and 10 thousand pounds, by style
- \( isyl \) = Index of truck style: 1 = pickup, 2 = other
4) Allocate sales among the aggregate major-use groups:

\[ CLTSAL_{i_s,sty,isc,N} = CLTSAL2A4TS_{i_s,sty,N} \times CLTSICSHR_{i_s,sty,isc} \quad \text{for} \quad is = 1 \]

\[ \text{and} \]

\[ CLTSAL_{i_s,sty,isc,N} = CLTSALOSUS_{i_s,sty,N} \times CLTSICSHR_{i_s,sty,isc} \quad \text{for} \quad is = 2 \]

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:

\[ CLTSTK_{i_s,sty,isc,N} = CLTSTK_{i_s,sty,isc,N-1} \times SURVCLT_{i_s} + CLTSAL_{i_s,sty,isc,N} \quad \text{(B-126)} \]

where:

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

LIGHT COMMERCIAL TRUCK MODEL

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

\[ CLTVMT_{i_s,sty,isc,N} = CLTVMT_{i_s,sty,isc,N-1} \times \left[ \frac{CLTSIC_{isc,N}}{CLTSIC_{isc,N-1}} \right] \quad \text{(B-127)} \]

where:

- CLTSIC_{isc} = 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:
\[ NCL TMPG_{l,t,sty,lic,N} = NCL TMPG_{l,t,sty,lic,N} -1 \times \left[ \frac{MPGT_{N}}{MPGT_{N-1}} \right] \] (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:

\[ CL TMPG_{l,t,sty,lic,N} = \left[ \left( \frac{CLTMPG_{l,t,sty,lic,N-1} \times \text{SUBCLTM}}{CL TMPG_{l,t,sty,lic,N-1}} \right) + \left( \frac{CLTSAL_{l,t,sty,lic,N-1} \times \text{CLTSAL} \times \text{LTD} \times \text{FRFG}_{N}}{CL TMPG_{l,t,sty,lic,N-1}} \right) \right]^{-1} \] (B-129)

where:

\( CL TMPG \) = Stock MPG of light commercial trucks, by truck type and style

\( LTD \times FRFG \) = Scaling factor, associated with the increased use of reformulated gasoline

LIGHT COMMERCIAL TRUCK MODEL

9) Calculate aggregate sales-weighted new LCT MPG:

\[ NCL TMPG_{l,t,sty,lic,N} = \left[ \sum_{l} \sum_{t} \sum_{sty} \sum_{lic} \left\{ \frac{CLTSAL_{l,t,sty,lic,N}}{\sum_{l} \sum_{t} \sum_{sty} \sum_{lic} \text{CLTSAL}_{l,t,sty,lic,N}} \times \left( \frac{CL TMPG_{l,t,sty,lic,N}}{NCL TMPG_{l,t,sty,lic,N}} \right) \right\} \right]^{-1} \] (B-130)

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

\[ CL TMPG_{l,t,sty,lic,N} = \left[ \sum_{l} \sum_{t} \sum_{sty} \sum_{lic} \left\{ \frac{CL VMT_{l,t,sty,lic,N}}{\sum_{l} \sum_{t} \sum_{sty} \sum_{lic} \text{CL VMT}_{l,t,sty,lic,N} \times 1 e^*} \times \left( \frac{CL TMPG_{l,t,sty,lic,N}}{CL TMPG_{l,t,sty,lic,N}} \right) \right\} \right]^{-1} \] (B-131)
11) Calculate fuel consumption in gallons and Btu's for each truck type, style, and major-use category:

\[ \text{CLTGAL}_{lt,sty,isc,N} = \frac{\text{CLTVMT}_{lt,sty,isc,N}}{\text{CLTMPG}_{lt,sty,isc,N}} \]

and

\[ \text{CLBTU}_{lt,sty,isc,N} = \text{CLTGAL}_{lt,sty,isc,N} \times \frac{5253}{42} \]  

(B-132)

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

\[ \text{CLBTUT}_{N} = \sum_{lt} \sum_{sty} \sum_{isc} \text{CLBTU}_{lt,sty,isc,N} \]  

(B-133)
LIGHT DUTY VEHICLE STOCK MODULE

LIGHT DUTY VEHICLE STOCK ACCOUNTING MODEL

Subroutine TSMOD

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

\[ \text{TECHNCS}_{IT, T} = \sum_{OSC = 1}^{6} \sum_{IR = 1}^{9} \text{NCSTECH}_{IR, OSC, IT, T} \]

\[ \text{TECHNLT}_{IT, T} = \sum_{OSC = 1}^{6} \sum_{IR = 1}^{9} \text{NLTECH}_{IR, OSC, IT, T} \]

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 \( VINT = 2-9 \):

\[ \text{PASSTK}_{IT, VINT, T} = \text{PASSTK}_{IT, VINT - 1, T - 1} \cdot \text{SSURVP}_{VINT - 1} \]

\[ \text{and:} \]

\[ \text{LTSTK}_{IT, VINT, T} = \text{LTSTK}_{IT, VINT - 1, T - 1} \cdot \text{SSURVLT}_{VINT - 1} \]
b) For \( VINT = 10 \):

\[
PASSTK_{IT,VINT=10,T} = \left( PASSTK_{IT,VINT=9,T-1} \ast SSURVP_{VINT=9} \right) \\
+ \left( PASSTK_{IT,VINT=10,T-1} \ast SSURVP_{VINT=10} \right)
\]

\[
LTSTK_{IT,VINT=10,T} = \left( LTSTK_{IT,VINT=9,T-1} \ast SSURVLT_{VINT=9} \right) \\
+ \left( LTSTK_{IT,VINT=10,T-1} \ast SSURVLT_{VINT=10} \right)
\]

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:

\[
PASSTK_{IT,VINT} = PASSTK_{IT,VINT} + OLFSTK_{VT=1,TYPE,ITECH,TINT}
\]

\[
LTSTK_{IT,VINT} = LTSTK_{IT,VINT} + OLFSTK_{VT=2,TYPE,ITECH,TINT}
\]

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:

\[
STKCAR_T = \sum_{VINT=1}^{10} \sum_{IT=1}^{15} PASSTK_{IT,VINT,T}
\]

and:

\[
STKTR_T = \sum_{VINT=1}^{10} \sum_{IT=1}^{16} LTSTK_{IT,VINT,T}
\]
where:

$$\text{STKCAR} = \text{Total stock of non-fleet automobiles in year } T$$

$$\text{STKTR} = \text{Total stock of non-fleet light trucks in year } T$$

5) Calculate LDV shares of each technology:

$$\text{VSPLDV}_{IT,T} = \frac{\sum_{\text{INT}=1}^{10} \left( \text{PASSTK}_{IT,\text{INT},T} + \text{LTSTK}_{IT,\text{INT},T} \right)}{\text{STKCAR}_{T} + \text{STKTR}_{T}}$$

(B-139)

where:

$$\text{VSPLDV} = \text{The light duty vehicle shares of each of the sixteen vehicle technologies}$$

LIGHT DUTY VEHICLE STOCK ACCOUNTING MODEL

Subroutine TMPGSTK

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

$$\text{NCS3A}_{IS,IT,T} = \sum_{\text{OSC}} \sum_{\text{IR}=1}^{9} \text{NCSTECH}_{IR,OSC,IS,IT,T}$$

and

$$\text{NLT3A}_{IS,IT,T} = \sum_{\text{OSC}} \sum_{\text{IR}=1}^{9} \text{NLTECH}_{IR,OSC,IS,IT,T}$$

(B-440)

where:

$$\text{NCS3A} = \text{New car sales by reduced size class and engine technology:}$$

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

$$\text{NLT3A} = \text{New light truck sales by reduced size class and technology:}$$

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

$$\text{NCSTECH} = \text{New car sales by region, technology, and six size classes}$$

$$\text{NLTECH} = \text{New light truck sales by region, technology, and six size classes}$$

2) Calculate total regional sales of vehicles by reduced size class:
\[ NCSR_{IR,IS,T} = \sum_{OSC} NCSR_{IR,OSC,T} \]

and

\[ NLTSR_{IR,IS,T} = \sum_{OSC} NLTSR_{IR,OSC,T} \]

where:

\( NCSR \) = Regional new car sales by reduced size class
\( NLTSR \) = Regional new light truck sales by reduced size class

3) Sum across regions:

\[ NCSR_{IS,T} = \sum_{IR=1}^{9} NCSR_{IR,IS,T} \]

and

\[ NLTSR_{IS,T} = \sum_{IR=1}^{9} NLTSR_{IR,IS,T} \]

where:

\( NCSR_{IS,T} \) = Total new car sales by reduced size class
\( NLTSR_{IS,T} \) = Total new light truck sales by reduced size class

4) Sum conventional vehicle sales across regions:

\[ NNCSCA_{OSC,T} = \sum_{IR=1}^{9} NCSTEC{H}_{IR,OSC,T=16,T} \]

and

\[ NNLTCA_{OSC,T} = \sum_{IR=1}^{9} NLTEC{H}_{IR,OSC,T=16,T} \]

