The transportation demand module (TRAN) forecasts the consumption of transportation sector fuels by transportation mode, including the use of renewables and alternative fuels, subject to delivered prices of energy fuels and macroeconomic variables, including disposable personal income, gross domestic product, level of imports and exports, industrial output, new car and light truck sales, and population. The structure of the module is shown in Figure 8.

NEMS projections of future fuel prices influence fuel efficiency, vehicle-miles traveled, and alternative-fuel vehicle (AFV) market penetration for the current fleet of vehicles. Alternative-fuel shares are projected on the basis of a multinomial logit vehicle attribute model, subject to State and Federal government mandates.

Fuel Economy Submodule

This submodule projects new light-duty vehicle fuel efficiency by 12 U.S. Environmental Protection Agency (EPA) vehicle size classes and 15 engine technologies (gasoline, diesel, and 13 AFV technologies) as a function of energy prices and income-related variables. There are 59 fuel-saving technologies which vary in cost and marginal fuel savings by size class. Characteristics of a sample of these technologies are shown on page 40, a complete list is published in *Assumptions to the Annual Energy Outlook 2003*.[23] Technologies penetrate the market based on a cost-effectiveness algorithm which compares the technology cost to the discounted stream of fuel savings and the value of performance to the consumer. In general, higher fuel prices lead to higher fuel efficiency estimates within each size class, a shift to a more fuel-efficient size class mix, and an increase in the rate at which alternative-fuel vehicles enter the marketplace.

Regional Sales Submodule

Vehicle sales from the macroeconomic activity module are divided into car and light truck sales based on demographic analysis. The remainder of the submodule is a simple accounting mechanism that uses endogenous estimates of new car and light truck sales and the historical regional vehicle sales adjusted for regional population trends to produce estimates of regional sales, which are subsequently passed to the alternative-fuel vehicle and the light-duty vehicle stock submodules.

Alternative-Fuel Vehicle Submodule

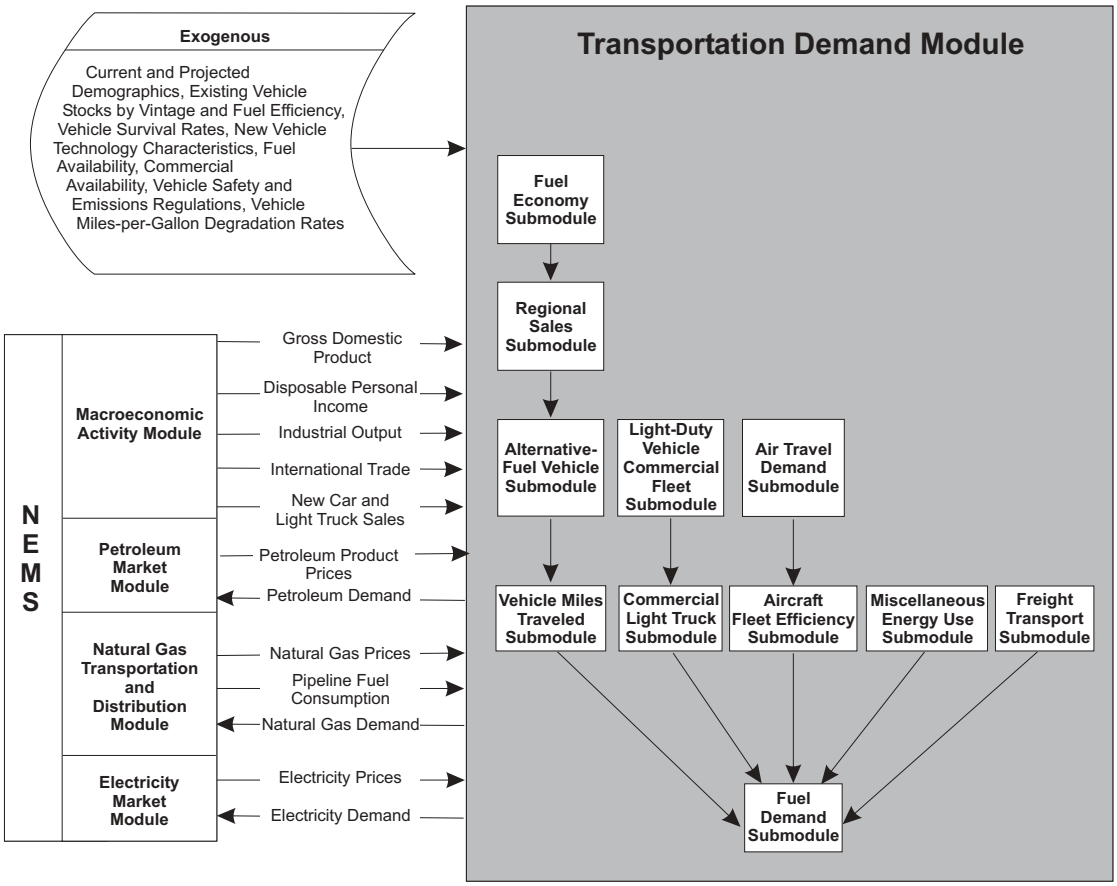
This submodule projects the sales shares of alternative-fuel technologies as a function of time, technology attributes, costs, and fuel prices. The alternative-fuel technologies are listed on the next page. Vehicle attributes are shown on page 40, derived from *Assumptions to the Annual Energy Outlook 2003*. Both conventional and new technology vehicles are considered. The alternative–fuel vehicle submodule receives regional new car and light truck sales by size class from the regional sales submodule.

