2021 SmartWay LTL Carbon Calculator:

Technical Documentation

Version 1.0

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Transportation and Climate Division
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1.0 Overview

This document provides background information on the calculation methods, data sources and assumptions used in the SmartWay Less-Than-Truckload (LTL) Carbon Calculator, available to all SmartWay partners through the SmartWay Partner Portal. The SmartWay LTL Carbon Calculator allows truck carriers, logistics companies and shippers to estimate the CO_2 emissions attributable to specific LTL shipments. The SmartWay LTL Carbon Calculator provides a standardized approach, requiring only zip codes for one or more origin and destination pairs and shipment weight(s) to estimate carbon mass emissions, in pounds and kilograms. The methodology supporting the SmartWay LTL Carbon Calculator has been validated by EPA.

Using the new SmartWay LTL Carbon Calculator, SmartWay partners active in the LTL freight market can now complement their company's annual SmartWay fleet inventories with information on the carbon emissions generated by their LTL shipments. For LTL truck carriers, the SmartWay LTL Carbon Calculator can be used to help factor sustainability into plans to improve routing and network performance. Logistics companies can also use the SmartWay LTL Carbon Calculator to better serve their environmentally conscious shippers. Shippers may find the new calculator useful to share shipment-level emissions data with their customers.

2.0 Background

The SmartWay LTL Carbon Calculator is based on a model developed by Veloso and Woolard at the Massachusetts Institute of Technology's (MIT) Center for Transportation and Logistics in 2014.[1] This work was sponsored by C.H. Robinson. Their model estimates CO_2 emissions associated with LTL shipments and is representative of the unique hub-and-spoke operations of a typical LTL freight network.

To assist EPA in validating the Veloso and Woolard model, three SmartWay partners (see acknowledgements) provided detailed data on their LTL networks. This data included day-to-day operational data on millions of individual shipments (i.e., origin, destination, and shipment weight), as well as information on fuel consumption. The shipment data and associated fuel use covered activity on their networks during quarters one and three of 2016. The SmartWay partners that supported EPA's validation work track many data points independently, providing a rich data set that is representative of the overall LTL industry. EPA supplemented this data with other sources that are publicly available from government and industry.

The datasets provided by the partners were used by EPA to construct models based on Veloso and Woolard's approach. EPA's goal in developing the SmartWay LTL Carbon Calculator was to make it as accurate as possible, while still having simple and practical inputs from a user's perspective. Based on the data from its collaborating partners, EPA updated and refined certain parameters for its models regarding the distances allocated to the long haul and pick-up/delivery (P/D) segments of LTL shipments. Other refinements included adding factors to the model to account for lane-specific payloads, seasonal MPG variation, and volumetric shipment characteristics such as those available through the National Motor Freight Classification system. While some factors improved the model, none improved the model enough to warrant the additional inputs from shippers these factors would require.

EPA also developed a methodology for accounting for rail usage in line-haul shipment movements. For the individual carriers, this greatly improved the model and should be used, where possible, in accounting for emissions from LTL shipments. However, accounting for rail requires very detailed data and network information from carriers and is not practical in a general model.

Finally, EPA developed a version of the model that accounts for generic uncertainty in carbon emissions. This uncertainty can come from many factors such as individual driver behavior, individual truck characteristics, weather, traffic conditions, and time of day. As is the case with the rail improvements, applying and understanding this uncertainty correctly requires detailed, carrier-specific data and is not practical for the general model.

Overall, EPA's SmartWay LTL Carbon Calculator is similar to the model published by Veloso and Woolard, with updated values and slight methodology improvements.

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[1] https://ctl.mit.edu/sites/ctl.mit.edu/files/library/public/2014fullthesis-AguiarWoolard.pdf

3.0 Methodology and Data Sources

The SmartWay LTL Carbon Calculator applies the basic methodology used in the MIT model and the updated parameters developed by EPA through its analysis. Only readily available data inputs - shipment weight, origin and destination zip codes - are needed to run the calculator, making it accessible and simple to obtain CO_2 emissions estimates for LTL shipments. Estimates can be obtained for one or many LTL shipments.

The CO_2 emission calculation used in the SmartWay LTL Carbon Calculator is presented in Equation 1.[2]

Equation 1.

$$E = \left[\frac{(1 + 0.0555) * D_{LH}}{6.683} * \frac{w}{25,500} + \frac{D_{PD}}{6.683} \right] * 22.44$$

Where:

E =	CO_2 mass emissions (pounds)
0.0555 =	average network empty mile fraction (unitless)
D_{LH} =	distance traveled during line haul segment (miles)
6.683 =	average fuel efficiency for line haul segment (miles/gallon)[3]
w =	shipment weight (pounds)
25,500 =	mean line haul payload (pounds)[3]
D_{PD} =	distance traveled with shipment during pick-up/delivery segment (miles)
6.683 =	fuel efficiency for pick-up/delivery segment (miles/gallon)[3]
22.44 =	conversion from diesel fuel consumption to CO_2 emissions (lbs. CO_2/gallon diesel)