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:
where:

\[ AMPGC_{IS,T} = \sum_{OSC} \frac{NCPMPG_{VT=1,OSC,T}}{2} \]

and

\[ AMPGT_{IS,T} = \sum_{OSC} \frac{NCPMPG_{VT=2,OSC,T}}{2} \]

\[ RATIO_{IS,T} = \frac{AMPGT_{IS,T}}{AMPGC_{IS,T}} \]

where:

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

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

\[ VT = \text{Index of vehicle type:} \ 1 = \text{cars}, \ 2 = \text{light trucks} \]

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

\[ RATIO_{IS,T} = \frac{AMPGT_{IS,T}}{AMPGC_{IS,T}} \]

where:

\[ RATIO = \text{Light truck MPG adjustment factor} \]

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

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

and:

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

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

\[ MPGT_{IT=16,T} = \left( \frac{\sum_{OSC=1}^{6} NNLTCU_{OSC,T}}{NLTMPG_{OSC,T}} \right)^{-1} \]

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:

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

\[ ANTMPG_{T} = \left[ \sum_{IT=1}^{16} \frac{APSHRNT_{IT,T}}{MPGT_{IT,T}} \right]^{-1} \]

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:

\[
TOTMICT = \sum_{II=1}^{16} \sum_{IV=1}^{10} PASSTK_{II,IV} \times PVMT_{IV}
\]

and:

\[
TOTMITT = \sum_{II=1}^{16} \sum_{IV=1}^{10} LTSTK_{II,IV} \times LVMT_{IV}
\]

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:

\[
CMPGT = \sum_{II=1}^{16} \sum_{IV=1}^{10} \frac{PASSTK_{II,IV} \times PVMT_{IV}}{CMPGSTK_{II,IV}} \times \frac{VDF_{VT=1}}{VDF_{VT=2}}
\]

and:

\[
TMPGT = \sum_{II=1}^{16} \sum_{IV=1}^{10} \frac{LTSTK_{II,IV} \times LVMT_{IV}}{TTMPGSTK_{II,IV}} \times \frac{VDF_{VT=1}}{VDF_{VT=2}}
\]

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:

\[ STMPG_T = \frac{TOTMITT_T}{TMPGT_T} \]

where:

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

13) Calculate average fuel efficiency of light duty vehicles:

\[ MPGFLT_T = \frac{TOTMICT_T + TOTMITT_T}{CMPGT_T + TMPGT_T} \]

where:

- MPGFLT = Stock MPG for all light duty vehicles

14) Calculate average fuel efficiency by technology:

\[ MPGTECH_{H,N} = \frac{\sum_{H=1}^{10} \frac{PASST_K_{H,N} * PVMT_H}{CMPGSTK_{H,N} * VDE_{VT1}} + \sum_{H+1}^{10} \frac{LTSTK_{H,N} * LVMT_H}{TMPGSTK_{H,N} * VDE_{VT2}}}{TOTMICT_T + TOTMITT_T} \]

where:

- MPGTECH = Average stock MPG by technology
VEHICLE MILES TRAVELED MODEL

1) Calculate the cost of driving per mile:

\[
COSTMI_T = \frac{TPMGTR_T \times 0.125}{MPGFLT_T}
\]  

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:

\[
INCOME_T = \frac{TMC_{YD_T}}{TMC_{POPAFO_T}}
\]  

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:

\[
VMT16_T = RHO \cdot VMTPC_{T-1} + ALPHA (1 - RHO)
- BETAPE (COSTMI_T - RHO \cdot COSTMI_{T-1})
+ BETAIE (INCOME_T - RHO \cdot INCOME_{T-1})
+ BETADEM (PrFem_T - RHO \cdot PrFem_{T-1})
\]  

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 personal 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:

\[ \text{ADJVMTPC}_T = \frac{VMT16_T}{TMC\_POP16_T} \times DAF_T \]

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

5) Calculate total VMT:

\[ \text{VMTLDV}_T = \text{ADJVMTPC}_T \times \text{TMC\_POP16}_T \]

where:
- VMTLDV = Total VMT for light duty vehicles

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

\[ \text{VMTEE}_T = \text{VMTLDV}_T - \left( \text{FLTVMT}_T + \text{FVMTSC}_{JS=1,T} \right) \]

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

7) Calculate VMT by technology:

\[ \text{VMTECH}_{IT,T} = \text{VMTEE}_T \times \text{VSPLDV}_{IT,T} \]

where:
- VMTECH = Personal travel VMT by technology
- VSPLDV = Sales shares of vehicles by technology
8) Calculate fractional change of VMT:

\[ XLDVMT_T = \frac{VMTEE_T}{VMTEE_{T=1}} \]  \hspace{1cm} (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:

\[ TRSAL_T = 0.408427 \times TMC_{SODTRUCKS}T \]  \hspace{1cm} (B-162)

where:

\( TRSAL \) = Light truck sales for freight
\( TMC_{SODTRUCKS} \) = Total light truck sales, from MACRO module

2) Calculate sales by technology:

\[ TRSALTECH_{T,T} = TRSAL_T \times FLVMTSHR_{JS=L,T,T} \]  \hspace{1cm} (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:

\[ TRSTKTECH_{IP=1,T} = TRSALTECH_{T,T} \]

\[ TRSTKTECH_{IP,T} = TRSTKTECH_{IP,T-I,T-1} \times SSURVLT_{IP-1}; \quad IV = 2 - 9 \]

and

\[ TRSTKTECH_{IP,T>10} = \{ TRSTKTECH_{IP,T>9,I-1} \times SSURVLT_{IP-9} \} \]

\[ \times \{ TRSTKTECH_{IP,T>10,I-1} \times SSURVLT_{IP>10} \} \]

where:

\( TRSTKTECH \) = Light truck stock by technology
SSURVLT = Array of survival rates for light trucks

4) Sum over vintages:

\[ TRSTKTOT_{I,T} = \sum_{I_T=1}^{10} TRSTKTECH_{I,T,I_T} \]  \hspace{1cm} (B-165)

where:

TRSTKTOT = Total light truck stock by technology

5) Sum over technologies:

\[ TRSTK_{T} = \sum_{I_T=1}^{5} TRSTKTOT_{I_T,T} \]  \hspace{1cm} (B-166)

where:

TRSTK = Total light truck stock

6) Calculate average MPG for light trucks:

\[ TRFLTMPG_{T} = \left[ \frac{\sum_{I_T=1}^{5} \left( \frac{TRSTKTOT_{I,T}}{FMPG_{I_T=1,I_T,T}} \right) + \sum_{I_T=1}^{5} TRSTKTOT_{I_T,T}}{\sum_{I_T=1}^{5} TRSTKTOT_{I_T,T}} \right]^{-1} \]  \hspace{1cm} (B-167)

where:

TRFLTMPG = Average light truck MPG
VEHICLE MILES TRAVELED MODEL

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

1) Sum fleet vehicle sales over size class:

\[
FLTECHSALT_{VT,ITY,ITECH,T} = \sum_{IS=1}^{3} FLTECHSAL_{VT,ITY,IS,ITECH,T}
\]  

where:

- \(FLTECHSALT\) = Vehicle purchases by fleet type and technology
- \(FLTECHSAL\) = 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:

\[
FLTMPGNEW_{VT,ITECH,T} = \left[ \frac{\sum_{ITY=1}^{3} FLTECHSALT_{VT,ITY,ITECH,T}}{FLMPG_{VT,ITY,ITECH,T}} \right]^{-1}
\]

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:

\[
FLTSTOCK_{VT,ITECH,T} = \sum_{ITY=1}^{3} FLTECHSTK_{VT,ITY,ITECH,T}
\]  

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:

\[
\text{CCMPGLDV}_{IT,T} = \left( \frac{\text{TECHNCS}_{IT,T}}{\text{MPGC}_{IT,T}} + \frac{\text{FLTSTOCK}_{VT=1,ITECH,T}}{\text{FLTMPGNEW}_{VT=1,ITECH,T}} \right)^{-1} \quad \text{(B-171)}
\]

   where:

   \( \text{CCMPGLDV} \) = 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
   \( \text{TECHNCS} \) = Non-fleet new car sales, by technology IT
   \( \text{MPGC} \) = New car MPG, by technology IT
   \( \text{FLTSTOCK} \) = New fleet stock, by vehicle type and technology ITECH
   \( \text{FLTMPGNEW} \) = New fleet vehicle MPG, by vehicle type and technology ITECH

   b) For light trucks:

\[
\text{TTMPGLDV}_{IT,T} = \left( \frac{\text{TECHNLT}_{IT,T}}{\text{MPGT}_{IT,T}} + \frac{\text{FLTSTOCK}_{VT=2,ITECH,T}}{\text{FLTMPGNEW}_{VT=2,ITECH,T}} \right)^{-1} \quad \text{(B-172)}
\]

   where:

   \( \text{TTMPGLDV} \) = New light truck MPG, by technology IT
   \( \text{TECHNLT} \) = Non-fleet new light truck sales, by technology IT
   \( \text{MPGT} \) = New light truck MPG, by technology IT

