

# QUANTIFYING THE EXTERNAL COSTS OF VEHICLE USE: EVIDENCE FROM AMERICA'S TOP SELLING LIGHT-DUTY MODELS

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## ABSTRACT

Vehicle externality costs include emissions of greenhouse and other gases (affecting global warming and human health), crash costs (imposed on crash partners), roadway congestion, and space consumption, among others. These five sources of external costs by vehicle make and model were estimated for the top-selling passenger cars and light-duty trucks in the U.S. Among these external costs, those associated with crashes and congestion are estimated to be the most practically significant. When crash costs are included, the worst offenders (in terms of highest external costs) were found to be pickups. If crash costs are removed from the comparisons, the worst offenders tend to be four pickups and a very large SUV: the Ford F-350 and F-250, Chevrolet Silverado 3500, Dodge Ram 3500, and Hummer H2, respectively. Regardless of how the costs are estimated, they are considerable in magnitude, and nearly on par with vehicle purchase prices.

## INTRODUCTION

Vehicle ownership and use impose a variety of social costs that are not directly borne by vehicle owners. Furthermore, these external costs vary greatly depending on the size and type of vehicle. Many studies have examined such external costs. For example, Delucchi (1998) and Litman<sup>1</sup> (2002) sought to characterize the total costs of motor vehicle transport. Others characterize such costs across travel modes (see, e.g., IBI Group 1995, Poorman 1995, and DeCorla-Souza and Jensen-Fisher 1997). Still others (Douglass 1995, Sansom et al. 2001, Schreyer et al. 2004, and Parry et al. 2007) look at the issue from the perspective of developing pricing policies.

These earlier studies share a common attribute: costs are examined at an aggregate level. While a few studies observe certain cost variations by vehicle class, none does so by vehicle model. In contrast, this paper examines such variations in external costs of light-duty vehicle ownership and use by vehicle make and model. Though a wide array of external transportation costs have been investigated previously, some do not apply well at the level of individual vehicle makes and models. This is discussed in more detail later in the paper. Consequently, this paper focuses on five cost categories: emissions of greenhouse and other gases (affecting global warming and air quality), crash costs (for partner vehicles in multi-vehicle crashes), roadway congestion, and space consumption. These external costs were estimated for the US's best-selling<sup>2</sup> year-2006 passenger vehicle models in each class. Such costs also were estimated for several other vehicles of particular interest, including GM's Hummer and several hybrid drive train vehicles. Ward's Automotive Yearbook (2007) categorizes passenger vehicles across eight classes: small cars, mid-sized cars, large cars, luxury cars, crossover utility vehicles (CUVs), sport-utility vehicles (SUVs), pickups, and vans (including minivans). Table 1 shows US sales volumes for 107 vehicles – top sellers and other vehicles of interest<sup>3</sup>.

This paper quantifies five external costs associated with ownership and use of each vehicle model. It compares these to existing federal taxes on emissions and fuel economy, as well as standard operations costs. It also identifies the main offenders (i.e., those vehicles with highest external cost estimates). The purpose of this work is to highlight, for consumers and policymakers, social cost distinctions that can exist across vehicle types.

## **FEDERAL LEGISLATION**

Two pieces of federal regulation relating to fuel consumption presently exist in the U.S. The first is called the gas guzzler tax (CFR § 600.513-91), and it is applied *only to passenger cars* (rather than to light-duty trucks [LDTs]) whose EPA-measured combined (highway/city) fuel economy standard falls below 22.5 mpg. The marginal tax (per mpg below 22.5) increases as fuel economy falls. (For example, for a fuel economy lying between 21.5 and 22.5 mpg, the fine is \$1,000; for a fuel economy between 20.5 and 21.5 mpg, the fine is \$1,300.) A maximum fine of \$7,700 is assessed when a car's fuel economy falls below 12.5 mpg.

The second is a punitive fine, and applies to manufacturers that do not meet the Corporate Average Fuel Economy (CAFE) standards over their entire passenger car fleet and/or their light-duty truck fleet (49 U.S.C. § 32912). The standard for passenger car fleets, 27.5 mpg, has not changed for many years. However, the standard for LDT fleets increased recently, from 20.7 mpg in 2004 to 21.0 in 2005, 21.6 in 2006, and 22.2 mpg in 2007 (EPA 2004). For each 0.1 mpg that a manufacturer's fleet of passenger cars or LDTs lies below the CAFE standard in a given model year, a per-vehicle fine of \$5.50 is imposed. While the fine does not pertain to individual vehicles or apply when the fleet average meets the target, the implied value of such a fine, at the level of individual vehicle models, can be computed. While these two pieces of federal legislation provide some means of providing incentives for reductions in external vehicle costs, they are not based on estimates of global warming cost or other negative impacts.

## **EXTERNAL COST ESTIMATES**

This study estimates external costs for over 100 different vehicle models. These costs include a global warming cost, a health cost of emissions, a crash cost (as imposed on crash partners), a

traffic congestion cost<sup>4</sup>, and a land consumption cost. Several parameters were used in making these calculations: fuel economy (city and highway), EPA air pollution scores, vehicle dimensions, curb weight, and class of vehicle (e.g. passenger car, van, pickup, long SUV, and small SUV<sup>5</sup>). The methods used in making these calculations are described below.

It is also important to recognize that the five external costs calculated in this analysis do not encompass all possible external costs associated with vehicle ownership and use. For example, noise pollution imposes significant costs. Sansom et al. (2001) estimated external costs of passenger-vehicle noise to range from \$0.005 to \$0.03 per vehicle mile, while Schreyer et al. (2004) valued such costs at roughly \$0.01 per passenger mile, ranking fourth among the eight external costs they characterized. Both these studies were conducted in Europe; nevertheless, their findings are consistent with U.S. noise cost estimates, which generally range between \$0.005 and \$0.01 per passenger-vehicle mile (Litman 2002). Of course, there is inherent difficulty in quantifying noise pollution costs on the basis of vehicle make and model. Higher levels of noise are generally caused by higher speeds (Sansom et al. 2001) or older vehicles, making it difficult to assign costs on the basis of vehicle type alone. And costs are unlikely to vary greatly by make and model. For these reasons, noise costs were not included here.

Based on his review of the transport-cost literature, Litman (2002) believes that the largest external costs of automobile ownership and use relate to land use impacts (about \$0.07 per vehicle mile). These impacts include increased temperatures caused by paved surfaces (the so-called “heat island” effect), watershed degradation due to the clearing and paving of lands, loss of green space, and urban sprawl, which have a variety of negative impacts (e.g., increased pollution, increased costs of public services, and decreased accessibility of land resulting from destination dispersal and reduced travel options). However, these costs are, to a large extent, indirect. In other words, they are a result of auto-oriented travel patterns and will not vary much by vehicle type, make and model. Thus, they are not examined here.

Many other external costs associated with driving exist, and many of these have been characterized at an aggregate scale, rather than by make and model. For instance, DeCorla-Souza and Jensen-Fisher (1997) and Litman (2002) suggest disposal costs<sup>6</sup> (at the end of a vehicle’s “life”) average about \$0.002 per vehicle mile. Water contamination occurs from runoff of hazardous chemicals from roads and parking lots, costing anywhere from \$0.002 (DeCorla-Souza and Jensen-Fisher 1997) to about \$0.013 (Litman 2002) per vehicle mile traveled. However, like the noise and land use costs described above, these other costs are difficult to distinguish by make and model. Thus, they are not covered here.

While certain studies have analyzed other types of external cost, beyond the five quantified here, these studies have been aggregate in nature, focusing on passenger vehicles as a whole, or cars versus light-duty trucks. In contrast, this work looks at likely variations across specific makes and models.

### **Global Warming Cost Estimation**

It is well understood that fossil fuel combustion adds greenhouse gases to the atmosphere. Nordhaus and Boyer (2000) performed a comprehensive analysis of the cost of carbon removal from the atmosphere, and Pearce (2005) and Tol (2005) provided insightful literature reviews on

this topic. Atmospheric damage cost estimates range from \$10 to \$50 per ton of carbon-dioxide, though some estimates are as high as \$300 or more per ton<sup>7</sup>. Similar to estimates by Fischer et al. (2007), the EPA (2008), and CRAI (2008), this paper’s global warming external cost assumption is \$50 per ton.<sup>8</sup>

Since 26 pounds of carbon dioxide are emitted for every gallon of gasoline refined and burned in an internal combustion engine (Nordhaus 1991), each vehicle’s global warming cost (*GWC*) on a

per mile basis can be estimated as follows: 
$$GWC = \frac{26 \frac{lbs}{gal}}{FE} \times \frac{50 \frac{\$}{ton}}{2000 \frac{lbs}{ton}}$$

where *FE* represents the vehicle’s combined fuel economy. Table 2 presents the global warming costs for LDTs and passenger cars. These range from \$0.0134 per vehicle mile traveled (VMT) for a 48.5 mpg Honda Insight (a Hybrid small car) to \$0.0610 per VMT for a 10.7 mpg Ford F-350, Chevrolet Silverado 3500, and Dodge Ram 3500 (all pickups). As a point of reference, Schreyer et al. (2004) and Sansom et al. (2001) have estimated climate change costs at 0.0176 Euros per passenger-km (roughly \$0.0224 per VMT) and 0.39 UK pence per veh-km (about \$0.0121 per VMT), respectively.