As shown in Equation 1, the SmartWay LTL Carbon Calculator adds precision by differentiating how emissions are estimated for line haul versus pick-up/delivery segments. D_{LH} represents the full distance of the line haul portion of the shipment, while D_{PD} represents only the portion of the total mileage driven during pick-up/delivery with the shipment onboard. This is because pick-up and delivery fuel usage are allocated evenly on a per-shipment basis independent of size or weight, while line haul fuel usage is allocated strictly by shipment weight. As a result, the line haul term includes shipment weight and truck payload, but the pick-up/delivery term does not include mass.

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[2] The SmartWay LTL Carbon Calculator also displays CO_2 emissions in kilograms (2.2046 lbs/kg).
[3] Average MPG and average payload values based on SmartWay partner and publicly available LTL data.

The average pick-up/delivery distances used in the SmartWay LTL Carbon Calculator vary by region of the country, as shown in Table 1 below. These estimates are based on the average pick-up/delivery distance per shipment for all terminals operated by one of the SmartWay study collaborators.

Table 1. Regional Pick-up/Delivery Segment Average Distances (miles)

North East	North Middle	North West	South East	South Middle	South West
6.49	9.24	9.55	6.75	7.86	6.90

A regression analysis was conducted using data from one of the SmartWay study collaborators to predict line haul distance as a function of great circle distance (GCD).[4] Equation 2 presents resulting relationship between line haul distance (D_{LH}) and GCD.

Equation 2.

$$D_{LH} = 40.51 + 1.21 \, x \, GCD$$

The SmartWay LTL Carbon Calculator calculates the GCD between origin and destination points by first determining approximate latitude and longitude values for each zip code in the lower 48 U.S. states.[5] The SmartWay LTL Carbon Calculator then uses the latitude/longitude pairs to calculate the GCD, as shown in Equation 3.

Equation 3.

$$GCD = 2 * 3{,}963 * \arcsin\left(\sqrt{\sin^2\left(\frac{LAT_o - LAT_d}{2}\right) + \cos(LAT_o)\cos(LAT_d)\sin^2\left(\frac{LON_o - LON_d}{2}\right)}\right)$$

Where:

GCD = Great Circle Distance (miles)

LAT_o = Origin latitude (radians)

LAT_d = Destination latitude (radians)

LON_d = Origin longitude (radians)

LON_o = Destination longitude (radians)

$3{,}963$ = Earth radius (miles)

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[4] GCD is the direct distance between two points on a sphere. Accordingly, the GCD represents the absolute minimum roadway distance between any O/D pair.
[5] See https://public.opendatasoft.com/explore/dataset/us-zip-code-latitude-and-longitude/export/.

4.0 Limitations and Uncertainties

The SmartWay LTL Carbon Calculator provides a straightforward, independently validated method of estimating carbon emissions for LTL shipments using readily available information. However, users should be aware of certain limitations of the calculator including the following:

- Restricted to truck transport (no rail segments included)
- Only covers diesel freight trucks (no gasoline or alternative fuels)
- Zip codes restricted to the lower 48 states

While the SmartWay LTL Carbon Calculator relies upon extensive LTL carrier and logistics company data, EPA recognizes the need for more information, especially from smaller, regional LTL carriers. The calculator methodology also includes inherent uncertainties, such as:

- Line haul distance for a particular shipment can vary substantially depending on (among other factors)
  - Zip code latitude/longitude assignment (of particular concern for large counties)
  - Deviations from standard routes (e.g. road closures, etc.)
- Pick-up/delivery segment distances will vary by company network. Emission estimates are disproportionately impacted by these distances. According to the Veloso and Woolard analyses, P/D segments account for approximately 2 percent of total network miles but can contribute up to an average of 30 percent of total carbon emissions.
- Average line haul payloads may vary substantially from carrier to carrier.
- Average fuel efficiency estimates may also vary substantially for a variety of reasons, including:
  - Truck class mix
  - Truck engine age distribution
  - Presence of aerodynamic retrofits and/or idle reduction devices
  - Driver behavior
  - Traffic and weather variability, road conditions, etc.
  - Fuel specification differences and/or use of biodiesel
  - Loading efficiency

EPA may update the SmartWay LTL Carbon Calculator parameters in the future as the LTL market evolves and new data becomes available (e.g., to account for fleet average efficiency improvements).

5.0 Acknowledgments

The SmartWay Transport Partnership would like to acknowledge our partner companies, C.H. Robinson, Estes Express Lines, and Yellow, for providing detailed data on their LTL networks and sharing their expertise with EPA on the LTL market. Their knowledge and support were indispensable and made it possible for EPA to develop and offer the SmartWay LTL Carbon Calculator.

For more information:

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