Raising the bar on emission calculations

A technical guide to calculating the sustainability of Flock Freight's shared truckload solution.

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Contents

Abstract

Transportation is the biggest emitter of greenhouse gases in the United States. To improve accountability among shipping businesses (and, ultimately, drive down supply chain emissions), technology company Flock Freight® is measuring shared truckload (STL) customers' environmental impact and sharing performance metrics via detailed reports.

This guide describes Flock Freight's process for tracking and analyzing STL emissions and includes the firm's:

- Updated STL calculation
- Calculation for comparing the emissions of STL and less than truckload (LTL)
- Calculation for comparing the emissions of STL and truckload (TL)

Keep reading to see how STL reduces emissions by roughly 15-40% compared to LTL and TL.

The need for transparency

Transportation accounts for the largest portion (29%) of greenhouse gas (GHG) emissions in the United States and 14% of emissions globally. Within transportation, heavy-duty trucks are the fastest-growing contributor to emissions.

Cutting transportation emissions is a vital step toward fighting climate change. As supply chain activity increases, the shipment of United States goods is projected to grow another 23.5% by 2025 and reach 45% by 2040. With more shipping will come more transportation and an alarming increase in fuel consumption.

Calculating and assessing the environmental impact of freight transportation is a business-critical component of sustainability for all shipping organizations. Human health depends on the well-being of biodiversity and ecosystems, which means measuring, planning and minimizing any activity that may alter the natural environment is vital. Because shippers generate a large portion of emissions, efforts by shipping businesses to reduce greenhouse gases are especially important.

Tracking and sharing corporate sustainability efforts — including emission reduction tactics — to minimize supply chain waste have yet to become standard across the freight industry, but businesses must embrace this shared responsibility to see high-impact improvement across shipping operations.

To do our part, Flock Freight has updated the method we use to measure our environmental impact, using the most credible information available to us.

Shared truckload emission calculation

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$$E_{Load} = (W_{Load} / W_{Total}) \times D_{LH} \times (1/MPG) \times F_{Fuel} + F_{Equiv} \times D_{LH}$$

FORMULA 1

Key

E_{Load}	Emissions in pounds (lbs) of carbon dioxide (CO_2e)
W_{Load}	Weight of constituent load
W_{Total}	Weight of total payload
D_{LH}	Linehaul distance in miles
F_{MPG}	Fuel efficiency in miles per gallon (MPG), function of W_{Total}
F_{Fuel}	Emissions factor in CO_2 equivalents per gallon
F_{Equiv}	CO_2 equivalents of methane (CH_4) and nitrous oxide (N_2O) in CO_2e / mile

Revisions to previous calculations

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Flock Freight recently revised several of our emissions factors to better align with the Environmental Protection Agency (EPA), SmartWay and the Greenhouse Gas Protocol.

Revisions to Flock Freight's shared truckload emission calculations (Table 1):

	Units	Previous	Revised
W_{Total}	Pounds	45,000	35,250
MPG	Miles / gallon	6.5	6.17
F_{Fuel}	Pounds CO_2e / gallon	19.6	22.5
F_{Equiv}	Pounds CO_2e / mile	N/A	0.028835

TABLE 1

Revisions to previous calculations

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Weight of total payload reduced from 45,000 lbs to 35,250 lbs

We revised the total payload weight of a shared truckload to reflect the varying density of the freight that moves via this mode. Sometimes, a shared truckload cubes out (meaning truck capacity is reached by the freight's dimensions — length, width and height) before it weighs out (meaning truck capacity is reached by the freight's weight).

While 53-foot dry vans have a maximum payload capacity of 45,000 lbs, the typical total payload for LTL is closer to 25,500 lbs as indicated in the 2021 SmartWay research. Raw commodities (higher-density freight) often move in bulk via TL, while finished goods (lower-density freight) often move in smaller quantities via LTL.

Because shared truckload combines multiple loads that would traditionally move via LTL or individually as TL, the total payload weight for STL is set to bridge the two modes.

Emissions factor for fuel increased from 19.6 to 22.5 lbs of CO_2 per gallon

We revised the emissions factor to reflect the EPA's 2021 estimates.

Revisions to previous calculations

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Fuel efficiency reduced from 6.5 MPG to 6.17 MPG

We revised our MPG estimates to align with the Oak Ridge National Laboratory (ORNL) study on the fuel economy of Class 8 freight trucks and the 2021 SmartWay research.