### **Emissions Cost Estimation**

This study’s estimates of the health costs of vehicle emissions rely on two key sources. The first of these is EPA’s (2008) air pollution indices, by vehicle make and model.<sup>9</sup> The indices correspond to a single set of “limits” for oxides of nitrogen (NOx), volatile organic compounds (VOCs), carbon monoxide (CO), and particulate matter of 10 microns effective diameter or less (PM10) at the end of a vehicle’s “full useful life” (assumed by the EPA to be 100,000 to 120,000 miles)<sup>10</sup>. These limits form the basis for emissions cost estimates.

Ozbay and Berechman (2001) give estimates of morbidity and mortality (disease and death) costs of such emissions, per ton, though these costs are rather uncertain<sup>11</sup>. Based on the EPA scores and these costs, emissions costs were estimated for each vehicle type, as shown in Table 2. These range from \$0.0018 per VMT for the Honda Civic Hybrid (small car) and Honda Accord Hybrid (mid-sized car) to \$0.0245 per VMT for the Ford F-250 and F-350 (both pickups). These per-mile costs pale in comparison to the global warming and other cost estimates studied here. The light-duty vehicle fleet’s emissions have been regulated for so many years, with requirements becoming increasingly stringent over time, that most vehicles are becoming quite “clean”. However, the EPA figures are probably biased low, since actual vehicle operation may differ greatly from a chassis test on a rather gentle run cycle (Samuel et al. 2002, Pelkmans and Debal 2006), and some vehicles’ emissions equipment are poorly maintained. Kockelman (2000) also estimated emissions costs, for the average LDT versus the average passenger car. Using emissions limits by vehicle class (rather than make and model-specific values), Kockelman estimated the average cost of emissions to be \$600 more for LDTs than passenger cars, assuming a zero discount rate on future emissions. In this work, the difference in sales-weighted average costs between these two general vehicle types was computed to be higher, almost \$1000 (assuming a 120,000-mile vehicle life over 10 years with a 5% annual discount rate).

### **Crash Cost Estimation**

LDTs generally are more aggressive than other vehicles in crashes (White 2004), due to their heavier mass, higher chassis, and other design distinctions. In this way, they can cause more damage to others, including loss of life. The crash severities for LDTs relative to passenger cars were estimated using Wang and Kockelman's (2005) analytical results, which are virtually the only results that control for weight and vehicle type while conditioning on crash occurrence.<sup>12</sup> Using a heteroskedastic ordered probit specification for crash severity, they estimated the probability of certain injury types for occupants of crash "partner vehicles". These models control for the curb weights of the crash-involved vehicles, as well as vehicle type (coded as passenger car, SUV, minivan, pickup, and heavy truck). Wang and Kockelman used the KABCO injury scale<sup>13</sup>, which was translated to the maximum abbreviated injury scale (MAIS) for economic analysis (see, e.g., Lee et al. 2004).

Wang and Kockelman (2005) looked at the probability of injury (in each vehicle and its crash partner), given that the crash had occurred. They analyzed multi-vehicle crashes as sets of two-vehicle crashes (so some vehicles were represented more than once in the database)<sup>14</sup>. Using data provided by the U.S. FHWA on total vehicle miles traveled (VMT) in 2004 and (reported) crash data from the NHTSA for 2004, crash rates could be identified (while both data sources offer such data for passenger cars and LDTs separately, a single crash rate was identified for all vehicle types to provide consistency in the analysis<sup>15</sup>). Together these suggest that vehicles are involved in (reported) multi-vehicle crashes at a rate of about one every 314,000 VMT (3.18 per 10<sup>6</sup> VMT).<sup>16</sup> Using the FHWA estimates of annual VMT and passenger-miles traveled, average vehicle occupancy can also be computed.

Blincoe (2002) estimated economic and non-economic costs associated with different injury severities based on the MAIS scale<sup>17</sup>. These costs were used as the basis for the external crash cost calculations. In reality, there is a certain amount of risk inherent in driving and one should not be responsible for all of the costs borne by one's crash partner if one's crash partner was at fault for the crash. It was assumed that on average, a crashing vehicle is only responsible for half of the losses borne by its crash partners<sup>18</sup> (e.g., if vehicles A and B were in a collision, vehicle A was assumed to responsible for half of vehicle B's total costs, and vice versa). It is important to recognize two items in this analysis. First, due to 3-plus vehicle collisions, there is some systematic over-counting of the blame<sup>19</sup>. However, the majority (about 91%) of multi-vehicle crashes do involve only two vehicles, so this manner of over counting should be rather small. Second, the analysis only accounts for crash partners. Thus, any costs incurred by pedestrians or bicyclists in a crash are ignored. This is clearly a limitation of this work since these are significant costs (roughly 13% of all crash fatalities are non-occupants and about 4% of all non-fatal injuries are endured by non-occupants), and their inclusion would likely make the external-cost differential between big, tall and small, low-riding vehicles even greater (probably on the order of 10% higher).

Table 2 presents crash costs using Blincoe's (2002) cost estimates. These range from \$0.0660 per VMT for the Chrysler PT Cruiser (SUV) to \$0.2304 per VMT for the Toyota Tundra (pickup), and the sales weighted average value is \$0.1056 per VMT. Sansom et al. (2001) estimates external crash costs at 1.11 UK pence per veh-km (about \$0.035 per VMT), Schreyer

et al. (2004) estimate this cost at 0.0309 Euros per passenger-km (roughly \$0.039 per VMT), Parry and Small (2005) assume a central value of \$0.03 per VMT, Parry (2004) estimates low, middle, and high crash costs at \$0.022, \$0.044, and \$0.066 per VMT, respectively, and Litman's (2002) review of the literature suggests external crash costs range from \$0.01 to \$0.10 per VMT, averaging about \$0.035. Of course, once these estimates are corrected for inflation and certain differences in value of life assumptions, they will be higher. Nevertheless, our crash cost estimates appear rather high in comparison. This may be due to higher crash frequency assumptions and a rather high external cost assignment (50% of two-vehicle collision costs). However, Litman (2002) suggests external crash cost proportions that are reasonably coincident with our assumptions; his range from 15% to 50% of total crash costs (including single-vehicle crashes, which are roughly half of all crashes and involve no external cost assignment here). And Edlin and Karaca-Mandic (2006) estimate that external crash costs represent over 65% of total crash costs, though this study seemingly allocated all uninsured costs as external. Regardless, results and rankings of vehicles types are shown with and without crash costs, reflecting the uncertainty in these estimates.

### **Congestion Cost Estimation**

Kockelman and Shabih's (2000) traffic data analyses suggest that passenger car equivalents (PCEs) for regular SUVs, long SUVs, vans, and pickups at signalized intersections equal 1.07, 1.41, 1.34, and 1.14, respectively. (In other words, these other vehicles effectively require more "green time" than the average passenger car.) Using these PCE values and several other assumptions, the Bureau of Public Roads (BPR) link performance formula (as commonly used for travel demand forecasting and traffic studies [Martin and McGuckin, 1998]) can predict added delay due to each vehicle type. This calculation is performed by finding the marginal difference in BPR travel time estimates (when a single vehicle is added to the traffic stream). The congestion cost is assumed to be the value of that added delay, recognizing that different vehicle types have distinct PCE values. Here, BPR-required parameters alpha ( $\alpha$ ) and beta ( $\beta$ ) parameters were assumed to be 0.84 and 5.5, respectively (Martin and McGuckin 1998). The average congested roadway was assumed to have a free-flow speed of 40 mph, corresponding to 1.5 minutes of travel time at free-flow conditions ( $t_f$ ) per mile traveled. The roadway capacity is assumed to be 2000 vehicles per hour per lane (vphpl), and demand is assumed to be right at 95% of the total available capacity (corresponding to a demand of 1900 pcphpl) for some portion of the vehicle's traveling day. The portion of travel assumed to occur at these congested conditions ( $p$ ) is 0.1 (10 percent), and the remaining travel is assumed to occur at free-flow conditions, where the marginal cost associated with an additional vehicle would be practically zero. The final assumption needed is a value of travel time ( $VOTT$ ), conservatively estimated to equal \$8 per vehicle-hour. These assumptions permit a comparison of delays imposed by passenger cars and LDTs. To illustrate, the congestion costs (CC) imposed by a pickup (PCE = 1.14) are computed as follows.

$$CC = t_f * \alpha * \left[ \left( \frac{Vol + PCE_{Pickup}}{Cap} \right)^\beta - \left( \frac{Vol}{Cap} \right)^\beta \right] * Vol * VOTT * p$$

$$CC = 1.5 * 0.84 * \left[ \left( \frac{1900 + 1.14}{2000} \right)^{5.5} - \left( \frac{1900}{2000} \right)^{5.5} \right] * 1900 * \frac{8}{60} * 0.1 = \$0.0796 / \text{mile}$$

The results of this analysis yield marginal social costs \$0.0698, \$0.0747, \$0.0984, \$0.0935, and \$0.0796 per VMT for passenger cars, regular SUVs, long SUVs, vans, and pickups, respectively. If these results are averaged using 2006 sales figures as weights, the average social cost of added congestion is \$0.076 per VMT. As points of comparison, Litman (2002) suggests average congestion costs in urban areas to be about \$0.07 per VMT, similar to findings of Fischer et al. (2007) of \$0.065 per VMT, while Sansom et al. (2001) estimate UK congestion costs to be about \$0.306 per VMT (9.71 UK pence per veh-km). Parry and Small (2005) assumed average congestion costs of \$0.035 per VMT, after considering a range from \$0.015 to \$0.09 per VMT.