5) Calculate total stock by vehicle type and technology:

\[
\text{STOCKLDV}_{VT,IT2,T} = \text{STKCT}_{VT,IT,T} + \text{FLTSTOCK}_{VT,ITECH,T} \quad \text{(B-173)}
\]

   where:

   \( \text{STOCKLDV} \) = Total stock of fleet and non-fleet vehicles, by technology
   \( \text{STKCT} \) = 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:

\[ TSTOCKLDV_{vt, t} = \sum_{IT2=1}^{16} STOCKLDV_{vt, IT2, t} \] \hspace{1cm} (B-174)

where:

TSTOCKLDV = Total stock by vehicle type VT

7) Calculate average MPG of cars and light trucks:

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

\[ TMPGLDVSTK_{vt=2, t} = \left[ \frac{\sum_{IT2=1}^{16} \left( \frac{STOCKLDV_{vt=2, IT2, t}}{TTPMGLDV_{IT2, t}} \right)}{\sum_{IT2=1}^{16} STOCKLDV_{vt=2, IT2, t}} \right]^{-1} \] \hspace{1cm} (B-175)

where:

TMPGLDVSTK = Average MPG by vehicle type VT

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

\[ TLDVMPG_{t} = \left[ \frac{\sum_{VT=1}^{2} \left( \frac{TSTOCKLDV_{VT, t}}{TMPGLDVSTK_{VT, t}} \right)}{\sum_{VT=1}^{2} TSTOCKLDV_{VT, t}} \right]^{-1} \] \hspace{1cm} (B-176)

where:

TLDVMPG = Average fuel economy of light-duty vehicles
Estimate New Truck Fuel Economies

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

\[
AVGPRC_{T,FUEL} = \frac{PRICE_{T,FUEL} + PRICE_{T-1,FUEL} + PRICE_{T-2,FUEL}}{3}
\]  \hspace{1cm} (B-177)

where:

- \( T \) = Index referring to model run year; where \( T = 0, \ldots, 23 \)
- \( FUEL \) = 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:

\[
\text{For } TECH = 6, \ldots, 16
\]

\[
\text{If } AVGPRC_{T,FUEL} \geq TRIGPRC_{SC,FUEL,TECH}
\]

\[
\text{INITTYR}_{SC,FUEL,TECH} = T
\]

where:

- \( TECH \) = Index referring to fuel-saving technologies, where \( TECH = 1, \ldots, 5 \) refers to currently available technologies and \( TECH = 6, \ldots, 16 \) 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
- \( INITTYR \) = 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:

\[
\text{COEFT}_{\text{SC,FUEL,TECH}} = \frac{\ln(0.01)}{\text{CYCLE}_{\text{SC,FUEL,TECH}}} \quad \text{and} \quad \text{MIDYR}_{\text{SC,FUEL,TECH}} = \text{INITYR}_{\text{SC,FUEL,TECH}} + \frac{\text{CYCLE}_{\text{SC,FUEL,TECH}}}{2}
\]

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:

\[
\text{PREFF}_{\text{T,SC,FUEL,TECH}} = 1 + \text{PRCVAR}_{\text{SC,FUEL,TECH}} \cdot \frac{\text{AVGPRC}_{\text{T,FUEL}} - 1}{\frac{\text{TRIGPRC}_{\text{SC,FUEL,TECH}}}{\text{PRCVAR}_{\text{SC,FUEL,TECH}}}}
\]

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:
where:

\( \text{TECHSHR} = \) Market share of fuel-saving technology \( \text{TECH} \) for size class \( SC \) and fuel type \( FUEL \)

\( \text{CONST} = \) Exogenously determined market penetration curve parameter for existing technologies

\( \text{COEFT} = \) Market penetration curve parameter, exogenous for existing technologies, endogenous for future technologies

\( \text{BSHRT} = \) Exogenously determined market penetration curve parameter representing market share of existing technology \( \text{TECH} \) in 1992

\( \text{ESHRT} = \) Exogenously determined market penetration curve parameter representing final market share of technology \( \text{TECH} \) 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:

\[
\text{TECHSHR}_{T,SC,FUEL,TECH} = \left( 1 - \text{SPRSDEFF}_{T,SC,FUEL,TECH} \right) \cdot \text{TECHSHR}_{T,SC,FUEL,TECH}
\]

where:

\( \text{SPRSDEFF} = \) Superseding effect, equal to the market share of the superseding technology

7) Determine MPG effects:

\[
\text{MPGEFF}_{T,SC,FUEL} = \prod_{\text{TECH}=1}^{5} \left( 1 - \text{MPGINCR}_{T,SC,FUEL,TECH} \cdot \text{TECHSHR}_{T,SC,FUEL,TECH} \right)
\]

where:

\( \text{MPGEFF} = \) Total effect of all fuel-saving technologies on new truck fuel economy in year \( T \)

\( \text{MPGINCR} = \) 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:

\[
MPG_{T,SC,AGE=0, FUEL} = \frac{BASEMPG_{SC,FUEL} \cdot MPG_{EFF T,SC,FUEL} \cdot D}{TOTALMILES_{AGE=0, T,SC,FUEL}}
\]

where:

\[
BASEMPG = \text{Fuel economy of new medium and heavy trucks with no fuel-saving technologies}
\]

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:

\[
FCOST_{T,SC,FUEL} = \frac{AVGPRC_{T,FUEL} \cdot HTRATE}{MPG_{T,SC,FUEL}}
\]

where:

\[
FCOST = \text{Fuel cost of driving a truck of fuel type } FUEL, \text{ in dollars per mile}
\]

\[
HTRATE = \text{Heat rate of gasoline, in million Btu per gallon}
\]

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

\[
RCOST_{T,SC,FUEL} = 1 - \frac{FCOST_{T,SC,FUEL} - FCOST_{T,SC,FUEL = 1}}{PRCDIFFVAR_{SC,FUEL}}
\]

where:

\[
RCOST = \text{Fuel cost per mile of diesel relative to LPG and CNG}
\]

\[
PRCDIFFVAR = \text{Exogenously determined parameter representing inherent variation in AFV market share due to difference in fuel prices}
\]

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

\[
COEF_{AFV, SC,FUEL, FLT} = \frac{\ln(0.01)}{\left(\frac{TYR_{AFV, SC,FUEL, FLT}}{Cyc_{AFV, SC,FUEL, FLT}} \right)^2}
\]

and

\[
MYR_{AFV, SC,FUEL, FLT} = TYR_{AFV, SC,FUEL, FLT} + \frac{Cyc_{AFV, SC,FUEL, FLT}}{2}
\]
where:

\[ FLT = \text{Index referring to fleet type, where } FLT = 1 \text{ refers to trucks in fleets of nine or less and } FLT = 2 \text{ refers to trucks in fleets of ten or more} \]

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:

\[
MPATH_{T,SC,FUEL,FLT} = RCOAST_{T,SC,FUEL} \left[ BSHRF_{T,SC,FUEL,FLT}, ESHRF_{T,SC,FUEL,FLT} - BSHRF_{T,SC,FUEL,FLT} \right] \]  \hspace{1cm} (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:

\[
MPATH_{T,SC,FUEL=1,FLT} = BSHRF_{T,SC,FUEL,FLT} + \left[ ESHRF_{T,SC,FUEL,FLT} - BSHRF_{T,SC,FUEL,FLT} \right] \frac{1 - \text{CONSD}_{T,SC,FUEL,FLT}}{1 - \text{COEFD}_{T,SC,FUEL,FLT}} \]  \hspace{1cm} (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:

\[
FSHR_{T,SEC,SC,FUEL=3,A,FLT} = \max \left[ BSEC_{SEC,SC,FUEL,FLT} + MPATH_{T,SC,FUEL,FLT} \right] \]  \hspace{1cm} (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:

\[
FSHR_{T,SEC,SC,FUEL,FLY} = \left( 1 - \sum_{FUEL=3}^{4} FSHR_{T,SEC,SC,FUEL,FLY} \right) \left( \min \left[ MPATH_{T,SC,FUEL,FLY} \cdot BSECD_{SEC,SC,FUEL,FLY} \cdot 1 \right] \right)
\]

(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:

\[
FSHR_{T,SEC,SC,FUEL,FLY} = 1 - \sum_{FUEL=1,3,4} FSHR_{T,SEC,SC,FUEL,FLY}
\]

(B-192)

Determine Composition of Existing Truck Stock

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

\[
TRKSTK_{T,SEC,SC,AGE,FUEL,FLY} = TRKSTK_{T-1,SEC,SC,AGE,FUEL,FLY} \left( 1 - SCRAP_{SC,AGE-1} \right)
\]

(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:

\[
TRF1_{T,SEC,SC,AGE,FUEL} = TRFRATE_{SC,AGE} \cdot TRKSTK_{T,SEC,SC,AGE,FUEL,FLY-3}
\]

(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:

\[ TRF_{T, SEC, SC, AGE, FUEL=1, 4} = \text{FSHR}_{T, SEC, SC, FUEL, FLT=1} \times \left( \frac{\sum_{FUEL=1}^{4} \sum_{AGE=1}^{11} \sum_{SEC=1}^{12} TRKSTK_{T, SEC, SC, AGE, FUEL, FLT=1} }{TRKSTK_{T, SEC, SC, AGE, FUEL, FLT=1}} \right) \quad (B-195) \]

