5.0 Light-Duty Vehicle Fleet Model

5.1 Structure of the U.S. fleet model

The U.S. light-duty vehicle (LDV) fleet or “car parc” is composed of approximately 135 million cars and 100 million light-trucks, which include pickups, minivans, and sport utility vehicles (SUVs). New LDV sales in 2006 totaled nearly 16.6 million units, comprising 8.1 million passenger cars and 8.5 million light-trucks, or approximately 7% of the total LDV fleet. To evaluate the impact that emerging propulsion systems and fuels could have on total LDV fleet fuel use and greenhouse gas (GHG) emissions, the dynamics of fleet turnover and usage must be understood. This section explains the logic of the U.S. LDV Fleet Model used for this purpose.

The fleet model is a tool to track LDV stock, travel, fuel use, and greenhouse gas emissions. A simplified overview of the fleet model is shown in Figure 23. A description of previous versions of this model can be found in Heywood et al. [2004], and Bandivadekar and Heywood [2006]. The model is composed of several worksheets in Microsoft Excel that track new vehicle sales, market shares of different propulsion systems and their fuel consumption, vehicle aging and scrappage, vehicle stock, vehicle travel, and fuel mix. Historical data from 1960 onward is used to calibrate the model. In this section we describe the details of the model’s individual building blocks.

5.2 Data sources

Three different public sources of data on U.S. LDVs were used:

- The Transportation Energy Data Book (TEDB) compiles data from a variety of trade publications, such as Motor Vehicle Facts and Figures, published by the American Automobile Manufacturers Association, and Ward’s Automotive Yearbook. The TEDB data referred to here pertains to Edition 26 of the data book [Davis and Diegel 2007].

- The EPA Light-Duty Automotive Technology and Fuel Economy Trends report is a compilation of the data that are submitted for Corporate Average Fuel Economy (CAFE) standards and gas guzzler tax compliance purposes [Heavenrich 2006].

- The U.S. Department of Transportation report on Summary of Fuel Economy Performance compiled by National Highway Transportation and Safety Administration (NHTSA) for CAFE compliance [NHTSA 2008].

Wherever possible, the fleet model uses data compiled from these three sources. Other sources of data are listed where applicable in the following sections. The results of the model are calibrated against the light-duty vehicle data reported by the Federal Highway Administration [FHWA 2005], as compiled in the TEDB.
5.3 Sales mix

The annual sales of light-duty vehicles in the United States from 1970–2005 are shown in Figure 24. The differences in the data are due to different definitions and classification methods employed by the three data sets. Specifically, the TEDB sales numbers for light trucks include all light trucks weighing 4,550 kg (10,000 pounds) of gross vehicle weight (GVW) or less. The EPA and NHTSA data only include vehicles weighing less than 3,865 kg (8,500 lbs). The light trucks weighing between 8,500 and 10,000 lbs, known as Class 2b trucks, are estimated to account for 6–8% of total light truck sales [Davis and Truett 2002]. As a result, the TEDB sales numbers for light-trucks are substantially higher than the corresponding EPA or NHTSA numbers.

Starting in 2011, NHTSA plans to include in the CAFE program all SUVs and vans weighing less than 10,000 lbs, although light trucks weighing between 8,500–10,000 lbs will remain exempt. The default setting for calculating vehicle sales in the fleet model uses TEDB data, i.e., all light-duty vehicles weighing less than 10,000 lbs.

The share of light trucks in new LDV sales has increased from 15% in 1970 to over 50% in 2005. Much of this increase is due to increased numbers of sport utility vehicles (SUVs) and vans sold at the expense of small cars and wagons. The growth in the light-truck category, however, has slowed in the past few years [Heavenrich 2006]. As such, it is not clear if the market share of light trucks will continue to grow beyond the current new sales market shares. According to the TEDB, the data percentage of light-trucks in the new vehicle sales is currently about 55%, whereas EPA and NHTSA data put the light-trucks market share at 50% of new vehicle sales. The default setting
in the fleet model is to maintain the market share of cars and light-trucks at the current level. Any change from the default level is assumed to take place linearly.