Based on the ORNL fuel efficiency formula, we determined the fuel efficiency for a 25,500-pound payload to be 8.46 MPG. This is for a vehicle speed of 65 mph on flat terrain, and we assume the combined empty equipment weight of the tractor and trailer to be 34,000 pounds.

We cross-referenced the 2021 SmartWay calculator, which uses 6.683 MPG for a 25,500-pound payload, and determined we needed to apply a 1.78 MPG knockdown factor to account for more realistic driving conditions. Applying this to the 35,250-pound payload yields a fuel efficiency of 6.17 MPG.

ORNL fuel efficiency formula for a Class 8 vehicle at a speed of 65 mph on flat terrain (Formula 2):

$$\mathbf{MPG\ (W_{Load}) = (-5E - 10) \times (W_{Load})^2 + (8E - 06) \times (W_{Load}) + 9.6687}$$

This is the fuel efficiency formula knocked down by 1.78 MPG to tie-out with 2021 SmartWay assumptions of 6.683 MPG at 25,500 lbs. Here we assume factors in more realistic driving conditions (Formula 3):

$$\mathbf{MPG\ (W_{Load}) = (-5E - 10) \times (W_{Load})^2 + (8E - 06) \times (W_{Load}) + 7.8887}$$

Revisions to previous calculations

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CO_2 equivalents of CH_4 and N_2O updated in CO_2e / mile

These are the EPA emission factors for CH_4 and N_2O by medium- and heavy-duty vehicles using diesel fuel, along with the global warming potential (relating emissions to CO_2e factors). CH_4 and N_2O emissions depend on the total distance a shipment travels. Mobile combustion of CH_4 and N_2O for on-road diesel:

	CH_4	N_2O	$F_{Equiv} = CH_4 + N_2O$
Grams per mile (vehicle 2007 or later)	0.0095	0.0431	N/A
Pounds / mile	0.000021	0.000095	N/A
Global Warming Potential (GWP)	25	298	N/A
Pouds of CO_2e / mile	0.000525	0.02831	0.028835

TABLE 2

The above changes to our shared truckload emissions formula make the estimates of our STL emission savings impact more conservative than before.

Emission calculation for mode comparison

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Formula 1 provides a standardized formula for calculating the emissions of an individual load that moves as part of a shared truckload. To compare emissions between shared truckload and other over-the-road modes, we extended Formula 1 to capture emissions of both LTL and TL in addition to STL:

$$E_{Load} = [(W_{Load} / W_{Total}) \times (D_{LH} + D_{PD})] \times (1/MPG) \times F_{Fuel} + W_{Load} \times (D_{LH} + D_{PD}) \times F_{Terminals}$$

FORMULA 4

Key

E_{Load} Emissions in pounds (lbs) of carbon dioxide (CO_2e)

W_{Load} Weight of constituent load

W_{Total} Weight of total payload

D_{LH} Linehaul distance in miles, described as a function of the great circle distance (GCD). GCD is the shortest direct distance between two points on the surface of a sphere. D_{LH} takes into account road networks, can be described as a function of GCD and is mode-dependent.

D_{PD} Pickup and delivery segment miles. Specific to LTL and varies by region.

MPG Fuel efficiency in miles per gallon; function of W_{Total}

F_{Fuel} Emissions factor in CO_2 equivalents per gallon

$F_{Terminals}$ Emissions factor in CO_2 equivalents per pound mile; accounts for the hub-and-spoke network infrastructure that includes emissions from operations like power consumption and waste generated.

Emission calculation for mode comparison

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Summary of factors used in carbon emission calculations (Table 3):

	Units	LTL	TL	STL
W_{Total}	Pounds	25,500 [average]	45,500 [maximum]	25,500 - 45,000
D_{LH}	Miles	D_{LH_STL} x 1.04 + 32.31	D_{LH_STL}	D_{LH_STL}
D_{PD}	Miles	7.8 x 2 = 15.6 [average]	0.0	0.0
MPG	Miles / gallon	6.683 [average]	f (W_{Load} + 34,000)	f (W_{Total} + 34,000)
F_{Fuel}	Pounds of CO_2e / gallon	22.5	22.5	22.5
$F_{Terminals}$	Pounds CO_2e / lb-mile	4.35E - 06	N/A	N/A

TABLE 3

Linehaul distance in miles

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LTL factors are based on 2021 SmartWay research. The linehaul distance as a function of great circle distance is provided as part of the study. The following formula represents a linehaul estimate for shipments that move on-hub through a series of intermediate terminals:

FORMULA 5

$$D_{LH\_LTL} = 40.51 + 1.21 \times GCD$$

For the linehaul distance of TL and STL, Flock Freight performed a regression analysis using data across 1,000 lanes to predict the linehaul distance as a function of great circle distance to account for road network only (that is, the LTL hub-and-spoke network doesn't apply). The following formula represents a linehaul estimate for shipments that move off-hub, bypassing any intermediate terminals:

FORMULA 6

$$D_{LH\_STL} = 7.86 + 1.16 \times GCD$$

TL and STL share the same linehaul formula, which we simply call "DLH" in Table 3.