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:

\[ TRF_{T, SEC, SC, AGE, FUEL=1, 2} = TRF_{T, SEC, SC, AGE, FUEL, FLT} \quad \text{and} \]

\[ TRF_{T, SEC, SC, AGE, FUEL=3, 4} = \min \left( TRF_{T, SEC, SC, AGE, FUEL, FLT}, TRF_{T, SEC, SC, AGE, FUEL} \right) \quad (B-196) \]

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:

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

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:

\[ TRKSTK_{T, SEC, SC, AGE, FUEL, FLT=2} = TRKSTK_{T, SEC, SC, AGE, FUEL, FLT=2} - TRF_{T, SEC, SC, AGE, FUEL} \quad \text{and} \]

\[ TRKSTK_{T, SEC, SC, AGE, FUEL, FLT=1} = TRKSTK_{T, SEC, SC, AGE, FUEL, FLT=1} + TRFSHR_{T, SEC, SEC} \sum_{SEC=1}^{12} TRF_{T, SEC, SC, AGE, FUEL} \quad (B-198) \]
Calculate Purchases of New Trucks

23) Calculate index of average annual VMT per truck:

\[
VMT\text{TREND}_{T, SC} = \frac{\text{BSHRV}_{SC} + (\text{ESHRV}_{SC} - \text{BSHRV}_{SC})}{\text{BSHRV}_{SC} + (\text{ESHRV}_{SC} - \text{BSHRV}_{SC})} \left( \frac{1}{\text{CONSV}_{SC} + \text{COEFV}_{SC} \cdot 1992} \right)
\]

where:
- VMT\text{TREND} = 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:

\[
\text{ANNVMT}_{T, SEC, SC, AGE, FUEL} = \text{ANNVMTBASE}_{T, SEC, SC, AGE, FUEL} \cdot \text{VMT\text{TREND}}_{T, SC}
\]

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:

\[
\text{VMTOLD}_{T, SEC} = \sum_{\text{FUEL}=1}^{2} \sum_{\text{AGE}=1}^{11} \sum_{\text{SC}=1}^{2} \text{TRKSTK}_{T, SEC, SC, AGE, FUEL} \cdot \text{ANNVMT}_{SEC, SC, AGE, FUEL}
\]

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

\[ FACTR_{T,SEC} = \frac{AFFACBASE_{SEC}}{1 + e^{-COEFFAC \cdot (T90 - T)}} \]

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 \( T = 0 \):

\[ VMTDMD_{T,SEC} = VM\text{TDMDBASE}_{SEC} \cdot FACTR_{SEC} \cdot \frac{OUTPUT_{T,SEC}}{OUTPUT_{T-1,SEC}} \]

For \( T = 1-22 \):

\[ VMTDMD_{T,SEC} = VMTDMD_{T-1,SEC} \cdot FACTR_{SEC} \cdot \frac{OUTPUT_{T,SEC}}{OUTPUT_{T-1,SEC}} \]

where:
- \( VMTDMD \) = Demand for freight travel by sector SEC, in year \( T \)
- \( VM\text{TDMDBASE} \) = 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:

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

(B-204)
where:

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

29) Calculate perceived baseline VMT demand:

For $T = 0$

$$PVMTBASE_{T,SC} = 0.5 \cdot PVMTDBASE_{SEC}$$  \hspace{1cm} (B-205)

For $T = 1-22$

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

where:

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

30) Calculate perceived VMT demand:

$$PVMTBASE_{T,SEC} = 0.5 \cdot PVMTDM_{T-1,SEC} + 0.25 \cdot PVMTDM_{T-2,SEC}$$  \hspace{1cm} (B-206)

and

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

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:

$$PVMTUNMET_{T,SEC} = PVMTDM_{T,SEC} - VMTOLD_{T,SEC}$$  \hspace{1cm} (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.

\[
PVMT_{T,SEC,SC,FLT} = \max \left[ PVMTUNMET_{T,SEC} \cdot VMTSCFAC_{SEC,SC} \cdot \left( 1 - FLTSHR_{SEC,SC} \right), 0 \right]
\]

and

\[
PVMT_{T,SEC,SC,FLT} = \max \left[ PVMTUNMET_{T,SEC} \cdot VMTSCFAC_{SEC,SC} \cdot FLTSHR_{SEC,SC}, 0 \right]
\]

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:

\[
PVN_{T,SEC,SC,FLT} = \sum_{FUEL=1}^{4} FSHR_{T,SEC,SC,FUEL,FLT} \cdot \text{ANNUAL}_{T,SEC,SC,AGE=0,FUEL}
\]

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:

\[
TRKSTK_{T,SEC,SC,AGE=0,FUEL,FLT} = \frac{PVMT_{T,SEC,SC,FLT}}{PVN_{T,SEC,SC,FLT}} \cdot FSHR_{T,SEC,SC,FUEL,FLT}
\]
Calculate Fuel Consumption

35) Allocate actual VMT demand among truck types:

\[
VMT_{T,SEC,SC,AGE,FUEL,FLT} = \text{TRKSTK}_{T,SEC,SC,AGE,FUEL,FLT} \times \text{ANNVMT}_{T,SEC,SC,AGE,FUEL}
\]

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:

\[
MPGDEGFAC_{T,SC} = \frac{1}{1 - \left( 1 - MPGDEGFAC_{T,LDV} \right) \frac{\text{URBANSHR}_{SC}}{\text{URBSHRLDV}}} - \left( 1 - MPGDEGFAC_{T,LDV} \right) \frac{\text{URBANSHR}_{LDV}}{\text{URBSHRLDV}}
\]

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:

\[
FUEL_{T,SEC,SC,AGE,FUEL,FLT} = \frac{VMT_{T,SEC,SC,AGE,FUEL,FLT} \times MPG_{T,SEC,SC,AGE,FUEL} \times MPGDEGFAC_{T,SC}}{\text{MPGDEGFAC}_{T,SC}}
\]

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 degradation factor, overwritten in the code by 0.99.
38) Converting from gasoline equivalent to trillion Btu:

\[
TRIL_{T,SEC,SC,FUEL,FLT} = \sum_{AGE=0}^{11} \frac{FUEL_{T,SEC,SC,AGE,FUEL,FLT}}{HTRATE} \cdot 10^{-6}
\]

(B-214)

where:

\[TRIL = \text{Total fleet truck fuel consumption by sector, size class and fuel type in year } T, \text{ in trillion Btu}\]

**Roll Truck Population and Fuel Economy**

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

\[
MPG_{T+1,SC,AGE=10,FUEL} = \frac{\sum_{FLT=1}^{2} \sum_{AGE=10}^{11} \sum_{SEC=1}^{12} VMT_{T,SEC,SC,AGE,FUEL,FLT}}{\sum_{FLT=1}^{2} \sum_{AGE=10}^{11} \sum_{SEC=1}^{12} FUEL_{T,SEC,SC,AGE,FUEL,FLT}}
\]

(B-215)

where:

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

\[AGED = 11 \text{ refers to trucks in the eleventh vintage, i.e., trucks which are eleven years old or older during model run year } t\]

\[T+1 = \text{refers to the next model run year}\]

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

\[
TRKSTK_{T,SEC,SC,AGE=10,FUEL,FLT} = TRKSTK_{T,SEC,SC,AGE=10,FUEL,FLT} + TRKSTK_{T,SEC,SC,AGE=11,FUEL,FLT}
\]

(B-216)

**RAIL FREIGHT MODEL**

Subroutine TRAIL

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

\[
RTMT_{J,LT} = RTMT_{J,LT_{0}} \cdot FAC_{j,MODE} \cdot \frac{TSIC_{LT}}{TSIC_{LT_{0}}}
\]

(B-217)
where:

\( RTMT_I = \text{Rail ton-miles traveled, by industry } I \)

\( MODE = \text{Index of freight mode: truck, rail, marine} \)

\( TSIC_I = \text{Value of industrial output, by industry} \)

\( I = \text{Index of NEMS industrial category} \)

\( FAC = \text{Freight adjustment coefficient, by industry and mode} \)

2) Sum across industries:

\[ RTMT_{TT} = \sum_{I=1}^{10} RTMT_{IT} \]  

(B-218)

where:

\( RTMT_T = \text{Total rail ton-miles traveled} \)

3) Estimate energy consumption by rail:

\[ TQRAIL_T = FERAL_T \cdot RTMT_T \]  

(B-219)

where:

\( TQRAIL_T = \text{Total energy demand by rail} \)

\( FERAL = \text{Rail efficiency coefficient, in Btu/ton-mile} \)

4) Increment rail demand for specific fuels:

\[ TQRAIL_{IF,T} = TQRAIL_{IF,T-1} \cdot \left( \frac{TQRAIL_T}{TQRAIL_{T-1}} \right) \]  

(B-220)

where:

\( TQRAIL_{IF} = \text{Rail demand, by fuel IF} \)

\( IF = \text{Index of fuel type} \)

5) Divide into regions:

\[ TQRAIL_{IF,IR,T} = TQRAIL_{IF,T} \cdot SEDSHR_{IF,IR,T} \]  

