

The Impact of Lift Axles on Fuel Economy and GHG Emissions Reduction

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ABSTRACT

Using lift axles enables fleet to increase the load capacity of a vehicle, eliminating the need for multiple trips, thus reducing operational costs.

In a project to assess the potential of reducing fuel consumption and greenhouse gas (GHG) emissions by lifting axles on unloaded semi-trailers, lift axle regulations in various jurisdictions and the studies that led to these regulations were analyzed.

The SAE Fuel Consumption Test Procedures Type II (J1321) was used for fuel consumption track test evaluations. The tests were conducted on unloaded two-axle van semi-trailers, four-axle van semitrailers, and B-trains, and resulted in fuel savings of 1.3% to 4.8%, depending on vehicle configuration and the number of axles lifted during the test. Temperature measurements and thermal images taken during the tests show that the difference in temperature of rolling tires of tandem axles with one axle lifted, compared to the temperature of rolling tires of tandem axles with both axles on ground was minimal.

As such, lifting the axles of unloaded van semi-trailers shows an interesting potential in fuel savings and GHG emissions reduction because in many applications, semi-trailers travel unloaded 50% of the time. Special equipment is however necessary to lift axles and there are regulatory constraints regarding these devices. Several Canadian provinces allow the lifting of axles when a semi-trailer is empty, however, additional studies are necessary to evaluate the impact of lift axles on maintenance (tire wear) and safety (braking performance).

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INTRODUCTION

Context

Class 8 trucks consume approximately 68% of all fuel used by commercial trucks, from which about 70% is consumed by on-highway trucks [1]. Tire-rolling resistance accounts for approximately 30% of the energy necessary to sustain vehicle speed at 105 km/h, [2]. Therefore, a 10% reduction in tire rolling resistance would reflect fuel savings of 2% [3].

Given that the use of lift axles enables fleets to increase the load capacity of a vehicle, fleets equipped with lift axles can reduce the number of vehicles in operation, which results in reduction in operational costs. Furthermore, additional axles help to distribute the truck's load across the road surface, reducing the chances of damage to infrastructure. Lift axles can be raised when the vehicle has lighter load to save fuel and reduce wear and tear to the tires and axles. They can be deployed to improve traction, especially in icy off-road applications.

Despite their economic and practical benefits, lift axles reduce vehicle turning capabilities when deployed and may cause a vehicle to skid or swerve if the roadway is slippery. Deployed lift axles may also compromise a truck's stability and increase chances of rollover in tight turns due to excessive lateral resistance. Safety can also be compromised if the lift axle supports excessive weight due to uneven surfaces.

Given the potential in fuel saving and GHG reduction, as well as the safety and regulatory concerns related to lift axles, a project to evaluate the impact of raising a lift axle of empty van semi-trailers on fuel efficiency was conducted. The evaluation covered the following axle configurations:

- Two axles semitrailers: lifting, one at a time, front and rear axle;
- Four axles semi-trailers: lifting one or two front axles;
- B-train: lifting three axles, two on the front trailer and one on the rear trailer.

TECHNOLOGY REVIEW

Lift Axle Construction

Suspension air bags (air springs) are installed on lift axles to support the load when the axle is on the ground and to raise the axle when it is not in use. In the case where two sets of air bags are used on a configuration of lift axles, the driver may use electric or pneumatic controls to inflate or deflate the two sets of bags, and therefore, raise or lower the axle [4]. In this case, the lift axle consists of one suspension set to support the load and a second set to raise or lower the axle as shown in Figure 1. It should be mentioned that some air suspensions are not equipped with lift bags; axles are therefore raised and lowered using the pressure variation in the suspension air bags.

The load on the axle is equalized using an air pressure control in the suspension that makes it possible to ensure that the load is evenly distributed between the undeployed lift axle and fixed axles. An equalization valve adjusts the air pressure to permanently maintain equal distribution of the load on the axles. Unequal distribution of the load may cause a loss of traction and instability of the vehicle. For this reason, regulations (such as Ontario's SPIF regulations [5]) impose load equalization systems on vehicles with lift axles [6].

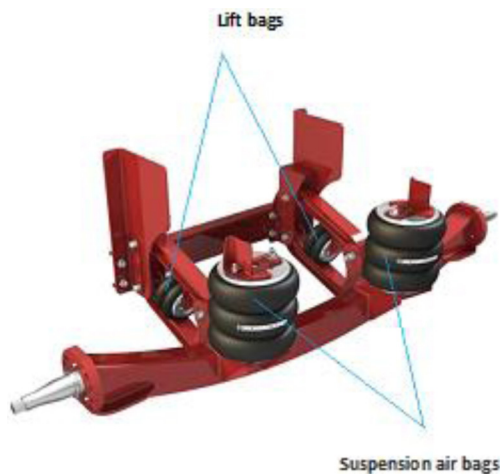


Figure 1. Air suspension of a lift axle (adapted from [7])

According to manufacturers of vehicle suspensions, air springs are interchangeable between fixed and lift axles. Consequently, an air spring used on a fixed axle may also be used on a lift axle, according to the application or the load to support. Suspensions are therefore made with air springs that can support the characteristic loads of both types of axles—both fixed and lift.