![U.S. Light-Duty Vehicle Sales (in million units per year)](image)

**Figure 24** U.S. light-duty vehicle sales [1970–2005]

### 5.4 Sales growth

There are approximately 800 vehicles per thousand people in the United States. By contrast, there are about 600 vehicles per thousand people in Canada and Western Europe, and fewer than 20 vehicles per thousand people in China. Presently, the number of light-duty vehicles on the road in the United States exceeds the number of licensed drivers [Davis and Diegel 2007]. Given this unprecedented level of vehicle ownership, it is unlikely that growth rate of light-duty vehicle sales will be much faster than the rate of growth in the U.S. population. According to the U.S. Bureau of the Census, the average rate of growth of the population is likely to decrease from 0.9% in the first decade of this century to 0.75% by 2040 [U.S. Census 2004]. Thus, the fleet model assumes an average annual growth rate of new vehicle sales of 0.8% per year.

### 5.5 Scrappage rate

There is considerable uncertainty about the scrappage rates of motor vehicles. No consistent data on survival of vehicles of different model years is available. In the literature, three different methodologies have been used to estimate vehicle scrappage rates.

Greene and Chen [1981] applied a logistic function to estimate the survival rate of light-duty vehicles. They estimated that the median lifetime of cars and light trucks from 1966–1977 was 9.9 and 14.5 years, respectively. Using a similar approach, Feeney and Cardebring [1988] estimated that the median lifetime of passenger cars increased from about 10 years in 1971 to about 13 years by 1983. Other sources also cite an increase in the median lifetime of vehicles, and indicate that light-trucks last longer than passenger cars. Recent editions of the TEDB, however,
report an increase in the expected median lifetime of passenger cars made after 1990 to 16.9 years [Table 20].

Libertiny [1993] applied a Weibull distribution to calculate attrition rates of passenger cars, and found no significant difference between domestic and imported cars. Libertiny also concluded that while vehicle scrappage rates decreased considerably between 1970 and 1980, there was not much difference in scrappage rates in the period between 1980 and 1990.

Table 20  Estimated median lifetime of U.S. light-duty vehicles

<table>
<thead>
<tr>
<th></th>
<th>1970 Model Year</th>
<th>1980 Model Year</th>
<th>1990 Model Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cars</td>
<td>10.7</td>
<td>11.5</td>
<td>12.1</td>
</tr>
<tr>
<td>Light Trucks</td>
<td>16.0</td>
<td>16.2</td>
<td>15.7</td>
</tr>
</tbody>
</table>

TEBD = Transportation Energy Data Book

Greenspan and Cohen [1999] separated the scrappage into engineering scrappage and cyclical scrappage. They defined engineering scrappage as scrappage resulting from vehicle aging and accompanying physical wear and tear. They report that the median lifetime of vehicles, based on engineering scrappage estimation, improved from about 10 years for model years 1960–1963 to approximately 13 years for model years 1977–1979. They estimated the cyclical component of scrappage based on income and price effects, and found that the cyclical scrappage rates vary inversely with the ratio of new car price to repair costs.

NHTSA [2006b] used the data from National Vehicle Population Profile (NVPP) compiled by the R. L. Polk and Co. to linearly regress \( \ln(-\ln(1 - \text{Survival Rate})) \) on vehicle age. NHTSA found support to the argument that attrition rates of passenger cars post-1990 may be lower than those of light trucks.

For the purpose of this model, the survival rate of new vehicles is determined by using a logistic curve as shown in Equation 5.1.

\[
1 - \text{Survival Rate} (t) = \frac{1}{\alpha + e^{-\beta(t - t_0)}}
\]  

(5.1)

where,

t_0 is the median lifetime of the corresponding model year

t, the age in a given year

\( \beta \), a growth parameter translating how fast vehicles are retired around \( t_0 \)

\( \alpha \), model parameter set to 1
The median lifetime is kept constant after the model year 1990 at 16.9 cars, 15.5 for light trucks. The growth parameter $\beta$ is fitted to 0.28 for cars and 0.22 for light trucks. For simplification purposes, model parameter $\alpha$ is set to 1, even though Miaou [1995] argues that setting $\alpha$ to 1 is overly restrictive.