(B-221)
where:

\[ T_{QRAIL R} = \text{Regional demand by fuel type} \]
\[ SEDS_{HR} = \text{Regional shares of fuel demand, from SEDS} \]
\[ IR = \text{Index of census region (1-9)} \]

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

\[ X_{RAIL} = \frac{RTM_{TT}}{RTM_{TT_{T=1}}} \]
\[ X_{RAILEFF} = \frac{F_{RAIL_{T=1}}}{F_{RAIL_{T}}} \]

where:

\[ X_{RAIL} = \text{Growth in rail travel from base year} \]
\[ X_{RAILEFF} = \text{Growth in rail efficiency from base year} \]

WATERBORNE FREIGHT MODEL

Subroutine TSHIP

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

\[ STMT_{I,T} = STMT_{I,T_0} \cdot \frac{FAC_{I,MODE}}{\left[ TSIC_{I,T} \right]} \cdot \frac{\left[ TSIC_{I,T_0} \right]}{TSIC_{I,T_0}} \]

where:

\[ STMT = \text{Ship ton-miles traveled, by industry } I \]

2) Sum across industries:

\[ STMTT_T = \sum_{I=1}^{16} STMT_{I,T} \]

where:

\[ STMTT = \text{Total ship ton-miles traveled} \]
3) Estimate energy consumption by ship:

\[ SFDT_T = FESHIP_T \times STMRT_T \times SFDBENCH \]  \hspace{1cm} (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:

\[ SFD_{IF,T} = SFDT_T \times SFSHARE_{IF} \]  \hspace{1cm} (B-226)

where:
- \( SFD \): Domestic ship energy demand, by fuel \( IF \)
- \( SFSHARE \): Constant allocation share for domestic shipping, by fuel

5) Divide into regions:

\[ TQSHIPR_{IF,R,T} = SFD_{IF,T} \times SEDSHR_{IF,R,T} \]  \hspace{1cm} (B-227)

where:
- \( TQSHIPR \): Regional ship demand by fuel type
- \( SEDSHR \): Regional shares of fuel demand, from SEDS

6) Calculate international shipping fuel demand:

\[ ISFDT_T = ISFDT_{T-1} + \left[ \frac{GROSST}{GROSST_{T-1}} - 1 \right] \times 0.5 \times ISFDT_{T-1} \]  \hspace{1cm} (B-228)

where:
- \( ISFDT \): Total international shipping fuel demand
- \( GROSST \): Value of gross trade (imports - exports)

7) Allocate among the considered fuels:
\[ ISFD_{IF,T} = ISFD_{IF,T} \times ISFSHARE_{IF} \]  
(B-229)

where:
ISFD = International ship energy demand, by fuel IF
ISFSHARE = Constant allocation share for international shipping, by fuel

8) Divide into regions:
\[ TQISHIPR_{IF,IR,T} = ISFD_{IF,T} \times SEDSHIP_{IF,IR,T} \]  
(B-230)

where:
TQISHIPR = Regional international shipping demand by fuel type

9) Calculate fractional change in domestic ship travel and fuel efficiency:
\[ XSHIP_T = \frac{STM_T}{STM_{T-1}} \]  
and
\[ XSHIPEFF_T = \frac{FESHIP_T}{FESHIP_{T-1}} \]  
(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

1) Calculate the cost of flying:

\[ YIELD_T = 9.73 + 0.794 \text{TPJFTR}_T \]  \hspace{1cm} (B-232)

where:

- \( YIELD \) = Cost of air travel, expressed in cents per RPM
- \( \text{TPJFTR} \) = 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:

\[ \text{RPMBPC}_T = 89.70 + 0.029 \left( \frac{TMC\_GDP_T}{TMC\_POPAFO_T} \right) - 16.04 YIELD_T \]  \hspace{1cm} (B-233)

b) For personal travel:

\[ \text{RPMPPC}_T = -481.34 + 0.083 \left( \frac{TMC\_YD_T}{TMC\_POPAFO_T} \right) - 18.68 YIELD_T \]  \hspace{1cm} (B-234)

c) For international travel:

\[ \text{RPMIPC}_T = PCTINT_T \cdot (\text{RPMBPC}_T + \text{RPMPPC}_T) \]  \hspace{1cm} (B-235)

where:

- \( \text{RPMBPC} \) = Per capita revenue passenger miles for business travel
- \( \text{RPMPPC} \) = Per capita revenue passenger miles for personal travel
- \( \text{RPMIPC} \) = 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:

\[ RTM_T = (-14.556 + 19.81 \times TMC\_EXD92_T + 3.49 \times TMC\_GDP_T) \times DFRT_T \]  (B-236)

where:
- TMC\_EXD92 = 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:

\[ RPMB_T = RPMBPC_T \times TMC\_POPAFO_T \]  (B-237)

b) For personal travel:

\[ RPMP_T = RPMPPC_T \times TMC\_POPAFO_T \times DI_T \]  (B-238)

c) For international travel:

\[ RPMI_T = RPMIPC_T \times TMC\_POPAFO_T \]  (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:

\[ RPMD_T = RPMB_T + RPMP_T \]  (B-240)

where:
- RPMD = Total domestic air travel

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

\[ ASMDEM_T = \left( \frac{RPMD_T}{LFDOM_T} \right) + \left( \frac{RPMI_T}{2 \times LFINTER_T} \right) + \left( RTM_T \times EQSM \right) \]  (B-241)
where:

\[ \text{ASMDEMD} = \text{Total demand for available seat-miles} \]

\[ \text{LFDOM} = \text{Load factor for domestic travel} \]

\[ \text{LFINTER} = \text{Load factor for international travel} \]

\[ \text{EQSM} = \text{Equivalent seat-miles conversion factor; used to transform freight RTM's} \]

AIRCRAFT FLEET EFFICIENCY MODEL

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

\[ ASMP_{i,t} = \frac{AIRHRS_{i,t}}{AVSPD_{i,t}} \times SEAT_{i,t} \] (B-242)

where:

\[ \text{ASMP} = \text{The available seat-miles per plane, by type.} \]

\[ \text{AIRHRS} = \text{The average number of airborne hours per aircraft.} \]

\[ \text{AVSPD} = \text{The average flight speed.} \]

\[ \text{SEAT} = \text{The average number of seats per aircraft.} \]

\[ i = \text{Index of aircraft type: 1 = narrow body, 2 = wide body} \]

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

\[ \text{SMFRACN}_T = \left[ \frac{\text{ASMDEMD}_{i=1,T} + \text{DELTA} \cdot \frac{\text{ASMDEMD}_{i=1,T}}{\text{SMDEMD}_T}}{\text{ASMDEMD}_{i=1,T} + \text{DELTA} \cdot \frac{\text{ASMDEMD}_{i=2,T}}{\text{SMDEMD}_T}} \right] ; \text{DELTA} \geq 0 \]

\[ = \left[ \frac{\text{ASMDEMD}_{i=1,T}}{\text{ASMDEMD}_{i=1,T} + \text{DELTA} \cdot \frac{\text{ASMDEMD}_{i=2,T}}{\text{SMDEMD}_T}} \right] \times (1 + \text{DELTA}) ; \text{DELTA} < 0 \] (B-243)

where:

\[ \text{SMFRACN} = \text{Fraction of seat-mile demand on narrow-body planes} \]

\[ \text{ASMDEMD} = \text{Demand for available seat-miles, by aircraft type} \]

\[ \text{DELTA} = \text{User-specified rate of passenger shifts between aircraft types} \]

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

\[ \text{ASMDEMD}_{i=1,T} = \text{SMDEMD}_T \times \text{SMFRACN}_T \]

[and]

\[ \text{ASMDEMD}_{i=2,T} = \text{SMDEMD}_T \times (1.0 - \text{SMFRACN}_T) \] (B-244)
4) Calculate survival rates of aircraft:

\[
SURVPCT_{IVINT} = \left[ 1 + \exp \left( SURVK \times (T50 - IVINT) \right) \right]^{-1}
\]

and

\[
SSURVPCT_{IVINT} = \frac{SURVPCT_{IVINT}}{SURVPCT_{IVINT-1}}
\]

where:
- \(SURVPCT\) = Survival rate of planes of a given vintage \(IVINT\)
- \(SSURVPCT\) = Marginal survival rate of planes of a given vintage \(IVINT\)
- \(IVINT\) = 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:

\[
SMSURV_{IT,T} = \sum_{IVINT=2}^{60} NPCHSE_{IT,IVINT-1,T-1} \times SSURVPCT_{IVINT} \times ASMP_{IT,T}
\]

where:
- \(SMSURV\) = Surviving available seat-miles, by aircraft type
- \(NPCHSE\) = Surviving aircraft stock, by vintage and aircraft type

6) Calculate new aircraft purchases:

\[
NPCHSE_{IT,IVINT=1,T} = \left[ \frac{ASMDEM_{IT,T} - SMSURV_{IT,T}}{ASMP_{IT,T}} \right]
\]