Of course, many assumptions are needed here, in order to arrive at such results, all of which vary by context. For instance, 10% of travel is assumed to occur during congested conditions and the remaining 90% at free-flow conditions. In reality, some regions are far more congested than others, and some drivers avoid congested corridors and times of day. Furthermore, Kockelman and Shabih's (2000) PCE estimates come from signalized intersection operations, and may not apply to freeways and other facilities. As a result, the estimates of congestion costs provided here are highly uncertain, and sensitivity analyses are useful, as illustrated later in this paper.

### **Space Consumption Cost Estimation**

Providing land for use by vehicles (either parked or moving) is expensive and infringes upon other possible uses of the land (e.g., greenspace and other buildings). Litman (2002) describes two different sources of external costs in the consumption of public space. Based on his review, he suggests parking costs and land value average \$0.042 and \$0.024 per VMT, respectively. Two methods of analysis for this cost were considered here. First, if land is assumed to be valued at \$2 million per acre (on average) in the core of a large urban area<sup>20</sup>, this translates to \$46 per sq. ft. If it is assumed that paved land costs an additional \$50 per sq. ft.<sup>21</sup>, that the life of a vehicle is 40% that of land (e.g., the typical vehicle life is assumed to be 10 years<sup>22</sup> and land value is almost fully discounted within about 25 years), and a vehicle spends half of its life consuming such publicly held land, then the value of public land devoted to storing a private vehicle is about \$19 per square foot over the life of the vehicle. Using the area of the vehicle, the external costs can be calculated. Using this method, a 100 sq. ft. Ford Taurus would accumulate a lifetime space consumption cost of about \$1,900, without discounting. It also should be noted that parking and roadway facilities are designed for a 'design' vehicle, with specific dimensions; thus, it seems reasonable to assume that larger vehicles contribute more toward design decisions and larger parking spaces. Thus, it may be argued that larger vehicles produce additional external space consumption costs, as compared to smaller vehicles.

The second method is directly related to the external parking costs of a vehicle. Using this method, parking costs may be assumed to average \$1 or \$2 per hour, which could then be translated into costs per space consumed relative to the average sized vehicle. However, this method would result in extremely large differentials in external costs between large and small vehicles. For instance, assuming \$1 per hour to park a vehicle, the cost per square foot per hour would be around \$0.01 (assuming an average vehicle area of 100 sq. ft). If a vehicle consumes

public land for 40% of its 10-year life, the difference in external costs for a 100 sq. ft. Ford Taurus (mid-sized car) and a 126 sq. ft. Ford F-Series (pickup) would be in the range of \$9,000 over the vehicle's life (assuming a vehicle life of 10 years).

To be conservative, the first method was used in this analysis. Of course, land rents vary over space and time of day, so assumptions may be modified substantially, and space consumption cost differences can reach (and exceed) the \$9,000 level. While this method of calculating land consumption costs is dependent on the vehicle life, for consistency with the other calculations, land consumption costs were computed as costs per mileage by dividing the total lifetime vehicle cost by an assumed lifetime mileage of 120,000 miles. Table 2 presents the findings, which range from \$0.0115 per VMT for the Honda Insight Hybrid (Hybrid small car) to \$0.0238 per VMT for the Ford F-350 (pickup). However, in comparison to Litman's (2002) costs estimates for external parking and roadway land value costs (about \$0.072 per VMT), our results seem rather low.

## **COMPARATIVE COST RESULTS**

The results of the analysis indicate that the largest external costs are associated with pickups. This is largely a result of the significant crash impacts that pickups tend to impose on others. After crash costs, added-delay/congestion costs and global warming costs are the next highest in magnitude.

### **Analysis of External Costs**

The analysis performed by Wang and Kockelman (2005) indicates that occupants in vehicles involved in a crash where the crash partner is a pickup are over twice as likely to suffer fatal injury relative to those where the crash partner is a passenger car. Occupants in vehicles where the crash partner is an SUV or van are slightly less likely to incur fatal injury relative to those where the crash partner is a passenger car. The associated monetary costs with fatal crashes are very high, causing the total external costs of pickups to be high, relative to those of other vehicle models. Investigation of the 25 worst models in terms of their associated external costs shows that 20 are pickups (these represent all of the pickups analyzed), 2 are long SUVs, and 3 are cargo vans (only 3 cargo vans were analyzed).

Because some variables, such as driver aggressiveness, were not controlled for in this crash analysis and because crash costs dominate the totals<sup>23</sup> (as shown in Figures 1 and 2), external cost totals without crash costs also were computed. Using these totals, the 25 worst models in terms of the associated external costs are quite different. Many of the pickup models fall out of the top 25 while large SUV models and vans rise to the top. Based on these totals, the four worst offenders are still pickups (the Ford F-250 and F-350, Chevrolet Silverado 3500, and Dodge Ram 3500), but a total of 10 pickup models are no longer found in the list of 25 worst models, and the list is instead composed of 4 large SUVs, 3 cargo vans, and 8 minivans, along with the 10 pickups. The highest congestion costs are associated with large SUVs and van models due to their higher passenger car equivalents. If congestion costs were ignored, the worst offenders would be even more heavily weighted toward pickups. The ordering of such an analysis would show close similarities to the 25 worst offenders with all external costs, where no regular SUVs or passenger cars would appear in the worst 25.



Land consumption costs are highest for pickup models, in general, but the variation between models for this external cost is relatively small. (For example, the difference between the biggest offender [a Ford F-350] and the least offensive [a Honda Insight hybrid] was only \$0.012 per VMT.) Therefore, an analysis of the biggest overall offenders, without land consumption costs, again would look quite similar to the 25 worst offenders with all external costs included.

In any case, there are 15 vehicle models that appear in the 25 worst offenders when all costs are considered and when any one of the three costs discussed above is not included. These include 2 long SUVs (the Hummer H2 and Ford Expedition), 10 pickups (Chevrolet's Silverado 1500, 2500, and 3500; Ford's F-150, F-250, and F-350; Dodge's Ram 1500, 2500, and 3500; and Nissan's Titan), and 3 cargo vans (the Chevrolet Express, Ford Econoline, and GMC Savanna). Not surprisingly, these are some of the largest vehicles included in our analysis, and all but one (the Nissan Titan) come from U.S. manufacturers. Such lists of top offenders do not include any passenger cars, minivans, or small SUVs.

### **Analysis of LDTs**

Cost calculations of LDT models were compared to the top-selling passenger car model of 2006, the Toyota Camry. While the ordering of the "worst" offenders in the LDT class of vehicles does not change, it is important to recognize the difference in magnitudes. For many of the LDT models, the external costs are more than 50% greater than those of the Camry (when crash costs are included in the comparison), including all three top selling models of 2006 (the Dodge Ram, Chevrolet Silverado, and Ford F-Series [all pickups]). This suggests that if LDT models were all (costlessly) traded in for Camrys or comparable passenger car models, the potential benefits to the greater U.S. community would be enormous (on the order of \$100 billion<sup>24</sup>).

### **Analysis of Hybrids**

Calculated external costs of hybrid models can be compared to the top-selling in-class vehicle for 2006. All hybrids analyzed here perform better, in terms of total external costs, than their top-selling in-class vehicle counterparts. In general, external costs of vehicle ownership and use could be reduced a fair amount via a within-class shift to hybrids, at least in the SUV and car classes. For example, when shifting from the top-selling vehicles to their within-class hybrids, reductions in external costs are in the range of 2.0% for pickups, 11.3% to 15.9% for regular SUVs, 1.0% to 11.2% for mid-sized cars, and 3.4% to 9.2% for small cars. These reductions are even greater if crash costs are ignored (3.8% for pickups, 13.7% to 17.2% for regular SUVs, 2.5% to 13.5% for mid-sized cars, and 6.0% to 9.4% for small cars). As expected, the greenhouse-gas-emissions benefits of a shift to hybrids are sizable.

### **Sensitivity Analysis**

The cost calculations depend on many assumptions, and all are simply point estimates. As these estimates change (by location, driving styles, route choices, etc.), differences in results arise. Here, we investigate such variations, as parameter and input values are adjusted.

In the case of the global warming costs, the main assumption is the cost of carbon removal from the atmosphere (assumed to be \$50 per ton), which is directly proportional to the global warming external cost estimates; at \$25 and \$100/ton, the external cost of a Ford F-150 pickup will be \$0.022 and \$0.088/mi. In the case of crash costs, a key assumption is the fraction of multi-

vehicle-crash costs that are endured by crash partners. 50% was assumed here, but this assumption may be reduced to 40% or 30%, reducing external crash costs by 20% or 40%, respectively. Of course, the calculations used here ignore crashes with cyclists and pedestrians, which also carry heavy crash costs, and may well raise the cost per mile back up, beyond our starting assumptions.

In analyzing the sensitivity of external congestion costs, there are several assumptions that come into play. For instance, in using the BPR formula, free-flow speed was assumed to be 40 mph, link capacity 2000 pcphpl, demand 1900 pcphpl, the value of travel time \$8/vehicle-hr, and 10% of VMT was assumed to occur under congested conditions (with the remaining 90% at free-flow conditions). In the case of pickups (with an assumed PCE of 1.14), external congestion costs were estimated to average \$0.0796/mi. If the free-flow speed were changed to 30 mph or 50 mph, the corresponding congestion cost would be \$0.1058/mi or \$0.0635/mi, respectively. Clearly, the external congestion cost is greater for lower free-flow speeds, and smaller for higher free-flow speeds. If the value of travel time is instead \$5 or \$15 per vehicle-hour, congestion cost estimates for pickups will average \$0.0496 and \$0.1487/mi, respectively. Maybe the most debatable assumptions are those defining congested conditions (when demand reaches 95% of capacity here) and the fraction of travel that occurs under such conditions. If one assumes that congested conditions occur when demand equals 75% of capacity, and the portion of travel occurring under these conditions is 50%, the congestion cost for a pickup would be \$0.1084/mi. Of course, a more comprehensive analysis may seek to include several levels of congestion, a variety of free-flow speeds/roadway types, and assume corresponding fractions of travel for each condition. Such analyses may be more realistic but also unnecessarily complicated.

