



# The Importance of Lightweighting in Commercial Trucking

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**C**ommercial trucking is the backbone on which North American shipping and distribution relies. Nearly every product on store shelves or in one's home has been delivered by commercial trucks, known as semi or big-rig trucks. These trucks are designed to pull various loads behind them in the form of a large rectangular box trailer (called a dry van), a refrigerated box trailer (called a reefer), or tankers (that carry fuel or other liquid or gas materials). Because they are designed to carry heavy loads over long distances, commercial trucks face unique concerns when it comes to lightweighting and fuel economy.

## Commercial Trucks vs. Cars

Commercial trucks are generally comprised of two components, the semi-truck (called a tractor) and the load (the trailer or tanker), which together comprise the tractor-trailer. The tractor may be designed with a day cab (for hauls that can be made in a single day) or a sleeper cab (which features a built-in bed and rest area for drivers who are making long hauls across the country that can take several days). When looking at the tractor, it is easy to make the mistake of assuming that it is just an oversized car. However, there are fundamental differences between the two.

The first and most obvious difference is the weight of the vehicle. A typical car, like the Toyota Camry, weighs around 3,500 lbs. By comparison, a tractor without a trailer can weigh between 15,000 and 20,000 lbs (6,800-9,100 kg) by itself, while a tractor-trailer hauling a dry van (which represents about 90% of the commercial trucks on American roads) has a total weight of around 67,000 lbs (30,400 kg), with the interstate limit being 80,000 lbs.<sup>1</sup> Reefer tractor-trailers typically weigh around the same,

because they fill the available volume before reaching the maximum allowable weight, and tankers are generally only able to be filled up to 80% due to weight limits.

Second, the mileage use of a commercial truck is much higher than a car. The average American drives a total of 13,500 miles per year,<sup>2</sup> whereas a commercial truck can drive around 110,000 miles per year. For example, Hell Bent Xpress, a weight-sensitive tanker fleet, has been known to drive their trucks an average of 132,000 miles per year.<sup>3</sup> In other words, a single year of commercial truck driving is almost the same as the full lifetime of a typical passenger car.

Third, unlike passenger cars, which are designed for commuting or recreation, commercial trucks are heavy duty tools—and this consideration is taken into account whether the truck is being purchased by an individual or a fleet owner. When purchasing tractor and trailer, the fleet has a multitude of options, based on performance, product life, aesthetics, weight, and how the selection affects the total cost of ownership (TCO). The truck buyer can customize their order as they wish to meet their hauling needs, specifying down to exact components, including the axle, wheels (with disc or drum brakes), fuel tanks, and so on.

Another major consideration in commercial trucks is return on investment (ROI) and resale value. Generally, a fleet owner wants a tractor to achieve ROI within three to five years, after which they will sell it. Therefore, owners tend to specify the purchase of a tractor that will sell quickly and with a high value. From this perspective, the engine is a key factor. The use of a 13-liter engine can cut 300-500 lbs (136-227 kg) from the vehicle weight, improving efficiency while being able to haul the same amount of cargo. However, most second buyers want to purchase a tractor with the largest-sized engine (15-liter),

which weighs as much as a Mini Cooper. Despite the benefits of utilizing a smaller engine, the fleet owner is not likely to purchase it, as they will not be able to sell that tractor as quickly and for as much money. Some fleets sell as many as 20,000 tractors per year, so resale strategy is critical to the company success.

## Materials and Lightweighting Design

Many methods exist for cutting weight on a commercial truck, which depend heavily on the business case and the duty cycle of the truck. When considering which of these methods to invest in, fleet managers and engineers look to the North American Council on Freight Efficiency (NACFE), which provides objective reports on over 80 trucking technologies. The council recently updated its lightweighting report in 2021, bringing the business case for weight reduction into consideration.<sup>1</sup>

For this report, the NACFE team surveyed commercial truck fleets about what materials or components they selected for their trucks and whether this choice was due to weight, appearance, or some other reason. Various options included the use of a lightweight cab, frame, or bumper; aluminum air or fuel tanks; aluminum wheels; engine size; and various other parameters (such as wheel base).

The report found that the business case for lightweighting does not necessarily include fuel economy. Rather, if a commercial truck fleet wants to cut fuel usage, they will prioritize aerodynamics, engine and transmission configurations, and improving driver behavior.

Fleet managers will invest in weight reduction when they believe it will improve their business by increasing payload, which is an all-encompassing term for the freight and the vehicle equipment. Payload can impact factors like profitability and/or driver comfort. A lighter tractor enables the truck to carry heavier loads, which increases the value of the haul. However, driver comfort also needs to be taken into consideration. A sleeper cab is significantly heavier than a day cab, by about 1,600 lbs (725 kg). Despite this weight increase, a sleeper cab is critical for providing comfort to those drivers who drive their trucks for days or weeks at a time. It has been reported that the U.S. market is short as many of 150,000 drivers, so driver comfort and satisfaction is another key element in maintaining a successful fleet. Another set of factors on truck weight are government mandates, such as the requirement of diesel emissions equipment, which adds about 400 lbs (180 kg) to the tractor. Lightweighting of commercial trucks is apparently a dance between reducing vehicle weight to increase payload, while market influences (such as driver shortages and government regulations) bring the weight back in.