Figure 25 shows the estimated survival rates of passenger cars and light-trucks. Note that NHTSA estimates suggest a faster turnover of vehicle fleet. The estimated model survival rates are between the TEDB and NHTSA estimates for vehicles less than 10 years old.

Figure 25  Estimated survival rates of U.S. light-duty vehicles [model year 1990 onward]
5.6 Average per-vehicle kilometers traveled (VKT)

Increase in total vehicle kilometers traveled takes place as a result of an increase in the number of vehicles on the road and an increase in kilometers traveled per vehicle. Table 21 shows the annualized growth rate in vehicle kilometers traveled (VKT) per vehicle as calculated from the rate of growth in the stock of light-duty vehicles, and total annual vehicle kilometers traveled (VKT) as reported by TEDB.

The long-term growth in VKT per vehicle for light-duty vehicles is thus 0.5-0.6% per year. In the future, the rate of growth in per-vehicle kilometers traveled is assumed to decrease from 0.5% per year between 2005 and 2020, to 0.25% per year in 2021–2030, to 0.1% per year in the years after 2030. This is a simplifying assumption that prevents the distance driven per vehicle from escalating rapidly beyond 30,000 km per year. Note that this represents a decrease in total annual VKT growth rate from 1.3% at present to 0.9% by 2035, since the new vehicles sales are assumed to grow at a rate of 0.8% a year.

Table 21 U.S. light-duty vehicle VKT growth rates (1971–2005) [Davis and Diegel 2007]

<table>
<thead>
<tr>
<th>Years</th>
<th>Annual Vehicle Stock Growth (%)</th>
<th>Annual Total VKT Growth (%)</th>
<th>Annual VKT/Vehicle Growth (%)</th>
<th>Annual Vehicle Stock Growth (%)</th>
<th>Annual Total VKT Growth (%)</th>
<th>Annual VKT/Vehicle Growth (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971-1980</td>
<td>3.1</td>
<td>1.6</td>
<td>-1.4</td>
<td>7.0</td>
<td>8.7</td>
<td>1.6</td>
</tr>
<tr>
<td>1981-1990</td>
<td>0.9</td>
<td>2.4</td>
<td>1.5</td>
<td>5.9</td>
<td>7.6</td>
<td>1.7</td>
</tr>
<tr>
<td>1991-2000</td>
<td>0.5</td>
<td>1.8</td>
<td>1.4</td>
<td>4.5</td>
<td>4.0</td>
<td>-0.5</td>
</tr>
<tr>
<td>2001-2005</td>
<td>-0.2</td>
<td>0.9</td>
<td>1.1</td>
<td>3.2</td>
<td>3.0</td>
<td>-0.2</td>
</tr>
<tr>
<td>1971-2005</td>
<td>1.1</td>
<td>1.7</td>
<td>0.5</td>
<td>5.6</td>
<td>6.2</td>
<td>0.6</td>
</tr>
</tbody>
</table>

It is assumed that in 2000, new cars are driven 25,760 km (16,000 miles) in their first year, whereas new light trucks are driven 27,370 km (17,000 miles) in their first year of operation.\(^{50}\) After the first year, the average per-vehicle kilometer travel decreases at an annual rate (denoted \(r\)) of 4% for cars and 5% for light-trucks [Greene and Rath, 1990; NRC 2002]. Thus, the average per-vehicle kilometers of travel (VKT) of a vehicle aged \(i\) years is calculated as:

\[
VKT_i = VKT_{new} \times e^{-ri}
\]  

\(^{50}\) These assumptions are similar to NHSTA and EPA data. NHSTA estimates new car travel at 22,675 km in the first year, and 25,215 for trucks in their first year. EPA uses 24,000 km for the first year of new car travel and 31,375 km for light trucks below 6,000 lbs (2,720 kg), or 34,330 km for trucks between 6,000 and 8,000 lbs (2,720 to 3,630 kg) (NHSTA 2006a; EPA 2007a).
Based on Table 21 and Equation 5.2, the average per-vehicle kilometers traveled by LDVs of different ages can be calculated. Figure 26 shows the distance traveled by the new cars and light-trucks sold in years 1970, 1980, 1990, and 2000.