7) Adjust array of aircraft stocks by vintage:

\[
NPCHSE_{IT,IVINT,T} = NPCHSE_{IT,IVINT-1,T-1} \times SSURVPCT_{IVINT} ; \quad IVINT = 2 - 60
\]

8) Calculate aircraft stock across vintages:

\[
NSURV_{IT,T} = \sum_{IVINT=1}^{60} NPCHSE_{IT,IVINT,T}
\]
where:

$$NSURV = \text{Number of surviving aircraft, by type}$$

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

$$STKOLD_{IT} = \frac{(NSURV_{IT} - NPCHSE_{IT, IVINT-1, T})}{NSURV_{IT}}$$  \hspace{1cm} (B-250)

where:

$$STKOLD = \text{Fraction of planes older than one year, by aircraft type}$$

10) Calculate effect of technology improvements:

a) Calculate time effect:

$$TIMEFX_{IFX, T} = TIMEFX_{IFX, T-1} + \left( TIMECONST \cdot TPN_{IFX} \cdot TYRN_{IFX} \right)$$  \hspace{1cm} (B-251)

where:

$$TIMEFX = \text{Factor reflecting the length of time an aircraft technology improvement has been commercially viable}$$

$$IFX = \text{Index of technology improvements (1-6)}$$

$$TIMECONST = \text{User-specified scaling constant, reflecting the importance of the passage of time}$$

$$TPN = \text{Binary variable (0,1) which tests whether current fuel price exceeds the considered technology's trigger price}$$

$$TYRN = \text{Binary variable which tests whether current year exceeds the considered technology's year of introduction}$$

b) Calculate the cost effect:

$$COSTFX_{IFX, T} = 10 \left( \frac{TPJFGAL_T - TRIGPRICE_{IFX}}{TPJFGAL_T} \right) \cdot TPN_{IFX} \cdot TYRN_{IFX} \cdot TPZ_{IFX}$$  \hspace{1cm} (B-252)

where:

$$COSTFX = \text{Factor reflecting the magnitude of the difference between the price of jet fuel and the trigger price of the considered technology}$$

$$TPJFGAL = \text{Price of jet fuel}$$

$$TRIGPRICE = \text{Price of jet fuel above which the considered technology is assumed to be commercially viable}$$

$$TPZ = \text{Binary variable which tests whether implementation of the considered technology is dependent on fuel price}$$
c) Calculate the total effect:

\[
TOTALFX_{IFX,T} = TIMEFX_{IFX,T} + COSTFX_{IFX,T} - BASECONST
\]  \hspace{1cm} (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:

\[
TECHFRAC_{IFX,T} = \left[ 1 + \exp \left( -TOTALFX_{IFX,T} \right) \right]^{-1}
\]  \hspace{1cm} (B-254)

where:

- TECHFRAC = Fraction of new aircraft purchases which incorporate a given technology

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

\[
FRACIMP_{IFX,T} = 1.0 + \sum_{IFX=1}^{6} EFFIMP_{IFX-T} \times TECHFRAC_{IFX,T} - TECHFRAC_{IFX-T-1}
\]

\[
FRACIMP_{IFX,T} = 1.0 + \sum_{IFX=2}^{6} EFFIMP_{IFX} \times TECHFRAC_{IFX,T}
\]  \hspace{1cm} (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:

\[
NEWSMPG_{IFX,T} = \max \left[ FRACIMP_{IFX-T} \times SMPG_{IFX,T-1} + \left[ \left( 1.0 + RHO_{IFX} \right) \times SMPG_{IFX,T-1} \times 1.05 \right] \right]
\]  \hspace{1cm} (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:

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

14) Calculate average fuel economy of aircraft fleet:

\[
SMPGT = \left[ \frac{SMFRCN_{IT}}{SMPG_{IT-1,T}} \right] + \left[ \frac{1 - SMFRCN_{IT}}{SMPG_{IT-1,T}} \right]^{-1}
\] (B-258)

where:

\[ SMPGT = \text{Overall fleet average seat-miles per gallon} \]

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

\[
JFGAL_{IT} = \left( \frac{SMDEMD_{IT}}{SMPGT_{IT}} \right) \times 1.05
\] (B-259)

where:

\[ JFGAL = \text{Consumption of jet fuel, in gallons} \]

16) Calculate demand for aviation gasoline:

\[
AGD_{IT} = BASEAGD + GAMMA \times \exp \left[ -KAPPA \times (IYEAR - 1979) \right]
\] (B-260)

where:

\[ AGD = \text{Demand for aviation gasoline, in gallons} \]
\[ BASEAGD = \text{Baseline demand for aviation gasoline} \]
\[ GAMMA = \text{Baseline adjustment factor} \]
\[ KAPPA = \text{Exogenously-specified decay constant} \]
\[ IYEAR = \text{Current year} \]
17) Convert from gallons to Btu:

\[ J_{FBTU_T} = J_{FGAL_T} \times \left( \frac{5.670 \text{ MMBtu/bbl}}{42 \text{ gal/bbl}} \right) \]

\[ AG_{DBTU_T} = AG_{DT_T} \times \left( \frac{5.048 \text{ MMBtu/bbl}}{42 \text{ gal/bbl}} \right) \]  

(B-261)

where:

\[ J_{FBTU} = \text{jet fuel demand, in Btu} \]
\[ AG_{DBTU} = \text{Aviation gasoline demand, in Btu} \]

18) Regionalize demand:

\[ Q_{JETR_{IR,T}} = J_{FBTU_T} \cdot SEDSHR_{IR,T} \]

\[ Q_{AGR_{IR,T}} = Q_{AGDBTU_T} \cdot SEDSHR_{IR,T} \]  

(B-262)

where:

\[ Q_{JETR} = \text{Regional demand for jet fuel} \]
\[ Q_{AGR} = \text{Regional demand for aviation gasoline} \]
\[ SEDSHR = \text{Regional shares of fuel demand, from SEDS} \]

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

\[ X_{AIR_T} = \frac{SM_{DEMD_T}}{SM_{DEMD_{T-1}}} \]

\[ X_{AIR_{EFF_T}} = \frac{SM_{PGT_T}}{SM_{PGT_{T-1}}} \]  

(B-263)

where:

\[ X_{AIR} = \text{Fractional change in air travel from base year} \]
\[ X_{AIR_{EFF}} = \text{Fractional change in aircraft fuel efficiency from base year} \]
MISCELLANEOUS TRANSPORTATION ENERGY DEMAND MODULE

MILITARY DEMAND MODEL

Calculate military energy use:

1) Calculate growth in military budget:

\[ \text{MILTARGR}_T = \frac{TMC\_GRML87_T}{TMC\_GFML87_{T-1}} \]  \hspace{1cm} (B-264)

where:
- MILTARGR = Fractional growth of military budget
- TMC\_GRML87 = Military budget, from MACRO module

2) Calculate fuel demand:

\[ MFD_{IF,T} = MFD_{IF,T-1} \times \text{MILTARGR}_T \]  \hspace{1cm} (B-265)

where:
- MFD = Demand for fuel by military
- IF = Index of fuel type

3) Regionalize demand:

\[ QMILT_{IF,IR,T} = MFD_{IF,T} \times \text{MILTRSHR}_{IF,IR,T} \]  \hspace{1cm} (B-266)

where:
- QMILT = Regional military demand for fuel
- MILTRSHR = Regional shares of military demand for fuel
MASS TRANSIT DEMAND MODEL

Calculate mass-transit consumption:

1) Calculate passenger-miles by mode:

\[ TMOD_{IM,T} = VMTEE \times TMLOAD89 \]

and:

\[ TMOD_{IM,T} = TMOD_{IM,T-1} \times \frac{TMOD_{1,T}}{TMOD_{1,T-1}} \]

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:

\[ TMEFFL_{IM,T} = \frac{TMLOAD89_{IM}}{TMOD_{IM,T}} \times \frac{FMPG_{TYPE,T}}{FMPG89_{TYPE}} \]

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:

\[ TMFD_{IM,T} = TMOD_{IM,T} \times TMEFFL_{IM,T} \]
where:

\[ \text{TMFD} = \text{Total mass-transit fuel consumption by mode} \]

4) Regionalize consumption:

\[ Q_{\text{MODR},IMR,T} = \frac{\text{TMFD}_{IM,T} \cdot \frac{TMC_{\text{POPAFO}},IR,T}{\sum_{IR=1}^{9} TMC_{\text{POPAFO}},IR,T}}}{(B-270)} \]

where:

\[ Q_{\text{MODR}} = \text{Regional consumption of fuel, by mode} \]

\[ TMC_{\text{POPAFO}} = \text{Regional population forecasts, from the Macro Module} \]

RECREATIONAL BOATING DEMAND MODEL

Subroutine TMISC

Calculate recreational boat fuel use:

1) Calculate fuel demand:

\[ \text{RECFD}_T = \text{RECFD}_{T-1} \cdot \frac{TMC_{\text{YD}},T}{TMC_{\text{YD}},T-1} \]

\[ (B-271) \]

where:

\[ \text{RECFD} = \text{National recreational boat gasoline consumption in year } T \]

\[ TMC_{\text{YD}} = \text{Total disposable personal income, from the Macro Module} \]

\[ \text{BETAREC} = \text{Coefficient of proportionality relating income to fuel demand for boats} \]