In computing external space consumption costs, several assumptions are made. Land is valued at \$2M per acre (\$46 per sq. ft.), paving costs \$50 per sq. ft., vehicle life is 10 years, land value is fully discounted over 25 years, and 50% of a vehicle's life is assumed to occupy public space. Based on these assumptions, the external space consumption cost for a vehicle is about \$19 per sq. ft. over the vehicle's lifetime. As the ratio of vehicle life to land's discounting period increases, the space consumption cost increases. If land is fully discounted over 35 years (instead of 25 years), the cost estimate will fall to \$13.70/sf. In addition, as the portion of a vehicle's life spent occupying public land rises, external costs rise. If a vehicle is housed 80% of the time on privately held land, the social cost estimate would fall to \$7.60/sf.

### **Aggregate External Cost Analysis**

Although only five particular cost categories are analyzed in this paper, it is important to appreciate the relative magnitudes of other external costs associated with vehicle ownership and use. Verhoef (1994) identified and characterized nine different sources of vehicle externalities, but did not actually estimate values of each. In the literature, there is really only one study that characterizes what could be considered a comprehensive analysis of all external costs: Litman (2002) studied 14 distinct external cost categories of vehicle ownership and use (most of which are similar to those identified by Verhoef [1994]), of which five equate to the five cost categories analyzed here. Litman's (2002) estimates for these five external costs are about \$0.189 per VMT. Using a sales weighted average over vehicle makes and model, our estimates for these five costs are about \$0.236 per VMT. One important distinction between the two estimates is that Litman's costs are an average – over all vehicle miles, while land and congestion parameters

used here assume urban travel, resulting in higher costs. The total for the Litman's (2002) remaining external cost categories is about \$0.140 per VMT, for an overall external-cost total of about \$0.329 per VMT.

### **Internal Cost Comparison**

To better understand the magnitudes of the external costs associated with vehicle ownership and use, the magnitudes of internalized costs must be recognized. The American Automobile Association (AAA) estimates such costs annually. (These costs include gas, maintenance, and tire costs, full coverage insurance, license and registration costs, taxes, depreciation, and an average finance charge<sup>25</sup> for vehicle ownership.) AAA (2006) offers driving costs for five vehicle classes: small cars, mid-sized cars, large cars, SUVs, and minivans.<sup>26</sup> It uses several vehicle models in each class to estimate average user costs for 10,000, 15,000, and 20,000 driving miles per year. For consistency in our analysis, linear interpolation of costs was performed to find average user costs for 12,000 annual VMT. AAA cost estimates range from about \$0.47 per mile driven (for small cars) to about \$0.74 per mile (for large SUVs). Figures 1 and 2 show absolute and percentage-based results of the AAA (2006) internal (user) costs, as compared to our calculated external costs for top selling vehicle models in each of the five AAA vehicle classes. Total costs (internal plus external [including crash costs]) range from \$0.65 per VMT for the Honda Civic (a small car) to \$1.09 per VMT for the Ford F-150 (pickup). External costs as a percentage of the total cost range from 22.9% (for the Ford Explorer, a regular SUV) to 31.1% (for the Ford F-150 pickup). It should be noted that AAA does not estimate the (direct) costs of pickup truck use, so these were assumed to be the same as for SUVs, except in the category of gasoline costs, which were adjusted upward to reflect the lower average fuel economy of pickups.

Mannering and Winston (1985) estimated vehicle ownership and use elasticities with respect to operating and purchase costs. Based on their estimates, it is possible to make predictions about what may occur if Americans were forced to pay the external costs they impose on others. These range from -0.3 to -0.6 for vehicle purchase decisions, with respect to vehicle price. (In other words, if the price of a particular make and model were to double, the manufacturer could expect sales to fall 30 to 60%.) More recently, Goodwin et al. (2004) have estimated somewhat lower elasticities of vehicle sales with respect to vehicle price (-0.24 in the short run and -0.49 in the long run). Interestingly, Mannering and Winston's (1985) elasticity estimates of vehicle ownership with respect to operating costs are quite high, ranging from -0.6 to -0.8. The trend is towards lower (absolute) elasticities, as incomes rise and fuel costs fall (as a fraction of vehicle usage costs): Goodwin et al.'s (2004) estimates are -0.08 and -0.25 for the short and long runs, respectively). Thus, if external costs were realized by vehicle users through operating expenses, sales of vehicles with high external costs could be expected to drop substantially. Finally, Mannering and Winston (1985) also estimated vehicle use (VMT) elasticities with respect to operating cost to be on the order of -0.06 in the short run and -0.1 in the long run. Goodwin et al.'s (2004) estimates are -0.1 and -0.29, respectively. Hence, one might expect U.S. vehicle usage levels to fall by 6 to 10% following a doubling in operating cost.

### **CONCLUSIONS**

This study has presented a methodology for the estimation of external costs of vehicle ownership and use. The results indicate great disparities in the social costs of vehicle use, by vehicle type,

make and model. While some uncertainty exists in all external cost estimates, and these costs do vary by location (e.g., a congested urban area with high land costs and low travel speeds versus a rural location), it seems clear that the true costs of travel are not borne directly by road users, and economic efficiency is not being realized in the vehicle market.

While federal taxation of vehicles with low fuel economy hints at price-based regulation, these costs do not offset global warming costs or address human health and other costs of vehicle design and emissions. The sales-weighted average of the sum of the CAFE fuel economy fine and gas guzzler tax is about \$2,930 (83%) less than our estimate of the external costs of global warming and health effects.<sup>27</sup> For passenger cars this difference is about \$1,860 (65% less than actual external costs) and for LDTs this difference is about \$3,780 (93% less than actual external costs). If LDTs were held to the same CAFE and emissions standards as passenger cars, the difference for LDTs would be approximately \$170 (4.3% less than the actual external costs).

It is important to recognize that great cost variations exist across vehicles, both direct and indirect, internalized and external. This work illuminates the variation in external costs by recognizing the costs arising from emissions, global warming, crashes, congestion delays, and land consumption. It suggests that many light-duty trucks impose dramatically far more costs on the larger community than their passenger car counterparts. Ideally, policy should require that markets reflect external costs, so that vehicle users bear them directly (through, for example, parking fees and emissions- and distance-based taxes or purchase taxes), and pay the true price of their vehicle use decisions. Revenues from such policies could be used to encourage provision and design of lower-cost substitutes (including hybrids, bicycles, walk paths, and safer vehicle bodies). In markets that internalize such costs, motorists may be expected to drive significantly less, purchase different vehicles, and, along with their communities, be much better off.

The analyses performed in this study, while quite informative, are by no means comprehensive. A more complete analysis would investigate other external costs, such as noise costs, water pollution costs, and end-of-life scrappage costs, all which could vary significantly by vehicle type. In addition to other external costs, the analysis is limited in the assumptions that were made in cost calculations. For instance, land consumption cost assumptions were based on land value in congested urban areas. Such land values would vary substantially by region, and may be minimal for rural areas. A wider range of contexts, and their associated costs, could enhance this work.

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## ENDNOTES

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<sup>1</sup> Litman's (2002) study is an extensive review of existing literature related to the estimation of vehicle costs. And Litman's costs represent an average of those found in others' studies.

<sup>2</sup> These sales numbers come from year 2006.

<sup>3</sup> These 107 vehicle types include 20 pickups (2 of which are hybrids), 3 cargo vans, 8 minivans, 4 long SUVs, 27 regular SUVs (5 of which are hybrids), 8 luxury cars, 8 large cars, 15 mid-sized cars (4 of which are hybrids), and 14 small cars (2 of which are hybrids).

<sup>4</sup> It should be noted that congestion costs are quite distinctive, in that they are borne by other motorists, and could be managed by a road authority if appropriate technologies and economically efficient pricing mechanisms were employed.

<sup>5</sup> SUV stands for sport utility vehicle. "Long SUVs" are defined as any SUV with an overall vehicle length greater than 200 inches, while "regular SUV" refers to all other SUVs.

<sup>6</sup> Disposal costs can include costs associated with human health, the environment, aesthetics, and other financial costs (Litman 2002).

<sup>7</sup> The great variation between cost estimates appears to be due to the way costs are aggregated over countries and the discount rate that is assumed (Tol 2005).

<sup>8</sup> The EPA's (2008) analysis relies on a suite of estimates that rise from roughly \$30 per ton in 2015 to \$70 in 2030, and over \$100 per ton by 2040. Such costs assume that international trade in carbon credits is permitted. Costs will be higher without trade permissions.

<sup>9</sup> For some makes and models (13 [about 14%] of those analyzed here), EPA air pollution scores were not available and so were estimated using scores of similar model types.

<sup>10</sup> Actual emissions standards are in fact lower for many vehicles, particular passenger cars and lower-weight LDTs and new cars.