There are also lift axles with a wide range of movement for 4-axle forestry semi-trailers (Figure 2), which are considerably different from the models used on fixed axles. They have a different configuration (longer suspension swing arms) and often have smaller

suspension air bags, which require the use of a proportion valve to ensure load equalization. A regular lift axle has a ground clearance of 7.5-10 cm, whereas the clearance of lift axles for forestry semi-trailers is in between 20 and 30 cm.



Figure 2. Air suspension of a lift axle on a forestry trailer

Lift and Load Transfer Axle Systems

There are manual control systems to raise self-steering or fixed lift axles when the vehicle is operating with no load or in reverse. Some manual control systems automatically lower the axles when they detect a load. Automatic pressure control systems in the suspension raise or lower the lift axle according to the load or when the vehicle is operating in reverse. Some systems restrict loaded self-steering axles above a certain speed (for example, 60 km/h), some equalize the load between axles, while others are equipped with display devices installed on the instrument panel that enable the driver to monitor the condition or status of the lift axle.

There are new systems on 6×2 tractors that transfer load from a dead axle to a drive axle under particular conditions, to increase traction and reduce tire wear and tear. They are equipped with automatic electronic pressure controls in the suspension for load transfer and a manual control to lift the dead axle carrying no load. These systems are safe and reduce fuel consumption [8], [9]. Other systems are automatically activated when the traction control system is active and a loss of traction occurs. These systems are automatically deactivated when traction is regained or at speeds higher than a certain limit (such as 40 km/h). Manual activation is possible at low speeds (for example, at speeds of less than 16 km/h) or when the automatic transfer controller (ATC) switch is turned on.

TEST METHODOLOGY

Fuel Consumption Test Procedure

The SAE Fuel Consumption Test Procedure Type II (J1321) was used for fuel consumption measurements on a test track [10]. The evaluation covered the following axle configurations:

- Two-axle semi-trailers: lifting, one at a time, front and rear axle;
- Four-axle semi-trailers: lifting one or two front axles;
- B-train: raising three axles, two on the front trailer and one on the rear trailer.

The series of tests compared the fuel consumption of a vehicle operating under each of the above conditions (test vehicle) with that of an unmodified vehicle (control vehicle). Fuel consumption was accurately measured by weighing portable tanks before and after each trip. Figure 3 shows the installation of the portable tanks on a vehicle.



Figure 3. Installation of the portable fuel tanks

The following equipment was used during the tests:

- Portable tanks with a capacity of 144 L (38 gallons) Norcan Aluminum 103461;
- Calibrated scale with a capacity of 226.80 kg and a resolution of 0.02 kg: Weigh-Tronix DS 2424 A - 005, serial no. 76096;
- Calibrated scale with a capacity of 150 kg and a resolution of 0.02 kg: Ohaus 3000 serial no. 0015208-635.

For each test, the control and test vehicles had the same general configuration and were coupled to the same semi-trailers for the baseline and final test segments. The vehicle (tractor and semi-trailer) weights remained the same throughout the entire test period. The vehicles were in good working condition, with all settings adjusted to the manufacturers' specifications.

The test consisted of a baseline segment (using non-modified vehicles, all the axles were on the ground) followed by a final segment (the test vehicles were modified, i.e. the axles were lifted as mentioned above, while the control vehicle stayed in its original state, with all the axles on the ground). For both the baseline and final segments, the representative results were the ratio between the average fuel consumed by the test vehicle and the average fuel consumed by the control vehicle (the T/C ratio).

The nominal values for fuel savings and for fuel improvement were determined from the analysis of the measured fuel data, and reflect the changes resulting from the modification being tested on the test vehicle. These nominal values consisted of the percentage difference between the baseline ratio $(T/C)_b$ and final ratio $(T/C)_f$:

- Fuel savings:

$$F_s = 100 * \frac{(T/C)_b - (T/C)_f}{(T/C)_b} \quad (1)$$

- Fuel improvement:

$$F_I = 100 * \frac{(T/C)_b - (T/C)_f}{(T/C)_f} \quad (2)$$

Fuel savings is calculated by dividing the difference between the baseline ratio $(T/C)_b$ and final ratio $(T/C)_f$ by the baseline ratio $(T/C)_b$ (thus determining the effect of the technology relative to baseline configuration). The fuel improvement is obtained by dividing the same difference by the final ratio $(T/C)_f$ (thus determining the effect to the technology relative to the final, and improved configuration). Fuel improvement is always greater than fuel savings.

The result was expressed for the confidence interval of 95%, complying with the SAE J1321 Fuel Consumption Test Procedure - Type II [10], and determined from the variation in the measured fuel consumption data relative to the nominal value and the number of data values obtained.

To minimize measurement uncertainties, the only measured parameter used to calculate the test results was the weight of the portable tanks. Other parameters, such as vehicle speed, distance and time, were recorded for information purposes only. In order to avoid potential problems related to the instruments, two recently calibrated scales were available on-site. For each run, the portable tanks were weighed using the same calibrated scale. Furthermore, the scale was periodically checked against a known weight of 120 kg (Figure 4). The scale was not moved between the initial and final weighing for a given test run. Distance measurement was not a factor because for each run, all vehicles departed and arrived at the same point after travelling the same number of laps and following the same path along the track.