The forecast of vehicle sales by technology utilizes a nested multinomial logit (NMNL) model that predicts sales shares based on relevant vehicle and fuel attributes. The nesting structure first predicts the probability of fuel choice for multi-fuel vechicles within a technology set. The second level nesting predicts penetration among similar technologies within a technology set (i.e. Gasoline versus diesel

TRAN Outputs	Inputs from NEMS	Exogenous Inputs
Fuel demand by mode	Energy product prices	Current and projected demographics
Sales, stocks and characteristics of vehicle types by size class	Gross domestic product	Existing vehicle stocks by vintage and fuel efficiency
Vehicle-miles traveled	Disposable personal income	Vehicle survival rates
Fuel efficiencies by technology type	Industrial output	New vehicle technology characteristics
Alternative-fuel vehicle sales by technology type	Vehicle sales	Fuel availability
Light-duty commercial fleet vehicle characteristics	International trade	Commercial availability
	Natural gas pipeline consumption	Vehicle safety and emissions regulations
		Vehicle miles-per-gallon degradation rates

[23] Energy Information Administration, *Assumptions to the Annual Energy Outlook 2003*, http:/www.eia.doe.gov/oiaf/aeo/assumption/pdf/0554(2003).pdf (Washngton, DC, January 2003).

Figure 8. Transportation Demand Module Structure



Alternative Fuel Vehicles

Methanol flex-fueled
Methanol neat (85 percent methanol)
Ethanol flex-fueled
Ethanol neat (85 percent ethanol)
Compressed natural gas (CNG)
CNG bi-fuel
Liquefied petroleum gas (LPG)
LPG bi-fuel
Electric
Diesel-electric hybrid
Fuel cell gasoline
Fuel cell hydrogen
Fuel cell methanol

hybrids). The third level choice determines market share among the different technology sets.[24] The technology sets include:

- Conventional fuel capable (gasoline, diesel, bi-fuel and flex-fuel),
- Hybrid (gasoline and diesel),
- Dedicated alternative fuel (CNG, LPG, methanol, and ethanol),
- Fuel cell (gasoline, methanol, and hydrogen), and

[24] Greene, David L. and S.M. Chin, "Alternative Fuels and Vehicles (AFV) Model Changes," Center for Transportation Analysis, Oak Ridge National Laboratory, page 1, (Oak Ridge, TN, November 14, 2000).

- Electric battery powered (lead acid, nickel-metal hydride, lithium polymer)[25]

The vehicles attributes considered in the choice algorithm include: price, maintenance cost, battery replacement cost, range, multi-fuel capability, home refueling capability, fuel economy, acceleration and luggage space. With the exception of maintenance cost, battery replacement cost, and luggage space, vehicle attributes are determined endogenously.[26] The fuel attributes used in market share estimation include availability and price. Vehicle attributes vary by six EPA size classes for cars and light trucks and fuel availability varies by Census division. The NMNL model coefficients were developed to reflect purchase decisions for cars and light trucks separately.