The total VKT for a given calendar year, \( j \), is obtained using Equation 5.3:

\[
VKT_j = \sum_i N_{i,j} \times VKT_{i,j} \quad (5.3)
\]

Where \( N_{i,j} \) is the number of vehicles of age \( i \) in calendar year \( j \), and \( VKT_{i,j} \) is the average annual vehicle travel for vehicles of age \( i \) in year \( j \).

Figure 26 Per-vehicle kilometer traveled by model year [1970–2000]
5.7 Vehicle fuel consumption

Figure 27 shows the new vehicle fuel consumption trend from 1975–2005, using NHTSA and EPA data. The EPA fuel consumption values are higher than NHTSA reported fuel consumption values primarily because EPA data do not include fuel economy credits from test procedure adjustments for cars, as well as fuel economy credits from alternative/flexible fuel vehicles. The model assumes that the new light trucks meet the CAFE standards for years 2006–2010. The new light truck CAFE standard in 2010 would be approximately 23.5 miles per gallon (10 L/100 km), assuming no major shifts in the sales mix [NHTSA 2006a].

![Figure 27](image_url)

**Figure 27**  New light-duty vehicle fuel consumption (1975–2005)

The fuel consumption values in Figure 27 are not adjusted for on-road performance. The on-road fuel consumption is higher than the test values because of differences between actual driving conditions and trip patterns, and the test cycles, as well as less than ideal state of maintenance of vehicles and aggressive driving behavior [Hellman and Murrell 1982]. Using actual test runs of a variety of vehicles, Hellman and Murrell [1984] estimated the average miles driven by vehicles per day and the fraction of those miles driven in an urban environment. Using these factors, and actual versus measured fuel economy, they estimated an adjustment factor of 0.9 for city driving and 0.78 for highway driving. When measured fuel economy is degraded by using these factors, the estimate for on-road fuel economy is about 15% lower than test results. In other words, on-road fuel consumption of light-duty vehicles needs to be adjusted upward, by $1/0.85 \approx 1.17$.

Mintz et al. [1993] argue that the adjustment factors are not stable over time, and are in fact increasing. They claim that the 0.85 degradation factor is an underestimation, since it does not adequately consider the impact of increasing share of urban driving as well as urban congestion, and increased vehicle speed on highways. Based on the analysis of 1985 Residential Transportation Energy Consumption Survey (RTECS), they estimated a fuel economy shortfall...
of 18.7% for cars and 20.7% for light trucks, or increase in fuel consumption by 23% for cars and 26% for light trucks from the test values.

EIA’s Annual Energy Outlook incorporates changing city/highway driving ratios, increasing congestion levels, and rising highway speeds to modify the degradation factors, as shown in Table 22.

Starting in model year 2008, EPA has decided to use a five-cycle average that includes an aggressive driving cycle (US06), a cold-start cycle (cold FTP), and an accessories loading cycle (SC03) along with traditional city and highway cycles to come up with fuel economy labels [EPA 2006]. As a result, EPA expects to report vehicle fuel economy values that could be lower by as much as 25% for years 2008–2010 [Heavenrich 2006b; EPA 2007]. According to EPA calculations, the average on-road fuel consumption of new vehicles from 1986–2005 is greater than their test fuel consumption by 21%.

### Table 22  Car and light truck degradation factors [EIA 2007c]

<table>
<thead>
<tr>
<th>Year</th>
<th>Cars</th>
<th>Light Truck</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fuel Economy shortfall (%)</td>
<td>Fuel Consumption Increase (%)</td>
</tr>
<tr>
<td>2000</td>
<td>20.8</td>
<td>26.2</td>
</tr>
<tr>
<td>2005</td>
<td>20.3</td>
<td>25.4</td>
</tr>
<tr>
<td>2010</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>2015</td>
<td>19.8</td>
<td>24.7</td>
</tr>
<tr>
<td>2020</td>
<td>19.4</td>
<td>24</td>
</tr>
<tr>
<td>2030</td>
<td>19</td>
<td>23.4</td>
</tr>
</tbody>
</table>

This model uses the same value as the IEA Sustainable Mobility project: an average shortfall of 19% in fuel economy or a 22% increase in fuel consumption [Fulton and Eads 2004]. For simplification purposes, it is also assumed that the fuel consumption of vehicles remains constant over the life of the vehicle.