To understand the relationship between off-hub (STL, TL) and on-hub (LTL) linehaul distances, we can rearrange the linehaul distance formulas:

FORMULA 7

$$D_{LH\_LTL} = 1.04 \times D_{LH\_STL} + 32.31$$

Formula 7 illustrates that we found a 4% plus 32.31-mile increase in LTL linehaul miles over STL or TL. It should be noted that Flock Freight uses a mapping software to attain DLH and attaches a 4% increase in linehaul mileage plus 32.31 miles to LTL shipments when comparing emissions to STL shipments.

Pickup and delivery segment miles

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The formula accounts for the LTL hub-and-spoke network in addition to the road network. For the pick and delivery distances, the 2021 SmartWay research provides estimates per region. Here, the average across regions is used and doubled (DPD = 7.8 miles / segment x 2 segments = 15.6 miles) to account for both pick and delivery.

2021 SmartWay research LTL regional pickup and delivery segment averages:

Northeast	North Middle	Northwest	Southeast	South Middle	Southwest	Average
6.49	9.24	9.55	6.75	7.86	6.9	**7.8**

TABLE 4

Terminal emissions factor in CO_2 equivalents per pound mile

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Several national LTL and TL carriers have adopted the Sustainability Accounting Standards Board (SASB) framework. In the SASB framework, emissions are broken down into three categories:

Scope 1
Direct emissions from operations (e.g. vehicle emissions)

Scope 2
Indirect emissions from purchased electricity (e.g. facility operations)

Scope 3
Other indirect emissions (e.g. downstream transportation and distribution, waste generation)

Scope 1 is the primary source of emissions for all asset-backed carriers, while Scope 3 is the primary source of emissions for all third-party logistics (3PL) providers. TL carriers with limited facilities generally don't report on Scope 2 emissions. (These emissions are immaterial.) LTL carriers, however, do report on Scope 2 emissions associated with terminal operations. In addition to these emission breakdowns, revenue ton-miles are also reported as part of the SASB framework.

To quantify the additional emissions associated with a terminal network at the load level, Scope 2 emissions can be divided by the revenue ton-miles. This was done for multiple LTL carriers that publish annual sustainability reports; the range was found to be 3.35E - 06 to 5.35E - 06 CO_2e / lb-mile. We use 4.35E - 06 CO_2e / lb-mile in this analysis.

Miles per gallon

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TL factors assume truckload utilization at a total payload weight that's equivalent to the individual load weight. The fuel efficiency is a function of this weight. TL provides direct point-to-point transit without a terminal network.

STL factors depend on the mode it's being compared to. The standard WTotal that Flock Freight uses to calculate carbon emissions is 35,250 lbs (detailed in the third section). For a consistent comparison between shared truckload and another mode, we modify this assumption. We use 25,500 lbs for LTL comparisons. We use 45,000 lbs for TL comparisons. The MPG is adjusted accordingly. Similar to TL, STL provides direct point-to-point transit without a terminal network, and pick and delivery miles are contained within the linehaul.

Removal of deadhead miles

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Notably removed from Formula 4 that's included in the 2021 SmartWay research is the factor for empty miles. Empty miles can arise from geographic supply and demand imbalances as well as freight-matching inefficiencies. Data comparing empty miles across modes in a clear, consistent way isn't sufficient enough to include in this study. A common industry objective is to minimize empty miles due to freight-matching inefficiencies. STL has the potential to magnify these gains as well as address underutilized capacity. Without sufficient data here, however, no gains are assumed for STL over LTL or TL.

Comparing STL to LTL

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We start with the linehaul distance formulas that can be rearranged to show the relationship between off-hub (STL, TL) and on-hub (LTL) linehaul distances in Table 3.

We then have to make assumptions about the number of loads and weight. For both modes, we assume three constituent shipments with a combined weight of 25,500 lbs (W_{Total}), which yields a fuel efficiency of 6.683 MPG. We assume the shipments are concentrated within the same origin city and headed to the same origin destination. For STL, the pick and delivery segment is contained within the linehaul (D_{Total_STL} = DLH_STL), which yields an additional 46.8 mile savings compared to LTL, assuming the average pick and delivery across regions.