2) Regionalize consumption according to population:

\[ Q_{\text{REC}},IR,T = \text{RECFD}_T \cdot \frac{TMC_{\text{POPAFO}},IR,T}{\sum_{IR=1}^{9} TMC_{\text{POPAFO}},IR,T} \]

\[ (B-272) \]

where:

\[ Q_{\text{REC}} = \text{Regional fuel consumption by recreational boats in year } T \]
LUBRICANT DEMAND MODEL

Subroutine TMISC

Calculate lubricant demand:

1) Sum freight truck VMT across size classes:

\[
FTVMT_T = \sum_{SC=1}^{3} FVMTSC_{SC,T}
\]  \hspace{1cm} (B-273)

where:

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

2) Calculate total highway travel:

\[
HYWAY_T = VMTEE_T + FTVMT_T + FLTVM_T
\]  \hspace{1cm} (B-274)

where:

\(HYWAY\) = Total highway VMT
\(FLTVM\) = Total fleet vehicle VMT, from the Fleet Module

3) Calculate lubricant demand:

\[
LUBFD_T = LUBFD_{T-1} \cdot \left( \frac{HYWAY_T}{HYWAY_{T-1}} \right)^{BETALUB}
\]  \hspace{1cm} (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:

\[
QLUBR_{IR,T} = LUBFD_T \cdot \left( \frac{VMTEE_T \cdot FTVMT_T \cdot SEDSHR_{IF,T}}{HYWAY_T} \right) \cdot \left( \frac{FVMT_T \cdot SEDSHR_{IF,T}}{HYWAY_T} \right)
\]  \hspace{1cm} (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
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:

\[ EMISS_{IE,IM,IR,T} = EFACT_{IE,IM,IR,T} \times U_{IM,IR,T} \]  \hspace{1cm} (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\(_2\), 2 = NO\(_x\), 3 = C, 4 = CO\(_2\), 5 = CO, 6 = VOC
- **IR** = Index identifying census region
Appendix C. References


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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:
David Chien
Energy Information Administration
Office of Integrated Analysis and Forecasting
Energy Demand and Integration Division
Energy Demand Analysis Branch
1000 Independence Avenue, SW
EI-813, Room 2F-094
Washington, DC 20585
Telephone: (202) 586-3994

Documentation:

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 Features:
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:
Status of Evaluation Efforts by Sponsor:
None.

DOE Input Sources:
- Residential Transportation Energy Consumption Survey (RTECS), 1991, December 1993

Non-DOE Input Sources:
- National Energy Accounts
- Department of Transportation Air Travel Statistics
- Air Transport Association of America, 1990 Air Travel Survey
Appendix E. Data Quality and Estimation

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Appendix E. Data Quality and Estimation

This appendix presents results of the statistical tests conducted for those components 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 validate 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:

\[ \ln \left( \frac{\text{CLASSSHARE}_i}{1 - \text{CLASSSHARE}_i} \right)_\text{YEAR} - \ln \left( \frac{\text{CLASSSHARE}_i}{1 - \text{CLASSSHARE}_i} \right)_{1990} = A \cdot \ln \left( \frac{\text{YEAR}}{1990} \right) \]

\[ + B \cdot \ln \left( \frac{\text{FUELCost}_\text{YEAR}}{\text{FUELCost}_{1990}} \right) + C \cdot \ln \left( \frac{\text{INCOME}_\text{YEAR} - 13,000}{\text{INCOME}_{1990} - 13,000} \right) \]

(E-1)

where:

- \text{CLASSSHARE}_i = \text{The market share of the } i^{th} \text{ vehicle class}
- \text{FUELCost} = \text{The price of gasoline}
- \text{INCOME} = \text{Per capita disposable income}

1Note: 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:

\[
\ln \left( \frac{\text{CLASSSHARE}_{t}}{1 - \text{CLASSSHARE}_{t}} \right)_{\text{YEAR}} - \ln \left( \frac{\text{CLASSSHARE}_{t}}{1 - \text{CLASSSHARE}_{t}} \right)_{1990} = A \times \ln \left( \frac{\text{YEAR}}{1990} \right) + B \times \ln \left( \frac{\text{FUELCONST}}{\text{FUELCONST}_{1990}} \right) + C \times \ln \left( \frac{\text{INCOME}}{\text{INCOME}_{1990}} \right)
\]

(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

<table>
<thead>
<tr>
<th>Group</th>
<th>F Val</th>
<th>R²</th>
<th>Intercept YEAR</th>
<th>FUELCONST</th>
<th>INCOME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini and Subcompact</td>
<td>14.359</td>
<td>0.891</td>
<td>-5.428</td>
<td>0.056 (1.761)</td>
<td>1.33 (1.828)</td>
</tr>
<tr>
<td>Sports</td>
<td>11.193</td>
<td>0.808</td>
<td>-2.475</td>
<td>-0.049 (-1.903)</td>
<td>0.26 (0.466)</td>
</tr>
<tr>
<td>Compact</td>
<td>5.533</td>
<td>0.76</td>
<td>-5.021</td>
<td>0.111 (2.117)</td>
<td>1.332 (1.35)</td>
</tr>
<tr>
<td>Intermediate</td>
<td>3.084</td>
<td>0.536</td>
<td>-1.01</td>
<td>-0.051 (-1.742)</td>
<td>-0.213 (-3.35)</td>
</tr>
<tr>
<td>Large</td>
<td>16.880</td>
<td>0.864</td>
<td>-3.312</td>
<td>-0.119 (-4.754)</td>
<td>0.042 (0.077)</td>
</tr>
<tr>
<td>Luxury</td>
<td>18.458</td>
<td>0.939</td>
<td>-3.1</td>
<td>0.126 (2.336)</td>
<td>1.166 (2.704)</td>
</tr>
<tr>
<td>Mini Truck</td>
<td>1.378</td>
<td>0.341</td>
<td>2.268</td>
<td>-0.018 (-0.168)</td>
<td>-3.648 (-1.6)</td>
</tr>
<tr>
<td>Compact Pickup</td>
<td>19.183</td>
<td>0.916</td>
<td>-8.749</td>
<td>-0.042 (-1.238)</td>
<td>-0.811 (-1.48)</td>
</tr>
<tr>
<td>Compact Van</td>
<td>804.167</td>
<td>0.998</td>
<td>-9.3</td>
<td>0.01 (.352)</td>
<td>0.832 (1.727)</td>
</tr>
<tr>
<td>Compact Utility</td>
<td>274.104</td>
<td>0.994</td>
<td>-7.36</td>
<td>-0.042 (-1.447)</td>
<td>-0.2 (-0.396)</td>
</tr>
<tr>
<td>Standard Size Trucks</td>
<td>1.582</td>
<td>0.475</td>
<td>-2.779</td>
<td>-0.056 (-1.523)</td>
<td>0.252 (.307)</td>
</tr>
</tbody>
</table>
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:

\[ VC_{IT,IR} = CONS_{IT} + \beta_1 VPRI_{IT,IN} + \beta_2 COST_{IT,IR} + \beta_3 RANGE_{IT,IN} + \beta_4 VRANGE^+_{IT,IN} + \beta_5 EMISS_{IT,IN} + \beta_6 EMISS^2_{IT,IN} + \beta_7 FAVAIL_{IT,IR} + \beta_8 FAVAIL^+_{IT,IN} \]  

(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$\n- \( VRANGE \) = 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

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>COEFFICIENT</th>
<th>T-STATISTIC</th>
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</thead>
<tbody>
<tr>
<td>VPRI</td>
<td>-.134</td>
<td>10.1</td>
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<td>COPCOST</td>
<td>-.190</td>
<td>16.4</td>
</tr>
<tr>
<td>VRANGE</td>
<td>2.52</td>
<td>11.4</td>
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<tr>
<td>VRANGE$^2$</td>
<td>-.408</td>
<td>7.4</td>
</tr>
<tr>
<td>EMISS</td>
<td>-2.45</td>
<td>7.0</td>
</tr>
<tr>
<td>EMISS$^2$</td>
<td>0.855</td>
<td>2.7</td>
</tr>
<tr>
<td>FAVAIL</td>
<td>2.96</td>
<td>5.7</td>
</tr>
<tr>
<td>FAVAIL$^2$</td>
<td>-1.63</td>
<td>3.5</td>
</tr>
<tr>
<td>CONST (Technology-Specific, as Follows)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasoline</td>
<td>0.0</td>
<td>—</td>
</tr>
<tr>
<td>Diesel</td>
<td>0.0</td>
<td>—</td>
</tr>
<tr>
<td>Ethanol Flex</td>
<td>0.693</td>
<td>6.7</td>
</tr>
<tr>
<td>Ethanol Neat</td>
<td>0.0979</td>
<td>0.9</td>
</tr>
<tr>
<td>Methanol Flex</td>
<td>0.693</td>
<td>6.7</td>
</tr>
<tr>
<td>Methanol Neat</td>
<td>0.0979</td>
<td>0.9</td>
</tr>
<tr>
<td>Electric</td>
<td>-0.240</td>
<td>0.1</td>
</tr>
<tr>
<td>Electric Hybrid/Large ICE</td>
<td>-0.257</td>
<td>1.5</td>
</tr>
<tr>
<td>Electric Hybrid/Small ICE</td>
<td>-0.257</td>
<td>1.5</td>
</tr>
<tr>
<td>Electric Hybrid/Turbine</td>
<td>-0.257</td>
<td>1.5</td>
</tr>
<tr>
<td>CNG</td>
<td>0.0979</td>
<td>0.9</td>
</tr>
<tr>
<td>LPG</td>
<td>0.0979</td>
<td>0.9</td>
</tr>
<tr>
<td>Turbine/Gasoline</td>
<td>0.0</td>
<td>—</td>
</tr>
<tr>
<td>Turbine/CNG</td>
<td>0.0979</td>
<td>0.9</td>
</tr>
<tr>
<td>Fuel Cell/Methanol</td>
<td>0.0979</td>
<td>0.9</td>
</tr>
<tr>
<td>Fuel Cell/Hydrogen</td>
<td>0.0979</td>
<td>0.9</td>
</tr>
</tbody>
</table>
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:

\[
 VMTPC_t = \rho VMTPC_{t-1} + 4.52 (1-\rho) - 7.50 (CPM_t - \rho CPM_{t-1}) \\
+ 3.6 \times 10^{-4} (YPC_t - \rho YPC_{t-1}) + 8.36 (PrFem_t - \rho PrFem_{t-1}) 
\]  

(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>
<thead>
<tr>
<th>Parameter</th>
<th>( \hat{\rho} )</th>
<th>( \hat{\alpha} )</th>
<th>CPM92</th>
<th>YPC92</th>
<th>PrFem</th>
<th>Adj. R-Sq</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-Statistic</td>
<td>0.736</td>
<td>0.28</td>
<td>-1.01</td>
<td>2.64 e-04</td>
<td>1.805</td>
<td>0.855</td>
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</table>
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. 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.

---

*For a description of the development of this model, see Appendix B, which reproduces the original report.*
<table>
<thead>
<tr>
<th>Year</th>
<th>RPM Domestic</th>
<th>Business Fraction</th>
<th>RPM Business</th>
<th>RPM Personal</th>
<th>RPM International</th>
<th>International Fraction</th>
<th>RTM</th>
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<tr>
<td>1979</td>
<td>212,701</td>
<td>55%</td>
<td>116,986</td>
<td>95,715</td>
<td>56,498</td>
<td>27%</td>
<td>6,355</td>
</tr>
<tr>
<td>1980</td>
<td>204,367</td>
<td>54%</td>
<td>109,336</td>
<td>95,031</td>
<td>65,103</td>
<td>32%</td>
<td>6,541</td>
</tr>
<tr>
<td>1981</td>
<td>201,435</td>
<td>52%</td>
<td>104,746</td>
<td>96,899</td>
<td>60,921</td>
<td>30%</td>
<td>6,543</td>
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<tr>
<td>1982</td>
<td>213,631</td>
<td>52%</td>
<td>110,020</td>
<td>103,611</td>
<td>59,894</td>
<td>28%</td>
<td>6,404</td>
</tr>
<tr>
<td>1983</td>
<td>232,165</td>
<td>51%</td>
<td>118,404</td>
<td>113,761</td>
<td>61,664</td>
<td>27%</td>
<td>7,017</td>
</tr>
<tr>
<td>1984</td>
<td>250,686</td>
<td>48%</td>
<td>120,329</td>
<td>130,357</td>
<td>70,599</td>
<td>28%</td>
<td>7,709</td>
</tr>
<tr>
<td>1985</td>
<td>277,836</td>
<td>50%</td>
<td>138,918</td>
<td>138,918</td>
<td>76,986</td>
<td>28%</td>
<td>7,389</td>
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<td>1986</td>
<td>307,884</td>
<td>46%</td>
<td>141,627</td>
<td>166,257</td>
<td>76,851</td>
<td>25%</td>
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<tr>
<td>1987</td>
<td>329,214</td>
<td>48%</td>
<td>158,023</td>
<td>171,191</td>
<td>91,917</td>
<td>28%</td>
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<tr>
<td>1988</td>
<td>334,290</td>
<td>50%</td>
<td>167,145</td>
<td>167,145</td>
<td>104,492</td>
<td>30%</td>
<td>12,795</td>
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<tr>
<td>1989</td>
<td>335,213</td>
<td>49%</td>
<td>164,254</td>
<td>170,959</td>
<td>111,475</td>
<td>33%</td>
<td>14,409</td>
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<tr>
<td>1990</td>
<td>345,763</td>
<td>48%</td>
<td>165,966</td>
<td>179,797</td>
<td>126,363</td>
<td>37%</td>
<td>14,409</td>
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<tr>
<td>1991</td>
<td>338,085</td>
<td>46%</td>
<td>155,519</td>
<td>182,566</td>
<td>145,213</td>
<td>43%</td>
<td>14,199</td>
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<tr>
<td>1992</td>
<td>354,764</td>
<td>46%</td>
<td>164,467</td>
<td>190,297</td>
<td>138,950</td>
<td>39%</td>
<td>15,114</td>
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<tr>
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<td>362,230</td>
<td>48%</td>
<td>173,870</td>
<td>188,360</td>
<td>143,766</td>
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<td>16,718</td>
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<td>170,895</td>
<td>217,503</td>
<td>149,096</td>
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<td>19,211</td>
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<tr>
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<td>403,786</td>
<td>41%</td>
<td>165,552</td>
<td>238,234</td>
<td>154,799</td>
<td>38%</td>
<td>20,699</td>
</tr>
</tbody>
</table>

**Sources:**


<table>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
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<td>224,873</td>
<td>3,354</td>
<td>4,728</td>
<td>212</td>
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<td>16.09</td>
<td>56.37</td>
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<td>237</td>
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<td>96.81</td>
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<td>88.02</td>
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<td>5,156</td>
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<td>33,842</td>
<td>41,988</td>
<td>13.64</td>
<td>54.54</td>
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<td>6,043</td>
<td>362</td>
<td>0.897</td>
<td>43,670</td>
<td>48,685</td>
<td>14.52</td>
<td>59.55</td>
<td>66.39</td>
<td>4.92</td>
</tr>
<tr>
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<td>250,270</td>
<td>4,485</td>
<td>6,139</td>
<td>392</td>
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<td>49,441</td>
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<td>76.71</td>
<td>81.96</td>
<td>6.07</td>
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<tr>
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<td>253,033</td>
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<td>6,079</td>
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<td>44,594</td>
<td>45,820</td>
<td>13.55</td>
<td>66.67</td>
<td>68.50</td>
<td>5.07</td>
</tr>
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<td>449</td>
<td>1.000</td>
<td>45,246</td>
<td>45,246</td>
<td>12.75</td>
<td>61.84</td>
<td>61.84</td>
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<td>13.32</td>
<td>58.70</td>
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<td>50,450</td>
<td>48,067</td>
<td>12.38</td>
<td>54.62</td>
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<td>3.85</td>
</tr>
<tr>
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<td>4,946</td>
<td>6,743</td>
<td>566</td>
<td>1.076</td>
<td>53,906</td>
<td>50,115</td>
<td>12.41</td>
<td>54.59</td>
<td>50.74</td>
<td>3.76</td>
</tr>
</tbody>
</table>
Domestic Yield
1987 Cents per Revenue Passenger Mile

\[ YIELD = 9.73 + 0.794 \, PJF \]

\[ SE = 0.055 \]
\[ t = 14.43 \]
\[ Adj.R^2 = 0.928 \quad D-W = 1.43 \]

Sources:


Per Capita Travel Demand

Business Travel

![Graph showing Per Capita Travel Demand from 1979 to 1995](image)

\[ RPMBPC = 89.70 + 0.029 \times GDPPC92 - 16.04 \times YIELD \]

\[ SE = 0.01, \quad t = 3.04, \quad Adj. R^2 = 0.849, \quad D-W = 1.15 \]

Sources:

1. RPMBPC: Quotient of Business RPM and Population.
2. GDPPC92: Gross Domestic Product per Capita, in 1992 dollars. From NEMS Macroeconomic Module.
**Per Capita Travel Demand**

**Personal Travel**

![Graph showing per capita travel demand from 1979 to 1995. The graph includes FAA data and estimated data.](image)

\[ RPMPPC = -481.84 + 0.083 \times DPIPC92 - 18.68 \text{ YIELD} \]

\[ SE = 0.13 \quad t = 8.40 \]

\[ Adj.R^2 = 0.96 \quad D-W = 1.48 \]

**Sources:**

1. **RPMPPC**: Quotient of Personal RPM and Population.


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Energy Information Administration
NEMS Transportation Demand Model Documentation Report
Freight Transport Demand

\[ RTM = (-14,556 + 19.81 \text{EXP92} + 3.49 \text{GDP92}) \cdot DFRT \]

\[ SE = 4.03 \quad 0.675 \]

\[ t = 4.91 \quad 5.18 \]

\[ Adj.R^2 = .98 \quad D-W = 1.22 \]

Sources:


(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.