Light Vehicle Size Classes

Cars:
- Mini-compact - less than 85 cubic feet
- Subcompact - between 85 and 99 cubic feet
- Compact - between 100 and 109 cubic feet
- Mid-size - between 110 and 119 cubic feet
- Large - 120 or more cubic feet, including all station wagons (small, mid-size, and large)
- Two-seater - designed to seat two adults

Trucks:
- Passenger vans
- Cargo vans
- Small pickups - trucks with gross vehicle weight rating (GVWR) less than 4,500 pounds
- Large pickups - trucks with GVWR 4,500 to 8,500 pounds
- Small utility
- Large utility

Light-Duty Vehicle Stock Submodule

This submodule specifies the inventory of light-duty vehicles from year to year. Survival rates are applied to each vintage, and new vehicle sales are introduced into the vehicle stock through an accounting framework. The fleet of vehicles and their fuel efficiency characteristics are important to the translation of transportation services demand into fuel demand.

TRAN maintains a level of detail that includes twenty vintage classifications and six passenger car and six light truck size classes corresponding to EPA interior volume classifications for all vehicles less than 8,500 pounds, as follows:

Vehicle-Miles Traveled (VMT) Submodule

This submodule projects travel demand for automobiles and light trucks. VMT per capita estimates are based on the fuel cost of driving per mile, per capita disposable personal income, and an adjustment for female-to-male driving ratios. Total VMT is calculated by multiplying VMT per capita by the driving age population.

Light-Duty Vehicle Commercial Fleet Submodule

This submodule generates estimates of the stock of cars and trucks used in business, government, and utility fleets. It also estimates travel demand, fuel efficiency, and energy consumption for the fleet vehicles prior to their transition to the private sector at predetermined vintages.

Commercial Light Truck Submodule

The commercial light truck submodule estimates sales, stocks, fuel efficiencies, travel, and fuel demand for all trucks greater than 8,500 pounds and less than 10,000 pounds.

Air Travel Demand Submodule

This submodule estimates the demand for both passenger and freight air travel. Passenger travel is forecasted by domestic travel, which is dissaggreregated between business and personal travel, and international travel. Dedicated air freight travel is disaggregated between the total air freight demand and air freight carried in the lower hull of commercial passenger aircraft. In each of the market segments, the demand for air travel is estimated as a function of the cost of air travel (including fuel costs)

[25] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, prepared by Interlaboratory Working Group, Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy Technologies by 2010 and Beyond, (Washington, DC, 1998).

[26] Energy and Environmental Analysis, Inc., Updates to the Fuel Economy Model (FEM) and Advanced Technology Vehicle (ATV) Module of the National Energy Modeling System (NEMS) Transportation Model, Prepared for the Energy Information Administration (EIA), (Arlington, VA, October 23, 2000).

and economic growth (GDP, disposable income, and merchandise exports).

Aircraft Fleet Efficiency Submodule

This submodule forecasts the total stock and the average fleet efficiency of narrow body and wide body aircraft required to meet the projected travel demand. The stock estimation is based on the growth of travel demand and a logistic function that calculates the survival of the older planes. The overall fleet efficiency is determined by the weighted average of the surviving aircraft efficiency (including retrofits) and the efficiencies of the newly acquired aircraft. The efficiency improvements of the new aircraft are determined by technology choice which depends on the trigger fuel price, the time in which the technology is commercially viable, and by the expected efficiency gains of aircraft incorporating those technologies. Technology characteristics are shown on page 41.

Freight Transport Submodule

This submodule translates NEMS estimates of industrial production into ton-miles traveled requirements for rail and ship travel, and into vehicle-miles traveled for trucks, then into fuel demand by mode of freight travel. The freight truck stock is subdivided into medium and heavy-duty trucks. VMT freight estimates by truck size class and technology are based on matching freight needs, as measured by the growth in industrial output by Standard Industrial Classification (SIC) code, to VMT levels associated with truck stocks and new vehicles. Rail and shipping ton-miles traveled are also estimated as a function of growth in industrial output.