Built into the LTL linehaul formula, it can be shown that:

FORMULA 8

$$D_{Total\_LTL} = D_{LH\_LTL} + {}_{DPD\_LTL} = 1.04 \times D_{Total\_STL} + 79.11$$

As illustrated in the rearranged formula for LTL distance as a function of STL distance, LTL adds 4% plus 79 miles to the STL distance when considering pickup and drop-off miles.
We can now look at the savings as a function of distance and observe typical savings in the 8-17% range. The savings on mileage directly translates to gallons of gas saved and emissions saved because we assume the same total payload weight.

Based on a theoretical analysis comparing less than truckload and shared truckload, Flock Freight estimates STL can lower emissions by around 15% compared to LTL.

Comparing STL to LTL

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STL mileage savings over LTL, considering three loads with a combined weight of 25,500 lbs:

STL (Miles)	LTL (Miles)	STL miles saved	STL miles saved (%)
500	599	99	17%
1,000	1,119	119	11%
1,500	1,639	139	8%

TABLE 5

We now need to add in the impact of the LTL terminal network emissions. When comparing total emissions for all three loads with a combined weight of 25,500 lbs, $W_{Load} = W_{Total}$ and Formula 4 simplifies to:

FORMULA 9

$$E_{Total} = (D_{LH} + D_{PD}) \times [\ (1/MPG) \times F_{Fuel} + W_{Load} \times F_{Terminals}\ ]$$

We can separate the total emissions into the components for fuel and the terminal network:

FORMULA 10

$$E_{Total\_Fuel} = (\ D_{LH} + D_{PD}\ ) \times (\ 1/MPG\ ) \times F_{Fuel}$$

FORMULA 11

$$E_{Total\_Terminals} = (\ D_{LH} + D_{PD}\ ) \times W_{Load} \times F_{Terminals}$$

Comparing STL to LTL

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We can again look at the emission savings as a function of distance and observe typical savings in the 11-19% range. The impact of the additional LTL pick and delivery miles has a bigger influence on STL savings as length of haul decreases.

If we were to increase the number of loads, additional savings would be recognized.

STL emission savings over LTL, considering three loads with a combined weight of 25,500 lbs:

Miles		Fuel emissions (lbs of CO_2e)		LTL terminal network emissions		Total emissions (lbs of CO_2e)		STL savings	
STL	**LTL**	**STL**	**LTL**	**STL**	**LTL**	**STL**	**LTL**	**lbs of CO_2e**	**%**
500	599	1,683	2,017	0	66	1,683	2,084	400	19%
1,000	1,119	3,367	3,768	0	124	3,367	3,892	525	13%
1,500	1,639	5,050	5,518	0	182	5,050	5,700	650	11%

TABLE 6

To further this analysis, Flock Freight applied these formulas across the same set of 1,000 lanes used to determine linehaul distance as a function of great circle distance for STL. We again assumed three loads with a combined weight of 25,500 lbs. The pick and delivery distance for LTL was based on the actual regions (not the average), and we found both the median and average mileage savings to be around 11% and overall emission savings of about 14% for STL compared to LTL.

We removed the $CH_4 + N_2O$ term for the fourth, fifth and sixth sections of this guide, although we do use it in all Flock Freight emission calculations. $CH_4 + N_2O$ is a function of total distance and often has less than a 1% impact on emission savings when comparing STL with LTL or TL. It's not shown in the fourth, fifth and sixth sections as a simplifying solution.

Comparing STL to TL

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For STL and TL, we use the same linehaul distance. The actual mileage is not a driving assumption, so we use 1,000 miles for illustration. We assume the shipments are concentrated within the same origin city and headed to the same origin destination.

Next, we make assumptions about the number of loads and weight. For both modes, we assume two constituent shipments each at 22,500 lbs and with a combined weight of 45,000 lbs (W_{Total}).

For TL, both loads move separately on two different trucks. Each truck has a payload of 22,500 lbs, which yields a fuel efficiency of 6.83 MPG. Each truck must cover the route distance of 1,000 miles, which sums to 2,000 total miles.

For STL, both loads move on a single truck. This truck has a total payload of 45,000 lbs, which yields a fuel efficiency of 5.56 MPG. The single truck must cover the route distance of 1,000 miles.

