# K. Inventory of Heavy-duty Truck Lightweighting Candidates

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## Objective

- Identify components and systems of heavy-duty trucks that have the greatest total fleet weight savings potential for the purpose of increased fuel efficiency and productivity.
  - Inventory the systems and components of Class 8 tractor-trailers.
  - Model the miles traveled and weight factor for the major component-system-vehicle combinations.
  - Rank and estimate the fuel consumption contribution of the most significant components.
  - Provide a model usable by potential component lightweighting developers to estimate the relative weight–miles contribution of candidate components.

## Approach

- Define the industry segments: types of vehicle bodies and vehicle configurations; define the numbers and annual miles of vehicles by type and configuration.
- Compile data on component and system configurations, weights, and materials of construction for the apparent major contributors to vehicle weight.
- Aggregate data on specific component weights and materials to prevent disclosure of individual manufacturers' proprietary information. Select representative values for component weights where a range of designs and weights are common.
- Determine the fuel economy distribution of weight ranges of heavy-duty trucks and calculate a representative fuel consumption of components per pound-mile.
- Design a model of the weight-miles traveled (pound-miles) and fuel consumption for any component or set of components to be considered for fleet weight savings and improved fuel economy.

## Accomplishments

- Successfully used the various databases to calculate numbers and total annual miles of vehicles by body type, vehicle configuration (truck and truck-tractor, number of trailers pulled, number of axles and tires), weight subclassification, and type of cargo hauled.
- Determined that buses and four types of trucks account for >90% of vehicle numbers and miles, and the four truck types account for the most trailer and haul unit miles.
- Determined that weight regulations normally impact the operation of platform, dump, and tank body vehicles, causing them to be weight-limited ("gross out").

- Obtained representative weights of major components common to all vehicle types and those specific to the four primary body types.
- Constructed an Excel-based model of component pound-miles and added a calculation of component fuel consumption.
- Identified the most significant contributors to pound-miles.
- Determined that extensive use of aluminum, high-strength steel, and new designs have already contributed to weight reduction and that further use these materials plus magnesium, titanium, and composites promises significant additional weight savings.

### Future Direction

- Incorporate final manufacturer data in summaries and model.
- Publish final report.
- Present findings to selected industry, government, and professional associations.
- Investigate opportunities and potential impact of materials such as aluminum, magnesium, and titanium.
- Discuss findings with vehicle and component manufacturers for consideration of focused developments.
- Discuss findings with military agencies for applicability to military ground vehicles.

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## Introduction

The purpose of this project is to assist Oak Ridge National Laboratory (ORNL) and DOE in prioritizing lightweighting technologies for heavy-duty trucks via an inventory of components that may aid in weight reduction. Identifying the components that contribute the most weight in the entire fleet of heavy trucks will enable ORNL/DOE to select projects with the greatest payoff in weight savings and reduced fuel consumption. The inventory must consider not only the weight of typical components but also the number of vehicle miles traveled by heavy trucks using that component over a typical year (pound-miles) and the fuel consumed carrying those components. A model will be provided that allows calculation of the pound-mile and fuel consumption figures for any component under consideration. It will incorporate the effect of applying the component to various truck body types and the miles traveled by trucks that use it. The model may be used to provide a quantitative estimate for comparing the weight and fuel consumption reduction potential of any proposed component.

## Project Deliverables

- A presentation has been made to DOE and ORNL personnel.
- A final report will provide details of the methodology and findings.
- A computer disk containing the model will be provided for use by DOE, ORNL, and potential component developers for calculating and identifying the weight and fuel savings potential of any proposed component.

## Heavy Vehicle Segments

Some components of heavy duty trucks and tractor trailers are used on every such vehicle; others may only be used on one vehicle type or configuration. In considering the development of a reduced-weight component, it is therefore necessary to understand its potential contribution to weight reduction over the entire vehicle fleet. To do so, it is necessary to have data on the number of vehicles of various types, and the miles traveled by each type, over a representative year. The weight or weight reduction potential of a component is multiplied by the number used on each vehicle type and the miles traveled by that type to obtain the pound-miles for the component. Adding the pound-miles for all vehicle types where a component would be used gives the total pound-miles for that component. If an average fuel economy figure is available for heavy trucks, it may be used to calculate the fuel consumed by each pound of weight of an average vehicle. The product of the pound-miles and the fuel consumed is an estimate of the fuel savings if that component were implemented across all applicable vehicles.