<sup>11</sup> For example, Ozbay and Berechman (2001) suggest that emissions of oxides of nitrogen (NOx) cost over \$10,000 per ton, while the FHWA's Surface Transportation Efficiency Analysis Model (STEAM) default values are just \$3,700 per ton (FHWA 2000).

<sup>12</sup> Other studies have compared crash involvement to vehicle registrations, but these hide use distinctions. For example, Kockelman and Zhao (2000) have shown that SUVs are driven roughly 25% more than passenger cars, everything else constant (including household size and income, and vehicle age). Kweon and Kockelman (2002) found that LDTs are less crash involved, per mile driven, than passenger cars, after controlling for driver age cohort and gender. It is difficult to compare crash frequency when so many unobserved variables may be impacting the results. SUVs and minivans are costlier, on average, than passenger cars, and may be driven by more highly educated, wealthy, and conservative drivers. All these impact crash involvement rates, per registered vehicle.

<sup>13</sup> In the KABCO scale, K = killed, A = incapacitating injury, B = non-incapacitating injury, C = possible injury, and O = no injury. The MAIS scale includes 7 levels (0, 1, 2, 3, 4, 5, and Fatal).

<sup>14</sup> For example, if a vehicle were between two others in a three-vehicle collision, it would be shown as participating in two two-vehicle crashes.

<sup>15</sup> Crash rates were assumed to be more a function of the driver than the vehicle type. On average, it was assumed that those who choose to drive pickups probably share similar driving behaviors that may cause these drivers to have higher or lower crash rates than those who choose to drive passenger cars (i.e. if a person that had always driven a pickup began driving a passenger car, it is unlikely that there would be a significant change in the rate of crashes for this person).

<sup>16</sup> Note that this value only represents police-reported crashes. Non-police-reported crashes can be difficult to estimate and likely have very different characteristics in terms of the crash severity.

<sup>17</sup> Blincoe's (2002) estimates of non-economic crash costs vary with injury severity. They are \$0 for no-injury crashes and then range from a low of \$4,500 (about 30% of total MAIS 1-injury crash costs) to \$2.4 million (about 70% of fatal-injury crash costs). Blincoe's assumed value of life is roughly \$2.4 million.

<sup>18</sup> Litman (2002) suggests that the fraction of crash costs borne by others (i.e., external to the vehicle owner and driver) is in the range of 15 to 50%. Thus, this study's assumption of 50% is on the high end. However, single vehicle crashes are not considered in our analysis (which likely have some external component), and non-occupant (e.g., pedestrians and bicyclists) injuries and fatalities are not considered (which also have some external component).

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<sup>19</sup> For example, if three vehicles, A, B, and C, are involved in a collision and vehicle B was between vehicles A and C, vehicle B is counted as being in two two-vehicle collisions. Because of this, vehicle B is assumed to be half responsible for the collision with vehicle A and half for the collision with vehicle C, while vehicles A and C would both be half responsible for their respective collisions with vehicle B.

<sup>20</sup> The \$2 million per acre assumption for the value of land will vary greatly, by geographic location (e.g., downtown San Francisco or suburban Dallas). Based on prices of vacant land in San Francisco from the Pacific Union website (2007), the \$2 million per acre estimate is rather conservative.

<sup>21</sup> This cost reflects the additional cost of paving land as well as its maintenance and operations costs. Litman (2002) suggests the total cost of highway construction in urban regions to range in cost from \$5 - \$10 million per lane-mile, which includes cost of right-of-way. If land acquisition is ignored, and one assumes highway construction to cost \$3 million per lane mile, this translates to about \$50 per sq ft.

<sup>22</sup> Chen and Niemeier (2005) suggest the average vehicle age at scrappage is approximately 11 years. Thus, the assumption of 10-year lifespan for vehicles is somewhat conservative.

<sup>23</sup> For most passenger cars in the analysis, external crash costs were greater than all other external costs combined.

<sup>24</sup> Of course, the Toyota Camry is not designed to go off-road, tow a trailer, or haul large, heavy equipment, and the like. So some losses would be incurred, particularly the subset of owners who really need such qualities in their vehicles.

<sup>25</sup> AAA (2006) assumes a 10% down payment and interest rate of 6% on the unpaid balance over 5 years.

<sup>26</sup> AAA's (2006) user cost estimates include costs of fuel, maintenance, tires, insurance, license and registration, taxes, depreciation, and finance costs (assuming a five-year loan at 6% interest with a 10% down payment).

<sup>27</sup> Global warming and health costs of emissions were converted to the basis of vehicle life for this computation. Consistent with earlier assumptions, vehicle life was assumed to be 120,000 vehicle miles over a ten year period. These cost estimates also reflect a discounting rate of 5%.

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**Table 1: Make and Model Characteristics**

Veh. Type	Make	Model	2006 Sales	Air Pollution Score	Area (sq. ft.)	Curb Weight (lbs)	Combined Fuel Economy (mpg)	Average Retail Price (\$)
Small Car	Toyota	Corolla	335,054	6.5	83.0	2,605	30.4	16,053
	Honda	Civic	272,899	6.5	84.2	2,776	28.7	19,795
	Chevrolet	Cobalt	211,449	6.0	85.1	2,828	24.1	17,565
	Ford	Focus	177,006	7.0	80.3	2,694	25.3	16,110
	Nissan	Sentra	117,922	6.5	87.9	2,922	26.7	17,940
	Saturn	Ion	102,042	6.0	86.7	2,849	24.6	16,620
	Hyundai	Elantra	98,853	7.0	86.1	2,737	27.7	12,165
	Mazda	Mazda3	94,437	6.5	85.0	2,863	25.5	17,390
	Dodge	Caliber	92,224	6.5	83.0	3,137	25.0	16,985
	Toyota	ScionTC	79,125	6.5	83.5	2,889	23.3	16,240
	Kia	Spectra	72,557	7.0	82.6	2,935	26.0	15,045
	Toyota	Yaris	70,308	6.5	73.8	2,293	31.6	12,068
	Honda	Insight (Hybrid [2006])	N/A	7.5	71.8	1,975	48.5	20,430
	Honda	Civic (Hybrid)	N/A	9.0	84.6	2,628	42.1	19,600
Mid-Sized Car	Toyota	Camry	362,961	6.5	94.2	3,483	23.9	23,625
	Honda	Accord	323,079	6.5	95.0	3,281	24.0	23,608
	Chevrolet	Impala	289,868	7.0	101.5	3,633	20.1	25,028
	Nissan	Altima	232,457	6.5	93.2	3,162	25.0	23,790
	Ford	Taurus	174,803	5.0	100.2	3,322	20.6	22,820
	Ford	Mustang	166,530	5.0	96.4	3,414	18.0	26,185
	Chevrolet	Malibu	163,853	6.0	91.4	3,295	22.5	20,940
	Pontiac	G6	157,644	6.0	92.7	3,425	21.2	24,208
	Hyundai	Sonata	149,463	6.5	94.6	3,362	23.4	20,795
	Ford	Fusion	142,502	5.0	95.4	3,276	21.9	21,260
	Pontiac	Grand Prix	108,634	6.0	101.6	3,539	20.8	25,815
	Toyota	Prius (Hybrid)	106,971	8.0	82.5	2,932	46.6	22,998
	Honda	Accord (Hybrid)	N/A	9.0	95.0	3,605	27.0	25,858
	Toyota	Camry (Hybrid)	N/A	8.0	93.4	3,637	33.4	26,200
	Saturn	Aura (Hybrid)	N/A	6.0	93.2	3,529	27.0	23,790
Large Car	Chrysler	300 Series	143,647	6.5	102.8	4,009	19.2	32,725
	Dodge	Charger	114,201	6.0	103.5	4,055	19.2	29,535
	Buick	Lucerne	96,515	7.0	104.1	3,889	19.0	30,780
	Toyota	Avalon	88,938	6.5	99.7	3,545	23.0	31,050
	Ford	Five Hundred	84,218	5.0	103.8	3,729	20.4	26,133
	Nissan	Maxima	69,763	6.5	96.8	3,585	21.3	29,780
	Ford	Crown Victoria	62,976	5.0	115.3	4,129	17.1	27,890
	Mercury	Grand Marquis	54,688	5.5	114.8	4,135	17.1	29,093
Luxury	BMW	3-Series	120,180	6.5	88.3	3,579	20.7	41,833
	Lexus	ES350	75,987	6.5	94.6	3,580	21.9	33,885
	Acura	TL	71,348	6.5	95.0	3,649	20.9	36,545
	Infiniti	G35	60,745	6.5	90.1	3,596	18.9	33,400
	Cadillac	DTS	58,224	6.5	107.8	4,009	17.5	45,675
	BMW	5-Series	56,756	6.5	96.5	3,649	18.8	51,695
	Cadillac	CTS	54,846	6.0	93.3	3,709	17.9	41,155