There are two counteracting inputs here. An individual TL truck has better fuel efficiency than STL since the payload is reduced. TL, however, must cover double the route mileage compared to STL since two truckloads are used.

We can now look at the emission buildup and observe a savings of nearly 40%. Here, gallons saved translates directly to emissions saved.

Based on a theoretical analysis comparing truckload and shared truckload, Flock Freight estimates STL can lower emissions by around 40% compared to TL.

Comparing STL to TL

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STL savings over TL, considering two truckloads with a combined weight of 45,000 lbs (Table 7):

	TL	STL
Miles	1,000	1,000
Loads	2	2
Payload / weight	22,500	22,500
Trucks	2	1
Miles / truck	1,000	1,000
Payload weight / truck	22,500	45,000
Equipment weight / truck	34,000	34,000
Total weight / truck	56,500	79,000
MPG	6.83	5.56
Miles total	2,000	1,000
Gallons total	293	180

TABLE 7

Gallons saved

Gallons saved (%)

Comparing STL to TL

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We see that the impact of combining two truckloads into one STL outweighs the fuel efficiency loss. Below, we illustrate several combinations of payload weights and a route of 1,000 miles. STL savings over TL, considering two loads with a combined weight of 45,000 lbs:

Load 1 (lbs)	**Load 2** (lbs)	**Total payload** (lbs)	**2 trucks (TL)** (gallons)	**1 truck (STL)** (gallons)	**STL gallons saved**	**STL gallons saved** (%)
22,500	22,500	45,000	293	180	113	**39%**
25,000	20,000	45,000	293	180	113	**39%**
30,000	15,000	45,000	295	180	115	**39%**
35,000	10,000	45,000	298	180	118	**40%**

TABLE 8

If we were to increase the number of loads (maintaining a fixed total payload of 45,000 lbs), additional savings would be recognized.

Enhancing supply chain sustainability

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Flock Freight determined it was time to update our emissions calculations and enhance our transparency using the most credible information available.

We know shippers, 3PLs and carriers alike must rectify the lack of environmental transparency within supply chains to drive meaningful change.

The future of our planet depends on our ability — as corporations and individuals — to come together and prevent climate change. Sharing our environmental impact and creating strategic processes that decrease our emissions are excellent starting points.

Contact Flock Freight's sustainability strategist, Lauren D'Orazio with any questions regarding our emission calculations.

References

EPA SmartWay LTL Carbon Calculator Technical Documentation (Version 1.0)
The EPA's SmartWay program helps companies improve supply chain sustainability by measuring and benchmarking freight transportation efficiency. This document provides information on the calculation methods, data sources and assumptions used in the SmartWay Less-Than-Truckload Carbon Calculator. The calculator estimates the CO2 emissions associated with specific LTL shipments, helping companies incorporate sustainability into their network and routing plans.

EPA Emission Factors for Greenhouse Gas Inventories
This EPA document provides a regularly updated set of default emission factors for greenhouse gas reporting. The most recent version (April 2021) includes updates to emission factors for upstream and downstream transportation, business travel, product transport, employee commuting, waste and purchased electricity.

GHG Protocol Technical Guidance for Calculating Scope 3 Emissions (version 1.0)
Greenhouse Gas Protocol establishes comprehensive global standardized frameworks for measuring greenhouse gas emissions. This document offers practical guidance for companies calculating their Scope 3 emissions and details an internationally accepted method of measuring the greenhouse gas emissions of corporate value chains.

Oak Ridge National Laboratory study: Effect of Weight and Roadway Grade on the Fuel Economy of Class-8 Freight Trucks
The Oak Ridge National Laboratory provides scientific and technical breakthroughs that create energy and national security solutions. Their fuel economy study analyzes the effects that vehicle speed and weight have on the fuel efficiency of Class 8 trucks on flat and mild uphill terrains.

SASB Road Transportation Research Brief
SASB is a nonprofit organization that develops sustainability accounting standards to guide the disclosure of financially material information by companies to their investors. The firm's Road Transportation Research Brief can be used to understand the data underlying SASB standards and highlights relevant legislative and regulatory trends, sustainability risks and opportunities, and evidence for material sustainability issues.

Get moving

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Flock Freight is a technology company that's creating a smarter, more sustainable supply chain. Our patented technology finds and fills trucks' empty spaces so shippers can save money, carriers can earn more money, and goods move terminal-free with more accuracy and fewer emissions.

Disclaimer: The emissions calculation methodology and claims in this white paper have not been validated by an independent third party. Flock has chosen to make the methodology free and publicly available in the spirit of transparency and collaboration.