Several databases were used to construct a master database of numbers and miles traveled for all types of trucks in each weight range of Class 7 and 8 vehicles. It lists 29 body styles, including dry van truck and trailer containers, refrigerated van truck and trailer containers, tank trucks and trailers, flat bed trucks and trailers, dump bodies, and cement mixers. Another truck-trailer classification includes the type of truck (truck or truck tractor), number of trailers pulled, number of axles, and number of wheels. Thus, for example, all tank trucks with 4 axles and 14 wheels pulling a full tank trailer with 3 axles and 12 wheels will have one estimated number with that configuration and total miles traveled. Three-axle, 10-wheel truck tractors pulling one 4-axle, 16-wheel flatbed trailer will have a different estimated number and miles traveled. These differences have been found to be very significant. Analysis of these vehicle types was also expected to assist in focusing effort on the vehicle body types and components with the most contribution to pound-miles and fuel consumption.

This last benefit of the analysis is best accomplished by charting the number and miles traveled for the various truck types, and the number of trailers and "haul units" traveled by those types. A haul unit is defined as one container or support structure for cargo carried by a truck or trailer (e.g., a tank truck pulling a tank trailer constitutes two haul units.)

Figure 1 shows the number of vehicles by type with similar types combined. This result shows that relatively few body types account for the great majority of vehicles. This finding is even more pronounced when the results for body type by miles traveled are shown (Figure 2). We then find that just four body types account for 90% of the miles driven by heavy trucks/tractor trailers: the various forms of vans (dry, refer, insulated, and drop body), platforms (with and without added devices, and drop frame), dump bodies, and liquid haul tanks. Other body types travel far fewer miles and therefore contribute little to the overall miles driven by the total heavy-duty fleet.

Buses, including school, inter-urban, and city transit, have been included in this analysis thus far. It is apparent that they contribute significantly to the total miles driven by heavy vehicles. This analysis

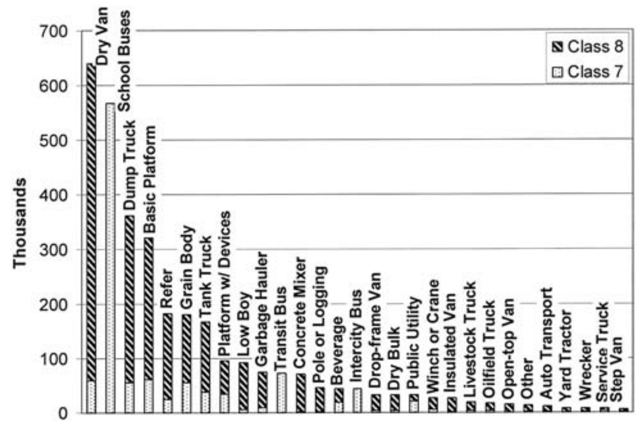


**Figure 1.** Number of vehicles by type.

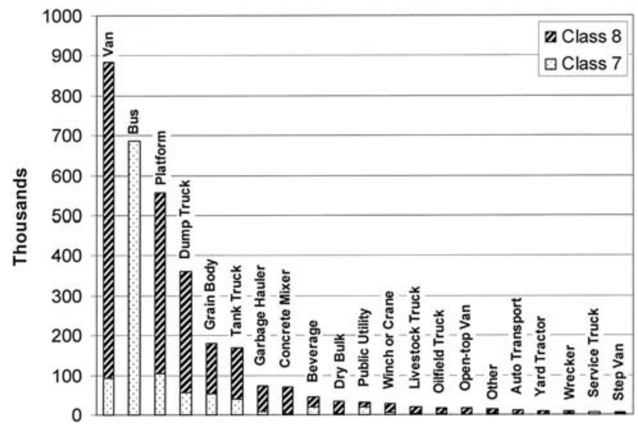


**Figure 2.** Number of vehicles by type; similar body types combined.

was conducted even though the original project scope included only trucks. During the investigation, it was found that, while bus weight and miles may be significant, the operation of buses is limited by passenger capacity and not by weight in most cases. Fuel savings by reduced weight is a secondary consideration for this industry. Therefore, owners and operators are not generally willing to pay any premium for weight savings. Methods to reduce bus weight may have significant fuel economy payoff but are likely to be adopted only if they carry no cost penalty. Since this topic was not in the original project scope, and buses are not generally weight limited, no further analysis was performed.

The number of trailer miles and of haul unit miles of the various types were analyzed to further confirm the overriding importance of the four types of vehicle bodies. Figure 3 shows the results for haul unit miles.