Finally, EPA estimates that the fuel economy of trucks weighing more than 8,500 lbs is, on average, about 14% lower than trucks weighing less than 8,500 lbs [Heavenrich 2006]. Since all Class 2b trucks are included in this model but are assigned the same fuel economy as that of Class 2a trucks, the net result is to underestimate fuel use by the order of 2%.

We assume that future reductions in fuel consumption start in 2010, since the product plans for the next two years have already been finalized. We can estimate the potential fuel use reductions that can materialize if more emphasis is placed on reducing fuel consumption in the future, as opposed to the little or no emphasis being placed on it today. Thus, no emphasis placed on fuel consumption reduction (0% ERFC) becomes our No Change Scenario. As can be seen in Figure 54, splitting the fuel efficiency benefit evenly between performance and fuel consumption reduction will level off the light-duty fleet fuel use by 2035 without any alternative propulsion systems. This is termed the Reference Scenario, where a modest but sustained pressure from gasoline price, increases in fuel economy standards, and competitive pressures all combine to prompt a shift away from a No Change Scenario. Using the information in Table 6 and Equation
4.1c, the relative onboard gasoline equivalent fuel consumption for different propulsion systems in the Reference Scenario can be calculated for years 2010–2035, as shown in Figure 28.

![Figure 28](image_url)

**Figure 28** Relative onboard gasoline-equivalent fuel consumption at 50% ERFC for different propulsion systems 2005–2035
5.8 Fleet fuel use and greenhouse gas emissions

The fuel use of the entire fleet is calculated by summing up the fuel use of vehicles using different technologies of the same age, which in turn is calculated by multiplying the number of vehicles in service of that age and technology type by the number of vehicle kilometers traveled, and then by their respective fuel consumption. Fuel use is calculated separately for each propulsion system type in gasoline equivalent units.

Greenhouse gas emissions are calculated on a well-to-wheel basis by multiplying the fuel use by a corresponding well-to-tank and tank-to-wheel greenhouse gas emissions coefficient, as discussed in Section 6. Energy use and greenhouse gas emissions from the vehicle manufacturing and disposal stage are also incorporated in the model, as discussed in Section 7.

5.9 Model results and comparison with DOE/EIA projections

Before comparing future projections of light-duty fleet characteristics, the model results are first evaluated against historical trends. Figure 29 shows the model calculated vehicle stock, vehicle travel, and fleet fuel use compared with highway statistics compiled by the Federal Highway Administration and reported by the Transportation Energy Data Book [TEDB]. The number of vehicles in the U.S. LDV fleet increased from about 108 million vehicles in 1970 to about 240 million vehicles in 2005 [Davis and Diegel, 2007, Table 3.3]. Most of the increase in stock came from the light truck segment. The model consistently overshoots the data, especially for the light trucks; this is because the model includes all light-duty vehicles under a gross vehicle weight of 10,000 lbs., whereas the TEDB data shown in Figure 29 only represents light trucks under 8,500 lbs.
Figure 29  Fleet model results compared with historical data (1970–2005)
Table 23 shows the average error in vehicle stock, VKT, and fleet fuel use for each decade since 1975 relative to the TEDB data. Additionally, the EPA and NHTSA also provide vehicle sales data that differs slightly from the TEDB [EPA 2007; NHTSA 2008]. Using the EPA and NHTSA data to calculate the light-duty vehicle fuel use, the average error between data and model is about 0.7% and 1%, respectively.