Selected Technology Characteristics for Automobiles

	Fractional Fuel Efficiency Change	First Year Introduced	Fractional Horsepower Change
Material Substitution IV	0.099	2006	0
Drag Reduction IV	0.063	2002	0
5–Speed Automatic	0.065	1995	0
CVT	0.105	1998	0
Automated Manual Trans	0.080	2006	0
VVL–6 Cylinder	0.050	2000	0.10
Camless Valve Actuation 6 Cylinder	0.110	2008	0.13
Electric Power Steering	0.020	2004	0
42V–Launch Assist and Regen	0.030	2005	-0.05

Examples of Midsize Automobile Attributes

	Year	Gasoline	Diesel Flex	Ethanol Flex	LPG	Electric-Diesel Hybrid	Fuel Cell Hydrogen
Vehicle Price (thousand 2001 dollars)	2001	25.0	27.2	27.3	30.7	36.1	81.0*
	2025	26.5	28.4	26.8	32.2	28.9	53.8
Vehicle Miles per Gallon	2001	26.7	35.9	26.9	27.7	42.6	52.9*
	2025	27.6	34.5	27.9	28.5	40.0	49.8
Vehicle Range (miles)	2001	450	610	330	390	590	450*
	2025	470	630	340	400	610	470
Fuel Availability Relative to Gasoline	2001	1.00	1.00	1.00**	0.30	1.00	0.00*
	2025	1.00	1.00	1.00	0.40	1.00	0.90

*Data for fuel cell hydrogen automobiles is for 2005, first year of availability.
**Due to availability using gasoline.

Freight truck fuel efficiency growth rates are tied to historical growth rates by size class and are also dependent on the maximum penetration, introduction year, fuel trigger price (based on cost-effectiveness), and fuel economy improvement of advanced technologies, which include alternative-fuel technologies. A subset of the technology characteristics are shown on page 42. In the rail and shipping modes, energy efficiency estimates are structured to evaluate the potential of both technology trends and efficiency improvements related to energy prices.

Miscellaneous Energy Use Submodule

This submodule projects the use of energy in military operations, mass transit vehicles, recreational boats, and lubricants, based on endogenous variables within NEMS (e.g., vehicle fuel efficiencies) and exogenous variables (e.g., the military budget).

Aircraft Technology Characteristics

Technology	Introduction Year	Jet Fuel Prices Necessary for Cost-Effectiveness (1997 dollars per gallon)	Seat-Miles per Gallon Gain Over 1990 (Percent)	
			Narrow Body	Wide Body
Engines				
Ultra-high Bypass	1995	0.69	10	10
Propfan	2000	1.36	23	0
Thermodynamics	2010	1.22	20	20
Aerodynamics				
Hybrid Laminar Flow	2020	1.53	15	15
Advanced Aerodynamics	2000	1.70	18	18
Other				
Weight Reducing Materials	2000	-	15	15

Freight Truck Technology Characteristics

	Fuel Economy Improvement (percent)		Maximum Penetration (percent)		Introduction Year		Capital Cost (2001 dollars)	
	Medium	Heavy	Medium	Heavy	Medium	Heavy	Medium	Heavy
Aero Dynamics: bumper, underside air baffles, wheel well covers	2.3	2.7	50	66	2005	2005	$280	$550
Low rolling resistence tires	3.6	2.3	50	40	2004	2005	$800	$1,500
Transmission: lock-up, electronic controls, reduced friction	1.8	1.8	100	100	2005	2005	$900	$1,000
Diesel Engine: hybrid electric powertrain	36.0	N/A	15	N/A	2010	N/A	$8,000	N/A
Reduce waste heat, thermal mgmt	N/A	9.0	N/A	35	N/A	2010	N/A	$2,000
Gasoline Engine:								
Direct injection	10.8	N/A	25	N/A	2008	N/A	$700	N/A
Weight Reduction	4.5	9.0	20	30	2007	2005	$2,000	$2,000
Diesel Emission NO_x non-thermal plasma catalyst	-1.5	-1.5	25	25	2006	2007	$1,200	$1,250
PM catalytic filter	-2.5	-1.5	95	95	2006	2006	$1,250	$1,500
HC/CO: oxidation catalyst	-0.5	-0.5	95	95	2002	2002	$200	$250
NO_X adsorbers	-3.0	-3.0	90	90	2006	2007	$2,000	$2,500