	Lexus	IS	54,267	6.5	88.7	3,553	22.3	33,695
Cargo Van	Ford	Econoline	180,457	2.0	122.3	5,141	<b>13.9</b>	30,963
	Chevrolet	Express	123,195	4.0	123.5	5,230	14.0	26,640
	GMC	Savana	29,973	4.0	123.5	5,437	14.5	26,143
Van (mini)	Dodge	Caravan	211,140	6.0	103.3	3,842	19.1	21,290
	Honda	Odyssey	177,919	6.5	107.6	4,534	19.1	31,865
	Toyota	Sienna	163,269	6.5	108.0	4,408	18.8	31,555
	Chrysler	Town & Country	159,105	6.5	106.4	4,171	19.1	29,423
	Chevrolet	Uplander	58,699	6.0	98.8	4,211	17.9	24,370
	Kia	Sedona	57,018	6.5	106.1	4,376	18.5	24,130
	Ford	Freestar	50,125	5.0	106.6	4,233	17.7	25,418
	Nissan	Quest	31,905	6.5	110.0	4,365	18.5	29,730
SUV	Ford	Explorer	179,229	5.0	103.3	4,617	15.5	30,285
	Chevrolet	TrailBlazer	174,797	5.5	99.4	4,573	15.5	31,480
	Honda	CRV	170,028	6.5	88.5	3,461	22.1	22,920
	Ford	Escape	157,395	5.0	85.1	3,466	21.6	23,955
	Honda	Pilot	152,154	6.5	101.2	5,950	17.6	30,765
	Toyota	RAV4	152,047	6.5	90.9	3,489	22.3	24,240
	Jeep	Grand Cherokee	139,148	5.0	111.7	4,568	16.6	36,878
	Jeep	Liberty	133,557	6.0	86.7	3,981	17.4	24,598
	Toyota	Highlander	129,794	6.0	92.2	3,726	20.1	29,150
	Chrysler	PT Cruiser	126,148	6.5	78.7	3,076	21.0	25,115
	Chevrolet	Equinox	113,888	6.5	93.6	3,813	19.4	23,825
	Toyota	4Runner	103,086	6.5	98.8	4,300	17.2	33,615
	Chevrolet	HHR	101,298	6.0	84.7	3,155	23.1	17,295
	Saturn	Vue	88,581	6.5	90.0	3,480	21.5	22,360
	Jeep	Commander	88,497	5.0	116.5	4,944	15.2	36,640
	Nissan	Murano	81,362	6.0	96.4	3,916	19.6	34,200
	Jeep	Wrangler	80,271	6.5	78.2	3,932	16.7	22,758
	Chrysler	Pacifica	78,243	6.5	109.3	4,529	17.6	30,548
	Lexus	RX 350	75,508	6.5	93.9	3,980	19.4	38,815
	GMC	Envoy	74,452	6.0	99.4	4,600	15.7	32,355
	Nissan	Pathfinder	73,120	6.5	94.8	4,616	16.8	31,450
	Hummer	H3	N/A	6.0	111.8	4,776	15.0	34,978
	Ford	Escape (Hybrid)	N/A	8.0	85.1	3,610	29.1	24,943
	Lexus	RX400H (Hybrid)	N/A	8.0	94.4	4,190	26.6	41,880
	Mercury	Mariner (Hybrid)	N/A	8.0	85.1	3,787	27.5	29,225
	Saturn	Vue (Hybrid)	N/A	6.0	90.1	3,466	25.4	20,488
Toyota	Highlander (Hybrid)	N/A	8.0	92.7	4,020	26.6	34,520	
Large SUV	Chevrolet	Tahoe	161,491	5.0	110.8	5,385	15.5	36,653
	Ford	Expedition	87,203	4.5	116.7	5,816	14.1	36,695
	Chevrolet	Suburban	77,211	5.0	122.2	5,679	15.5	41,725
	Hummer	H2	N/A	3.0	114.8	6,614	<b>11.2</b>	59,615
Pickup	Ford	F-150		4.0	125.9	5,232	14.7	29,368
	Ford	F-250	744,996	0.5	135.4	6,000	<b>11.2</b>	33,603
	Ford	F-350		0.5	148.7	6,399	<b>10.7</b>	34,778
	Chevrolet	Silverado 1500		4.0	126.2	4,819	15.9	27,630
	Chevrolet	Silverado 2500	636,069	1.0	133.2	5,656	<b>11.2</b>	36,150
	Chevrolet	Silverado 3500		1.0	146.7	5,747	<b>10.7</b>	36,445

Dodge	Ram 1500		4.5	126.3	4,982	14.7	30,120
Dodge	Ram 2500	364,177	1.5	132.2	6,468	<b>11.2</b>	41,770
Dodge	Ram 3500		1.0	146.1	6,573	<b>10.7</b>	40,208
GMC	Sierra	210,736	4.5	125.2	4,819	15.7	27,778
Toyota	Tacoma	178,351	6.0	104.9	3,620	20.6	20,603
Toyota	Tundra	124,508	6.5	125.5	6,600	15.4	32,715
Chevrolet	Colorado	93,876	6.0	94.5	3,666	18.2	19,510
Ford	Ranger	92,420	5.5	92.5	3,409	20.0	19,688
Nissan	Frontier	77,510	6.5	107.4	4,746	18.3	22,425
Dodge	Dakota	76,098	6.0	108.9	4,457	15.9	25,560
Nissan	Titan	72,192	6.0	122.7	4,987	13.2	30,685
Chevrolet	Avalanche	57,076	5.0	121.6	5,562	15.5	35,825
Chevy	Silverado 15 (Hybrid)	N/A	3.0	125.5	5,198	17.2	25,325
GMC	Sierra 15 (Hybrid)	N/A	3.0	125.5	5,198	17.2	27,483

Note: Model year for each vehicle is 2007 (except Honda Insight [2006]). Fuel economy is EPA's harmonically weighted average of highway and city driving fuel economies. Area, curb weight, fuel economy, and price values represent the midpoint in range given by Ward's (2007). Combined Fuel Economies shown in **bold** and *italics* are based on assumed values since no air pollution score was available for these models. These values were taken from other models with similar attributes. For some models, Ward's offers a range in values (e.g., length, width, weight, fuel economy). For such models, simple averages were taken using the minimum and maximum values offered by Ward's.

**Table 2: External Cost Estimates by Vehicle Make and Model, per Mile Driven**

Vehicle Type	Make & Model	Global Warming Cost	Crash Cost	Health Cost of Emissions	Congestion Cost	Land Consumption Cost	Total Cost	Total Cost (w/out crash cost)
Pickup	Dodge Ram 3500	<b>0.0610</b>	0.2295	0.0198	0.0796	0.0233	<b>0.4132</b>	<b>0.1837</b>
Pickup	Ford F-350	<b>0.0610</b>	0.2239	0.0245	0.0796	0.0238	<b>0.4128</b>	<b>0.1889</b>
Pickup	Dodge Ram 2500	<b>0.0583</b>	0.2261	0.0165	0.0796	0.0211	<b>0.4015</b>	<b>0.1754</b>
Pickup	Ford F-250	<b>0.0583</b>	0.2113	0.0245	0.0796	0.0217	<b>0.3953</b>	<b>0.1840</b>
Pickup	Chevrolet Silverado 3500	<b>0.0610</b>	0.2036	0.0198	0.0796	0.0235	<b>0.3874</b>	<b>0.1838</b>
Pickup	Chevrolet Silverado 2500	<b>0.0583</b>	0.2008	0.0198	0.0796	0.0213	<b>0.3797</b>	<b>0.1789</b>
Pickup	Toyota Tundra	0.0423	0.2304	0.0025	0.0796	0.0201	0.3748	0.1444
Pickup	Chevrolet Avalanche	0.0419	0.1981	0.0031	0.0796	0.0194	0.3420	0.1440
Pickup	Ford F-150	0.0442	0.1885	0.0051	0.0796	0.0201	0.3376	0.1490
Pickup	Nissan Titan	0.0494	0.1817	0.0028	0.0796	0.0196	0.3330	0.1513
Pickup	Chevy Silverado 15 (Hybrid)	0.0377	0.1876	0.0060	0.0796	0.0201	0.3310	0.1434
Pickup	GMC Sierra 15 (Hybrid)	0.0377	0.1876	0.0060	0.0796	0.0201	0.3310	0.1434
Pickup	Dodge Ram 1500	0.0442	0.1816	0.0041	0.0796	0.0202	0.3297	0.1481
Pickup	Chevrolet Silverado 1500	0.0409	0.1771	0.0051	0.0796	0.0202	0.3229	0.1458
Pickup	GMC Sierra	0.0413	0.1771	0.0041	0.0796	0.0200	0.3222	0.1450
Pickup	Nissan Frontier	0.0356	0.1752	0.0025	0.0796	0.0172	0.3100	0.1349
Pickup	Dodge Dakota	0.0409	0.1676	0.0028	0.0796	0.0174	0.3083	0.1407
Long SUV	Hummer H2	<b>0.0583</b>	0.1097	0.0060	0.0984	0.0183	<b>0.2907</b>	<b>0.1811</b>
Van (cargo)	Ford Econoline	<b>0.0469</b>	0.1107	0.0131	0.0935	0.0195	<b>0.2838</b>	<b>0.1731</b>
Pickup	Chevrolet Colorado	0.0356	0.1484	0.0028	0.0796	0.0151	0.2815	0.1331
Van (cargo)	GMC Savanna	0.0447	0.1153	0.0051	0.0935	0.0197	0.2785	0.1631
Pickup	Toyota Tacoma	0.0315	0.1474	0.0028	0.0796	0.0168	0.2780	0.1306
Van (cargo)	Chevrolet Express	0.0463	0.1121	0.0051	0.0935	0.0197	0.2768	0.1647
Pickup	Ford Ranger	0.0326	0.1427	0.0029	0.0796	0.0148	0.2725	0.1299
Long SUV	Ford Expedition	0.0460	0.0983	0.0041	0.0984	0.0187	0.2655	0.1673
Long SUV	Chevrolet Suburban	0.0419	0.0964	0.0031	0.0984	0.0195	0.2594	0.1629
Long SUV	Chevrolet Tahoe	0.0419	0.0925	0.0031	0.0984	0.0177	0.2537	0.1611
Van (mini)	Honda Odyssey	0.0341	0.1016	0.0025	0.0935	0.0172	0.2490	0.1474
Van (mini)	Nissan Quest	0.0351	0.0992	0.0025	0.0935	0.0176	0.2479	0.1487
Van (mini)	Toyota Sienna	0.0347	0.0998	0.0025	0.0935	0.0173	0.2478	0.1480