**Table 23** Percent difference between TEBD data and model calculation

<table>
<thead>
<tr>
<th>Decade</th>
<th>Stock Difference [%]</th>
<th>VKT Difference [%]</th>
<th>Fuel Use Difference [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975-1985</td>
<td>1.9</td>
<td>-3.4</td>
<td>-11.2</td>
</tr>
<tr>
<td>1985-1995</td>
<td>-1.1</td>
<td>-4.4</td>
<td>-5.1</td>
</tr>
<tr>
<td>1995-2005</td>
<td>-4.9</td>
<td>-6.3</td>
<td>-4.9</td>
</tr>
</tbody>
</table>

Figure 30 compares the light-duty vehicle fleet fuel use calculated by using the light-vehicle sales numbers from TEDB, EPA and NHTSA. On average, the TEDB fuel use calculation results in 5.8 percent and 6.5 percent higher fuel use than NHTSA and EPA calculations as shown in the Figure 30. The TEDB vehicle sales data is used as the primary source for calibrating and generating results from the MIT model.

Figure 30 Light-duty vehicle fleet fuel use projections using TEDB, NHTSA, and EPA sales data

Finally, the projections of the fleet model are also compared with the Energy Information Administration’s Annual Energy Outlook 2007 [EIA 2007a], and the Argonne National Laboratory’s VISION model [Singh at el. 2003] in Figure 31. While the VISION model is
updated to include AEO data, the two models differ in their assumptions about vehicle fuel economy under the business as usual scenario [DOE/ANL 2007].

The primary difference in the VKT between DOE/EIA projections and the MIT fleet model is in the assumptions about vehicle kilometers traveled and the rate of growth of travel per vehicle. While the VISION model in 2000 has a similar number of vehicle kilometers traveled per vehicle as the MIT model (~19,300 km/vehicle per year), the long-term VKT growth rate in VISION model is 1.7%, as opposed to 1.2% in the MIT model. In addition, the VISION model assumes a decline in car VKT in the early part of the present decade, so that the total car VKT is at the same level as 2000 in year 2010. The combined result is that the DOE/EIA model estimates of VKT and fuel use are lower than the MIT model until 2025, and higher after 2025. The sensitivity of the model to various parameters is shown in the next section.

![Figure 31](image-url)  
**Figure 31** Comparison of Fleet Model Projections with EIA Annual Energy Outlook and DOE VISION Model
5.10 Sensitivity to selected input parameters

The growth in sales of light trucks has been one of the drivers of LDV fuel use growth since the 1980s. Figure 32 evaluates the impact of a further increase or decrease in the light truck sales fraction from today’s value of 55%. Whether the light truck sales fraction increases linearly from 55% to 70% or decreases linearly from 55% to 30% by 2035, the total fleet fuel use is affected by less than 2% over the period under consideration. The impact of such changes in fleet composition appears to be limited until 2035, but will be more apparent in the decades to follow. This is due to two reasons. First, the light-truck CAFE standards for years 2005–2010 have narrowed the gap between passenger car and light truck fuel economy. Second, the inertia already present in the LDV fleet means that changes that do not significantly affect vehicle fuel consumption or travel patterns will have limited impact on aggregate fuel use of the fleet.

![Graph showing the effect of new light truck sales fraction on fleet fuel use from 2005 to 2035](image)

**Figure 32**  Effect of new light truck sales fraction on fleet fuel use from 2005 to 2035

Figure 33 illustrates the drivers of growth in LDV fleet fuel use, viz. the increase in LDV stock via new vehicle sales growth, and increase in average distance traveled per vehicle. If the sales growth of new vehicles is halved from the present rate of 0.8% per year, the LDV fleet fuel use in 2035 will be some 8.6% lower than indicated by the present growth trajectory. Halving both the rate of growth in travel per vehicle in addition to halving the sales growth will result in about 13.5% savings in fleet fuel use in 2035.

Such a reduction can only be achieved by a mix of mode shifting, trip consolidation, and fiscal and/or regulatory disincentives to own and operate vehicles. Of course, even with no further growth in vehicle sales and travel, i.e., no increase in aggregate vehicle kilometers traveled (VKT), total fleet fuel use will remain at the present level. Thus, even with no growth in demand beyond present level—an unlikely prospect—a dramatic reduction in vehicle fuel
consumption will be required if the LDV fuel use is to be brought back to the level of domestic oil production, which is projected to be 325 billion liters (5.6 mbd) in 2030 [EIA 2008].