As with most vehicles, commercial trucks vary in their material usage from company to company and model to model. Many truck manufacturers use plastics or sheet molded composites for components like the large chrome-painted grille on the front of a truck or large aerodynamic shields and covers.

When it comes to aluminum, commercial trucking has been ahead of the game. Tractors have been using aluminum in its doors and body panels long before the Ford F-150 converted to aluminum in 2015. Truck manufacturers, such as Daimler and PACCAR, have produced tractors with aluminum cabs for decades. Meanwhile, Volvo uses steel in its body panels, and International Navistar used aluminum for a period of time and then changed to steel. For a day cab tractor, an OEM can save an estimated 170-220 lbs (80-100 kg) by converting the body panels from steel to aluminum.

Multiple attempts have been made to produce light-weight aluminum frame rails, but these designs are no longer available due to field issues and low demand. Therefore, frame rails will likely remain steel, with light-weighting coming via gauge reduction with stronger steel alloys. Someday there may be a polymer composite frame rail for niche applications if these materials can bring a compelling business case beyond weight savings and corrosion resistance.

Beyond the rail, however, the truck frame can have as many as nine cross-members, an application for which aluminum is growing in popularity. Recently, this was highlighted by Daimler's Western Star vocational truck that cut 200 lbs, which was achieved in part to the conversion of three cross-members to aluminum.<sup>4</sup> Success breeds success, and now there are documented stories of aluminum cross-members being used in vehicles, from Jeeps to dump trucks.<sup>5</sup>

One interesting area for material selection is the wheel. Aluminum is 20 lbs (9 kg) lighter per wheel than painted steel (Figure 1). But when fleets were interviewed, different reasons were indicated for the purchase choice. Some weight-sensitive fleets pointed to lightweighting as to their choice of aluminum wheels, yet many others focused on aesthetics, because drivers prefer nice looking trucks and the resale value is higher. Steel wheels are galvanized or painted and require regular maintenance or the truck will start to look bad. On the other hand, aluminum wheels are produced with a bright and durable chrome finish that looks nice for a long time with minimal maintenance. On rear tandems, it is not unusual to see an aluminum wheel on the outside, with steel wheels inside where no one can see.



Figure 1. Aluminum wheels (left) are able to reduce weight compared to steel versions (right). (Source: Accuride and Maxion Wheels.)

Generally speaking, fleet owners are reluctant to invest in new lightweighting technologies, as they tend to be more expensive. A higher initial investment in the purchase of a commercial truck makes it more difficult for the fleet owner to achieve an ROI within the desired three to five year time span.

## New Drivetrains for Commercial Trucks

For many decades, commercial trucks ran on diesel, with a small portion running on natural gas. Now electrification is coming to the commercial trucking sector. When converting a Class 8 tractor from diesel to electric, the engine, transmission, and fluids are removed, which cuts around 8,000 lbs (3,600 kg) of weight. However, a motor, inverter, battery pack, protective cage, and electronics have to be added back in, all of which is heavier than the traditional diesel drive train. The net result is an electric tractor that is 6,000 lbs (2,700 kg) heavier than the diesel model, with only about 150 miles of driving range.

At the Advanced Clean Transportation (ACT) Expo held in August of this year, one Class 8 tractor was outfitted with 9,000 lbs of batteries to propel the estimated 29,000 lb (13,150 kg) tractor just 350 miles. The weight of the electric version is unbelievably high compared to a typical diesel tractor with a 100 gallon fuel tank, which weighs between 15,000 and 20,000 lbs (6,800-9,100 kg) and is able to achieve 700-1,000 miles of driving range.

It is expected that lightweighting will be the long-term focus of how to make electric commercial trucks viable. However, in the near term, the priority will be to achieve the fleet's duty cycle by tailoring the battery management system to achieve maximum performance. Range is a huge limitation in electric trucks. Even though the Class 8s are rated at 150 miles per day, they will still have to manage traffic, weather, elevation, and grade changes, which will reduce that mileage even further. Cost is another big hurdle, electric trucks and buses are reported to cost 2-3.5 times more than diesel. Some of these costs can be mitigated by taxpayer subsidies, but eventually these incentives will dry up.

What is the zero-emission vehicle (ZEV) solution for over the road trucks traveling 400-500 miles per day? Rather than electrification, many industry experts point to hydrogen fuel cell powertrains as a more viable option. In this kind of powertrain, hydrogen is stored under pressure (like compressed natural gas, CNG) and is used as the fuel source. Hydrogen fuel cells are lighter weight, having an energy-to-weight ratio that is ten times more than lithium-ion batteries. In addition, fleet owners that use hydrogen fuel cells in their trucks can obtain a 2,000 lb waiver from the U.S. Department of Transportation, which allows these trucks to drive on interstates with weights up 82,000 lbs without a penalty.

When considering clean powertrains, one cannot help but wonder if they will come with a big push for lightweighting. Because electric trucks are extremely heavy, it is likely that they will operate in non-weight-sensitive trucking applications in the near term. They will travel short distances, using lower weight day cabs. In terms of battery protection, commercial vehicles will likely follow the light duty truck market, which uses multi-hollow aluminum extrusions as a lightweight, efficient means to protect their battery packs. At the ACT Expo, the commercial trucks on display featured improved battery protection, some even finding ways to pack the batteries safely within the frame rails.

## References

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