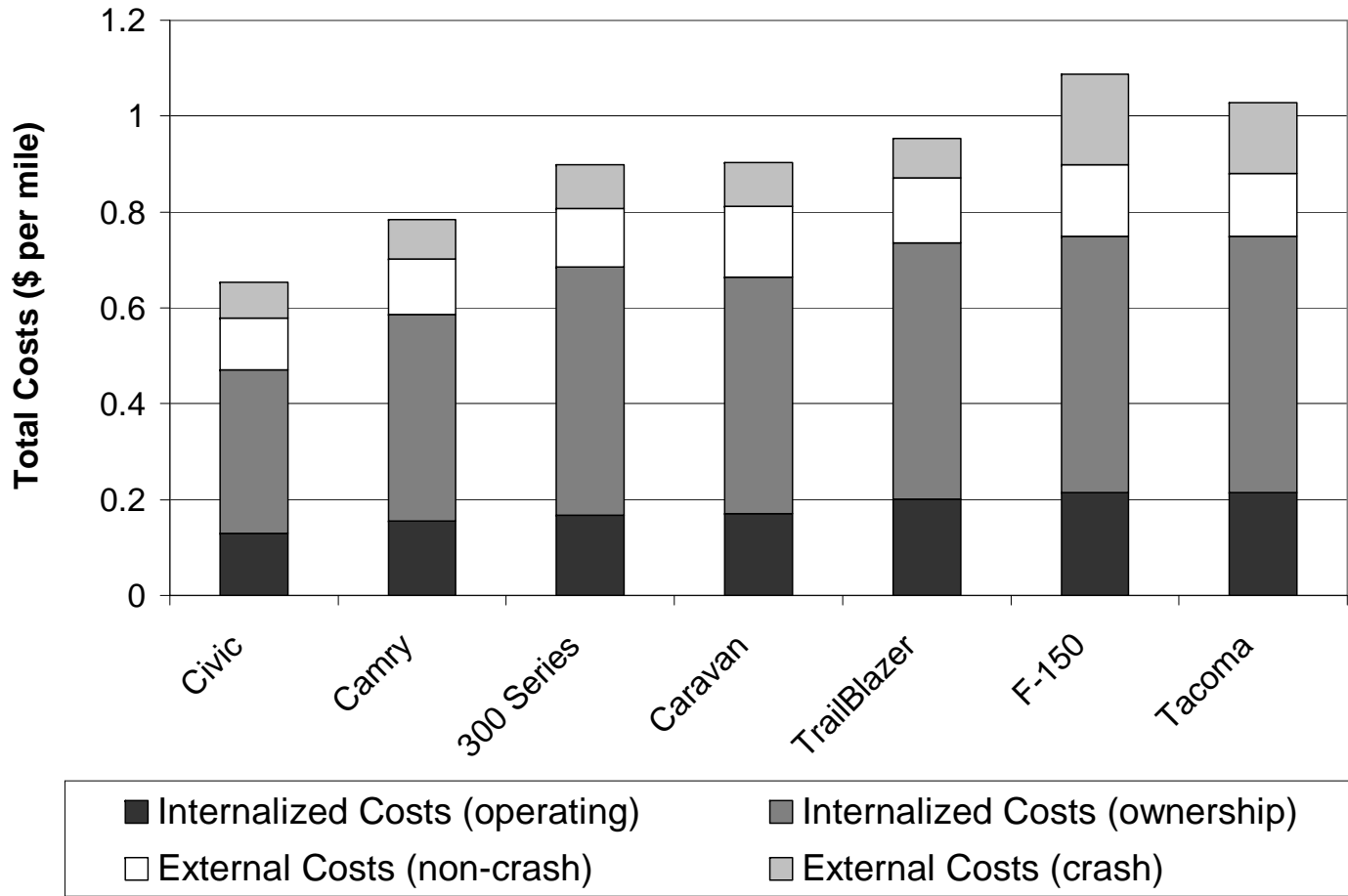
Van (mini)	Ford Freestar	0.0367	0.0973	0.0031	0.0935	0.0170	0.2477	0.1504
Van (mini)	Kia Sedona	0.0351	0.0993	0.0025	0.0935	0.0170	0.2474	0.1481
Van (mini)	Chevrolet Uplander	0.0364	0.0970	0.0028	0.0935	0.0158	0.2454	0.1484
Van (mini)	Chrysler Town & Country	0.0341	0.0964	0.0025	0.0935	0.0170	0.2436	0.1472
Van (mini)	Dodge Caravan	0.0341	0.0919	0.0028	0.0935	0.0165	0.2389	0.1469
Regular SUV	Honda Pilot	0.0370	0.1001	0.0025	0.0747	0.0162	0.2305	0.1304
Regular SUV	Jeep Commander	0.0427	0.0869	0.0031	0.0747	0.0186	0.2260	0.1391
Regular SUV	Hummer H3	0.0432	0.0848	0.0025	0.0747	0.0179	0.2231	0.1383
Large Car	Mercury Grand Marquis	0.0380	0.0923	0.0031	0.0698	0.0183	0.2215	0.1292
Large Car	Ford Crown Victoria	0.0380	0.0922	0.0031	0.0698	0.0184	0.2215	0.1293
Regular SUV	Ford Explorer	0.0419	0.0829	0.0031	0.0747	0.0165	0.2190	0.1362
Regular SUV	Chevrolet TrailBlazer	0.0419	0.0823	0.0029	0.0747	0.0159	0.2177	0.1354
Regular SUV	GMC Envoy	0.0415	0.0827	0.0028	0.0747	0.0159	0.2175	0.1348
Luxury Car	Cadillac DTS	0.0371	0.0905	0.0025	0.0698	0.0172	0.2172	0.1267
Regular SUV	Jeep Grand Cherokee	0.0392	0.0823	0.0031	0.0747	0.0179	0.2171	0.1349
Large Car	Dodge Charger	0.0339	0.0912	0.0025	0.0698	0.0165	0.2139	0.1227
Regular SUV	Nissan Pathfinder	0.0386	0.0829	0.0025	0.0747	0.0152	0.2138	0.1309
Regular SUV	Chrysler Pacifica	0.0368	0.0818	0.0025	0.0747	0.0175	0.2133	0.1315
Large Car	Chrysler 300 Series	0.0339	0.0905	0.0025	0.0698	0.0164	0.2131	0.1226
Large Car	Buick Lucerne	0.0343	0.0889	0.0023	0.0698	0.0166	0.2119	0.1230
Luxury Car	Cadillac CTS	0.0363	0.0864	0.0028	0.0698	0.0149	0.2102	0.1237
Regular SUV	Toyota 4Runner	0.0377	0.0791	0.0025	0.0747	0.0158	0.2098	0.1307
Large Car	Ford Five Hundred	0.0318	0.0867	0.0031	0.0698	0.0166	0.2080	0.1213
Luxury Car	BMW 5-Series	0.0345	0.0856	0.0025	0.0698	0.0154	0.2079	0.1223
Mid-Sized Car	Ford Mustang	0.0361	0.0826	0.0031	0.0698	0.0154	0.2069	0.1244
Luxury Car	Infiniti G35	0.0344	0.0849	0.0028	0.0698	0.0144	0.2063	0.1213
Mid-Sized Car	Chevrolet Impala	0.0323	0.0854	0.0025	0.0698	0.0162	0.2062	0.1208
Luxury Car	Acura TL	0.0311	0.0856	0.0025	0.0698	0.0152	0.2042	0.1186
Regular SUV	Jeep Liberty	0.0373	0.0755	0.0028	0.0747	0.0139	0.2041	0.1286
Mid-Sized Car	Pontiac Grand Prix	0.0313	0.0842	0.0025	0.0698	0.0162	0.2040	0.1198
Regular SUV	Jeep Wrangler	0.0388	0.0750	0.0025	0.0747	0.0125	0.2035	0.1285
Large Car	Nissan Maxima	0.0305	0.0848	0.0025	0.0698	0.0155	0.2031	0.1183
Luxury Car	BMW 3-Series	0.0315	0.0847	0.0023	0.0698	0.0141	0.2024	0.1176
Mid-Sized Car	Ford Taurus	0.0316	0.0814	0.0031	0.0698	0.0160	0.2019	0.1205
Luxury Car	Lexus ES350	0.0296	0.0847	0.0025	0.0698	0.0151	0.2018	0.1171