![Figure 33](image)

**Figure 33** Light-duty vehicle fleet fuel use projections for different sales and VKT/vehicle growth rates (2000–2035)

As noted previously, the median lifetime of LDVs is increasing as the vehicles have become more durable and reliable over time. As a result, there are a greater number of older vehicles on the road today, and they add to the inertia of the vehicle fleet. Reducing vehicle lifetime would slow down the growth in total vehicle stock, since more vehicles would be retired earlier.

The effect of reducing vehicle lifetime is shown in Figure 34. Reducing median vehicle lifetime from 16.5 years to 15.2 years for cars, and from 15.5 years to 14 years for light trucks—a 10% reduction in median vehicle lifetime of vehicles made after model year 2000—results in approximately 6.7% reduction in 2035 fleet fuel use. Similarly, a 20% reduction in vehicle median lifetime (13.5 years for cars, 12.4 years for light trucks) reduces 2035 fleet fuel use by approximately 14%. Note that this calculation does not assume that each vehicle that is scrapped from service is replaced by a new vehicle. Rather, the rate of growth in new vehicle sales is assumed to be constant. In practice, a shorter vehicle lifetime will have the effect of stimulating demand for new motor vehicles, and the actual effect of reducing vehicle lifetime will be much smaller than indicated in Figure 34.
Figure 34  Effect of reducing vehicle lifetime on fleet fuel use

The effect of shortening the median lifetime is similar but not exactly the same as that of chopping off the end of the survival curve of motor vehicles by scrapping older vehicles on the road. For example, if all vehicles of model year 1980 onward were scrapped when they reached age 21, fuel use in 2035 would be about 23 billion liters less (a 3% reduction in 2035 fuel use). Scrapping older vehicles will stimulate the second-hand car market, which in turn will increase the rate of new vehicle sales. While newer vehicles are likely to be more efficient, they are also more likely to be driven farther, as shown in Figure 26. Thus, the fuel savings calculated here provide an ideal lower bound; the actual savings from a vehicle scrappage scheme will be lower. To have a large-scale impact on fleet fuel use, vehicles will need to be scrapped near to their median lifetime, and the costs of doing so are likely to be significant [ECMT 1999].

Finally, the effect of on-road fuel economy adjustment factor on fleet fuel use is shown in Figure 35. The fleet fuel use is quite sensitive to this degradation factor, and a great deal of uncertainty persists about a reliable estimate of on-road versus test fuel economy performance. The fleet model at present uses a uniform 22% adjustment to fuel use for both cars and light-trucks. The latest EPA fuel economy trends report uses an adjustment factor of 17.1% for years 1975–1985, which increases from 1.175 in 1986 to 1.25 in year 2005. Note that variation in the adjustment factor does not affect comparison of the model results unless the adjustment factor is changed between the scenarios.
**Figure 35** Light-duty fleet fuel use for different on-road fuel economy factors

### 5.11 European comparison

As described in Bodek and Heywood [2008], a variety of data sources were used to develop and calibrate individual European country light-duty vehicle fleet models. The majority of the data came from country-level statistical offices, such as Deutscher Verkehrs-Verlag in Germany and Observatoire Économique et Statistique des Transports in France. These data sources show that the fraction of diesels in the sales mix has been growing throughout most of Europe for the last 20 years. Although their fraction may continue growing over the next several years, the *No Change Scenario* assumes that the diesel-to-gasoline sales share remains flat at its 2005 in the future. As will be discussed in the following section, a separate scenario was used to model the impact of further dieselization of Europe’s vehicle fleet.