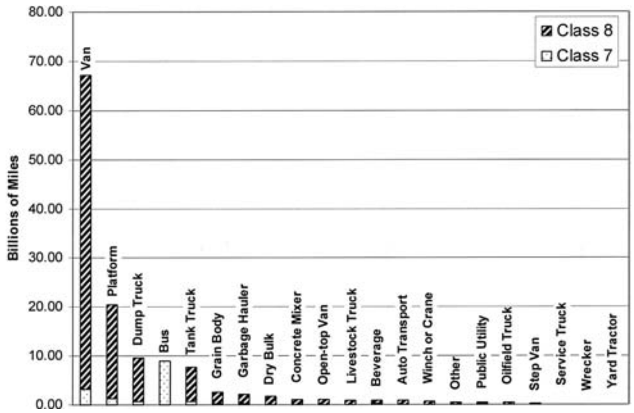


**Figure 3.** Miles traveled by vehicles of each type; similar body types combined.

We can definitively conclude that vehicles with body types including types of vans, flat beds, dump bodies, and tanks make the most significant contribution to miles traveled by heavy duty vehicles. It is also apparent that Class 8 vehicles other than buses travel far more miles than Class 7 vehicles, which may then be ignored in analysis of potential weight and fuel savings. Analysis of components used either on multiple-body type trucks or on these four primary types will provide the greatest potential for weight and fuel savings.

## Major Truck and Trailer Components

Some components of heavy vehicles are used on all body types and vehicle configurations, and others are specific to certain body types. Obviously, a relatively heavy component common to all types of vehicles will contribute much more to total pound-miles than a lighter component specific to only one body type.

Data were collected on the weights of components of all the major systems of trucks, tractors, and trailers. Much of this specific data, however, is proprietary and may not be disclosed. Attempts were therefore made to collect data from multiple manufacturers so that aggregate weights could be used in the analysis. In some cases, particularly where a wide variety of designs and weights are available for a type of component, representative weights were selected to facilitate the comparative analysis. Individual component weights discussed in this report therefore do not represent those of components from any one manufacturer.

**Common Components**. All truck and truck-tractor components are used in all body types. Engines, transmissions, truck frames, exhaust systems, axles, suspensions, cab features, drivelines, wheels, and tires, among others, are common components. Since 70% of haul units are trailers, several other components, such as fifth wheels, couplers, landing gear, "bogie" sliders, bumpers, and underrides, are used by nearly all vehicles. Some components are used on several major body types, such as van and flatbed floors, lower and upper side rails, main and cross beams. It is also important to consider in our analysis that some components are used multiple times per vehicle, including tires, wheels, axles, brakes and suspensions; such multiple use may make a component of moderate weight significant.

The engine is one of the heaviest components and is used on all vehicles. While there are numerous engine designs and engine sizes, many components are common to all or most designs. Figure 4 shows the relative weights of many of the major components. It is apparent that the block and cylinder head are by far the heaviest components and most likely to be significant contributors to pound-miles and fuel consumption. Wheels and tires, used multiple times on all vehicles, have already been the subject of weight reduction efforts. Traditional steel wheels have been partially replaced by light steel and aluminum wheels, with the latter being used on 40–50% of trucks but only about 10% of trailers. Super single aluminum wheel and tire combinations at ~240 lb per set are beginning to replace dual wheel/tires (~390 lb per set for conventional steel). Titanium provides weight and performance improvements for springs.

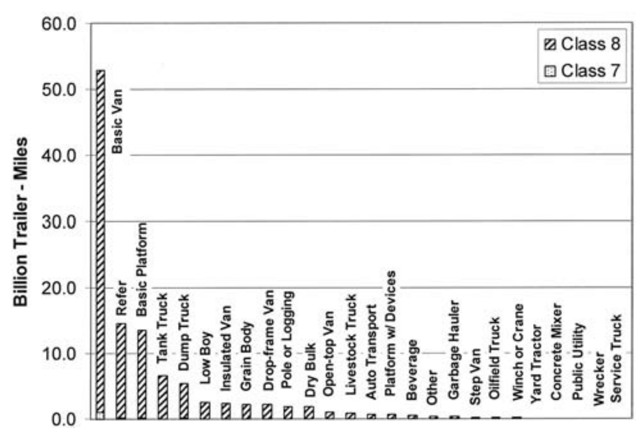


**Figure 4.** Miles traveled by trailers of each type.

**Body-Type-Specific Components.** Since four types of bodies predominate in numbers and miles traveled, we expect that some of their components will be among the largest contributors to pound-miles and fuel consumption. Among those components are the sides of van body trucks and trailers, with typical trailer side weights of 2000–3000 lb per set; the floors of van body vehicles and flatbed vehicles, which also weigh about 2000 lb; and parts such as base/side rails, top rails, floor crossmembers, rear frames, main beams, dump bodies, and liquid haul tanks. Data were collected on more than 100 such component types.