Regular SUV	Lexus RX 350	0.0334	0.0755	0.0025	0.0747	0.0150	0.2011	0.1256
Large Car	Toyota Avalon	0.0283	0.0843	0.0025	0.0698	0.0159	0.2008	0.1166
Mid-Sized Car	Pontiac G6	0.0307	0.0827	0.0028	0.0698	0.0148	0.2008	0.1180
Regular SUV	Nissan Murano	0.0331	0.0748	0.0028	0.0747	0.0154	0.2008	0.1260
Luxury Car	Lexus IS	0.0292	0.0844	0.0025	0.0698	0.0142	0.2000	0.1156
Regular SUV	Chevrolet Equinox	0.0335	0.0737	0.0025	0.0747	0.0150	0.1993	0.1256
Mid-Sized Car	Ford Fusion	0.0296	0.0808	0.0031	0.0698	0.0152	0.1986	0.1178
Mid-Sized Car	Toyota Camry	0.0272	0.0835	0.0023	0.0698	0.0151	0.1978	0.1143
Regular SUV	Toyota Highlander	0.0323	0.0727	0.0028	0.0747	0.0147	0.1972	0.1245
Mid-Sized Car	Hyundai Sonata	0.0278	0.0819	0.0025	0.0698	0.0151	0.1971	0.1152
Mid-Sized Car	Chevrolet Malibu	0.0289	0.0811	0.0028	0.0698	0.0146	0.1971	0.1161
Mid-Sized Car	Honda Accord (Hybrid)	0.0240	0.0851	0.0018	0.0698	0.0152	0.1958	0.1108
Mid-Sized Car	Saturn Aura (Hybrid)	0.0240	0.0841	0.0028	0.0698	0.0149	0.1955	0.1115
Mid-Sized Car	Honda Accord	0.0271	0.0809	0.0025	0.0698	0.0152	0.1955	0.1146
Regular SUV	Lexus RX400H (Hybrid)	0.0245	0.0779	0.0021	0.0747	0.0151	0.1942	0.1163
Mid-Sized Car	Nissan Altima	0.0260	0.0794	0.0023	0.0698	0.0149	0.1924	0.1130
Regular SUV	Toyota Highlander (Hybrid)	0.0245	0.0759	0.0021	0.0747	0.0148	0.1920	0.1161
Regular SUV	Saturn Vue	0.0303	0.0701	0.0025	0.0747	0.0144	0.1920	0.1219
Mid-Sized Car	Toyota Camry (Hybrid)	0.0194	0.0855	0.0021	0.0698	0.0149	0.1917	0.1062
Regular SUV	Ford Escape	0.0300	0.0700	0.0031	0.0747	0.0136	0.1914	0.1214
Regular SUV	Toyota RAV4	0.0291	0.0702	0.0025	0.0747	0.0145	0.1910	0.1208
Small Car	Dodge Caliber	0.0260	0.0791	0.0025	0.0698	0.0133	0.1907	0.1116
Regular SUV	Honda CRV	0.0294	0.0699	0.0025	0.0747	0.0141	0.1906	0.1207
Small Car	Toyota ScionTC	0.0279	0.0762	0.0025	0.0698	0.0133	0.1897	0.1135
Small Car	Chevrolet Cobalt	0.0269	0.0755	0.0025	0.0698	0.0136	0.1883	0.1128
Small Car	Saturn Ion	0.0264	0.0757	0.0025	0.0698	0.0139	0.1883	0.1125
Regular SUV	Saturn Vue (Hybrid)	0.0256	0.0700	0.0028	0.0747	0.0144	0.1874	0.1175
Regular SUV	Mercury Mariner (Hybrid)	0.0236	0.0734	0.0021	0.0747	0.0136	0.1874	0.1140
Small Car	Nissan Sentra	0.0243	0.0766	0.0025	0.0698	0.0141	0.1873	0.1107
Small Car	Mazda Mazda3	0.0255	0.0759	0.0022	0.0698	0.0136	0.1869	0.1110
Small Car	Kia Spectra	0.0250	0.0767	0.0022	0.0698	0.0132	0.1869	0.1102
Regular SUV	Chrysler PT Cruiser	0.0310	0.0660	0.0025	0.0747	0.0126	0.1868	0.1208
Regular SUV	Chevrolet HHR	0.0281	0.0668	0.0028	0.0747	0.0135	0.1859	0.1191
Small Car	Ford Focus	0.0257	0.0740	0.0028	0.0698	0.0128	0.1850	0.1111
Regular SUV	Ford Escape (Hybrid)	0.0224	0.0715	0.0021	0.0747	0.0136	0.1842	0.1127

Small Car	Hyundai Elantra	0.0235	0.0745	0.0022	0.0698	0.0138	0.1836	0.1092
Small Car	Honda Civic	0.0227	0.0749	0.0023	0.0698	0.0135	0.1831	0.1082
Small Car	Toyota Corolla	0.0214	0.0730	0.0025	0.0698	0.0133	0.1799	0.1069
Mid-Sized Car	Toyota Prius (Hybrid)	0.0139	0.0767	0.0019	0.0698	0.0132	0.1756	0.0989
Small Car	Toyota Yaris	0.0206	0.0696	0.0025	0.0698	0.0118	0.1743	0.1047
Small Car	Honda Civic (Hybrid)	0.0154	0.0732	0.0018	0.0698	0.0135	0.1737	0.1005
Small Car	Honda Insight (Hybrid [2006])	0.0134	0.0664	0.0022	0.0698	0.0115	0.1633	0.0969

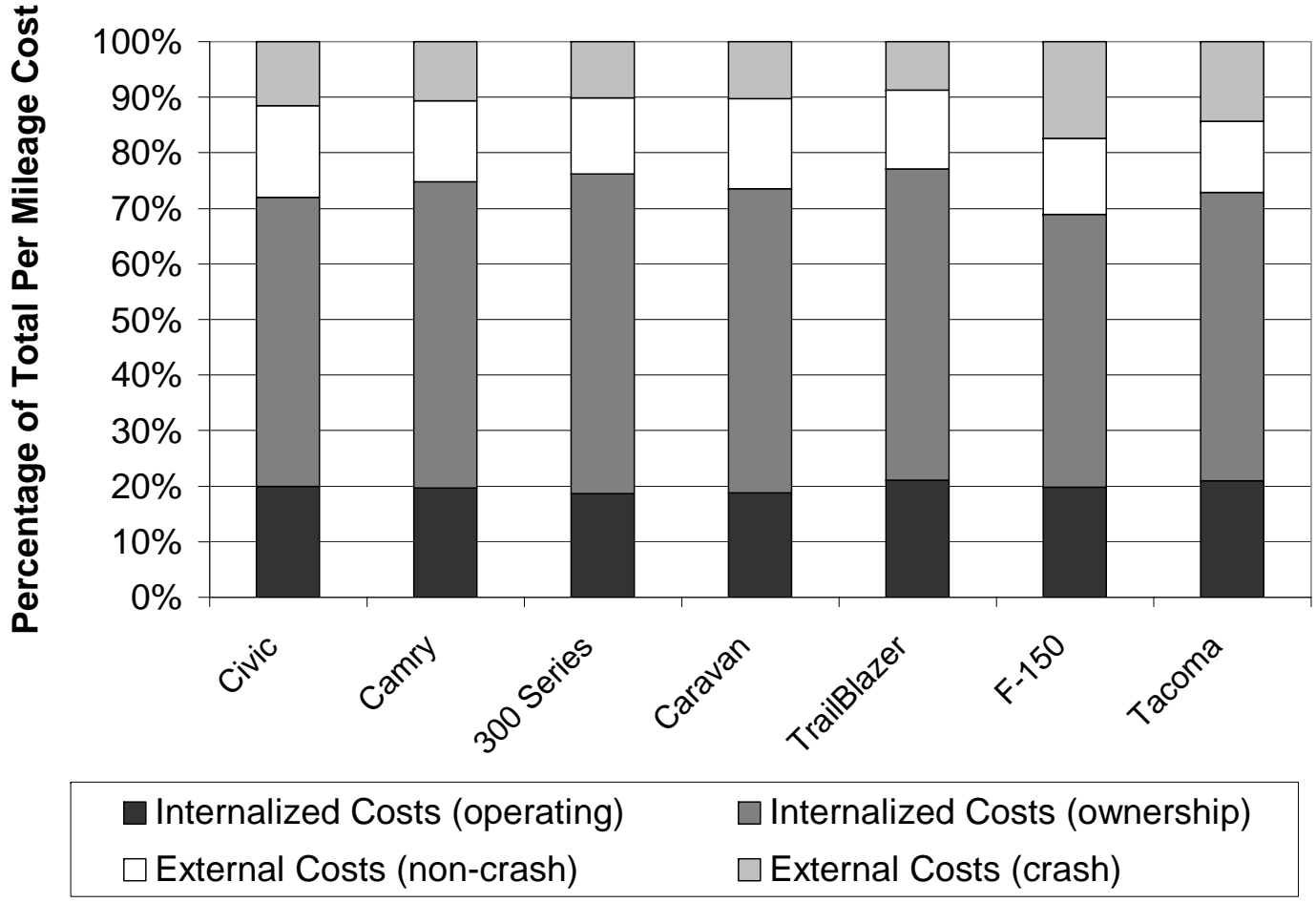
Note: Total Costs / Global Warming Costs shown in **bold** and *italics* are based on assumed values for Combined Fuel Economy since EPA does not measure fuel economy for these models. These values were taken from other models with similar attributes. Totals do not include the gas guzzler or CAFE fuel economy taxes. Vehicle life is assumed to be 10 years with an assumed annual mileage of 12,000.





**Figure 1: Costs of Driving per VMT (Internal [from AAA estimates] vs. External)**

Note: AAA (2006) costs assume new vehicles with low finance costs, and provides separate costs estimates for vehicles driven 10,000, 15,000, and 20,000 miles per year. Internal costs shown here were interpolated for a 12,000 miles per year assumption (consistent with other tables shown here). Internal costs for the F-150 and Tacoma were assumed to be the same as SUV costs, except gasoline costs were imputed based on average fuel economy.



**Figure 2: Costs of Driving per VMT as Percentage of Total**