The future sales growth rates in France, Germany, Italy, and the UK were modeled differently than in the United States to reflect the fact that, rather than simply tracking the population growth rate, the sales rate will also be influenced by growth in the number of vehicles per 1,000 people. New vehicle sales growth rates were estimated using United Nations [2005] population growth rate estimates and historical motorization (i.e., vehicles per 1,000 people) trends. New sales growth rates, using a five-year interval, were chosen such that the number of vehicles in the entire fleet would be sufficient to sustain the historical motorization trend of each country, given simultaneous changes in its human population. Table 24 details the estimated new sales growth rates necessary for achieving these rates of motorization, as well as the corresponding United Nations population growth-rate projections.

Basing the future VKT behavior of vehicles on historic trends is not as logical an approach for Europe as it is for the United States, where nearly all passenger vehicles are fueled by gasoline. As illustrated in Figure 36, the historic VKT data for gasoline and diesel vehicles in France highlights several important trends. Most significantly, diesel vehicles have consistently
been driven further per annum than gasoline vehicles. For example, in 2005 the average diesel vehicle was driven 64% further in France than the average gasoline vehicle. Another relevant trend is that the VKT of both gasoline and diesel vehicles in most European countries has been steadily declining. A number of studies have explored the range of potential factors that are responsible for these trends, such as the preferential use of diesels by high mileage drivers (e.g., taxis), differential tax regimes on gasoline and diesel fuel, and the increasing number of multi-car families in several European countries. Schipper et al. [2002] provide a comprehensive review of the literature in this area.

Despite a multitude of factors, the fundamental dynamic appears to be that diesel VKT—and gasoline VKT, to a lesser extent—decrease as the fraction of diesels in the fleet increases. Although there are always a certain fraction of high-mileage drivers, ordinary drivers who drive less increasingly come to own diesel vehicles. Conversely, as diesels continue to appeal to more and more ordinary drivers, their switching away from gasoline vehicles toward diesel vehicles lowers the average gasoline VKT. Note that the rising ratio of diesel to gasoline fuel demand is already straining diesel fuel refining capacity. These supply constraints may impact future European diesel car growth.

Table 24  United Nations population projections and new sales growth rate estimates

<table>
<thead>
<tr>
<th></th>
<th>UN Population and New Vehicle Sales Growth Rate (%)</th>
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<td>Pop. -0.08 0.0 0.0 -0.1 -0.1 -0.1 -0.2</td>
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<td>Sales 0.33 1.5 1.0 0.5 0.0 -0.5 -0.5</td>
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<tr>
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<td>Pop. 0.17 0.3 0.3 0.2 0.1 0.1 0.0</td>
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<tr>
<td></td>
<td>Sales 0.50 1.5 1.0 1.0 0.0 0.0 -0.5</td>
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<tr>
<td>UK</td>
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<tr>
<td></td>
<td>Sales 1.08 1.5 1.5 1.0 1.0 1.0 0.5</td>
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These observations informed the authors' approach for modeling the future VKT behavior of gasoline and diesel vehicles, in addition to the fact that the weighted VKT in both countries has remained roughly flat over the last 30 years. Figure 37 shows the resulting VKT behavior when this methodology is applied to the No Change Scenario for France’s vehicle sales mix. In this particular instance, diesel vehicles, which comprise nearly 70% of the fleet in 2035, are assumed to only travel approximately 25% farther per annum than gasoline vehicles. When scenarios with alternative powertrains are modeled, it is assumed for simplicity that they exhibit the same VKT behavior as NA gasoline vehicles.

As described in Section 0, the estimated ERFC in Europe is closer to 50%, compared with almost zero in the United States. Therefore, an ERFC of 50% was used when modeling the No Change Scenario for these European countries.
Figure 36  Historic VKT behavior and diesel fleet share in France

Figure 37  Future gasoline and diesel VKT behavior in the France No Change Scenario
5.12 Summary

This section has identified the primary trends underlying different factors for growth in LDV fleet fuel use and introduced the light-duty vehicle fleet model and its structure. The model results for the United States and for four of the larger European countries were compared against historical trends and projections of other models. The sensitivity of the fleet fuel use projection to different model parameters was also evaluated. The next two sections of this report will develop the fleet model further to incorporate the effects of changes in fuels, vehicles technology, and vehicle market penetration rates.