## Truck Fuel Economy

Various estimates of the fuel economy of heavy vehicles were encountered. To provide a supportable estimate for use in the comparison model, the VIUS database was exercised to provide the reported fuel economy of each 10,000 lb range in Classes 7 and 8. Class 8 fuel economy averages, weighted on miles reported, were calculated at 5.46 mpg, and the average vehicle weight at 64,400 lb. These points were used to calculate indicative fuel consumption by vehicle components of $2.84 \times 10^{-6}$ gallons per pound-mile.

## Pound-Mile Comparison Model

For the purposes of this study, a computational model is needed that includes the effect of component weight plus the number of times a component may be used in the entire fleet of trucks, and the fuel consumption per pound of vehicle. An MS Excel spreadsheet model was constructed including all of these factors. The full model includes consideration of the nine most common body types and all 49 vehicle configurations. To operate the model, the user enters a component name and weight and then decides the applicability of that component to each of the nine body types.

Applicability may be due to fundamental suitability or to an estimate of the portion of the entire fleet that is likely to adopt the component. The user will next enter the quantity of that component that would be used for each of the 49 configurations of truck and tractor trailer. The spreadsheet model then calculates the pound-miles of that component in the entire fleet, plus an estimate of the fuel that would be consumed by weight-limited vehicles over the entire fleet.

## Results

This procedure was followed for 74 of the heaviest components investigated. The results are shown in Figure 5 for the components with the greatest pound-mile and fuel consumption estimates. The values for the other 18 components are very small compared with these 56.

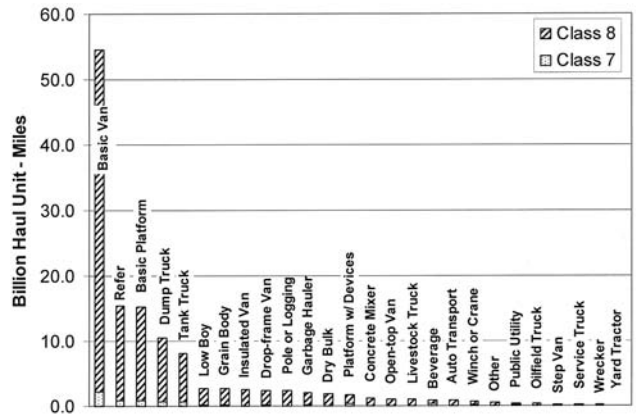


**Figure 5.** Miles traveled by haul units of each type.

## Conclusions

Based on the results of the analysis of heavy vehicle fleet segments, component weights, and the Pound-Mile and Fuel Consumption model, we can provide the following conclusions:

1. Class 8 trucks and tractor-trailers with four body types predominate in number of vehicles, miles traveled, number of trailers, and number of haul units. Weight reduction efforts will have the greatest payoff for vehicles with components common to all types, or to one or more of these four types. The four types are
    - Van bodies (basic enclosed vans, refrigerated vans, insulated vans and drop-frame vans)
    - Platform bodies (basic platforms, platforms with added devices, low boys)
    - Tank bodies (liquid or gas haul tank trucks and trailers)
    - Dump bodies (dump trucks, bottom and rear dump trailers)
2. Several factors act to make some components more likely to be major contributors to total fleet

weight and fuel consumption. They include these:

- All truck and truck-tractor components, and many trailer components, are used by all body types. These include engine, transmission, truck frame, exhaust, axles, suspensions, cabs, drive-lines, wheels, and tires.
- Since 70% of haul units are trailers, several other components are used by nearly all vehicles, including fifth wheels, couplers, landing gear, suspension sliders, and bumpers.
- Some components, such as floors, side rails, and main and cross beams, are used by several of the predominant body types.
- Some components, such as tires, wheels, axles, brakes, support cross members, and suspensions, are used multiple times per vehicle.

3. The pound-miles and fuel consumption contributions of a wide variety of components were determined so that they might be ranked in order of priority for lightweighting effort. The most significant contributors to pound-miles and fuel consumption include engines, tires and wheels, van sides, van and flatbed floors, suspensions, axles, brake drums, all frame members, cabs, couplers and fifth wheels, transmissions, and tanks. Some other component types are also significant contributors.
4. Efforts to reduce the weight of engine blocks and heads, for example, the use of aluminum or titanium, would likely produce the greatest payoff. Application of aluminum to additional components and titanium, magnesium, and composites to many components would result in of many trillions of pound-miles of lightweighting and millions of gallons of fuel savings.