# 2019 SmartWay Shipper Company Partner Tool:

# Technical Documentation

## U.S. Version 2.0.18 (Data Year 2018)

# 2019 SmartWay
# Shipper Company Partner Tool:

# Technical Documentation

## U.S. Version 2.0.18
## (Data Year 2018)

**Transportation and Climate Division**
**Office of Transportation and Air Quality**
**U.S. Environmental Protection Agency**

EPA-420-B-19-052
October 2019

# Table of Contents

# List of Tables

# Overview

The SmartWay Shipper Tool is intended to help shippers estimate and assess their carbon, PM, and $NO_x$ emissions associated with goods movement in the U.S. freight trucking, rail, air and barge sectors[1]. Shippers can track their freight-related emissions performance from year-to-year using the Tool and assess a range of strategies to improve the emissions performance of their freight operations, including selection of low-emissions carriers and implementation of operational strategies such as (but not limited to) packaging improvements, load optimization and logistical improvements.

The SmartWay truck, barge, air, logistics and multimodal carrier emissions performance data that EPA has included in the Tool, along with industry average Class I rail $CO_2$ data, will allow shippers to generate accurate emissions inventories. The data will also help shippers optimize their emissions performance by allowing them to better estimate the emissions impact of individual carriers, modal shifts, and operational strategies.

---

[1] Future versions of the tool will help Shippers evaluate the emissions performance associated with ocean going vessels.

# 1.0 Tool Inputs and Calculations

After shippers enter their company and contact information, they provide basic information about each company they operate, including the name and NAICS code for each of these companies. For these individual companies to show up on the SmartWay Partner list on the EPA website, shippers should submit separate Shipper Tools, one for each company.

For each company, shippers need to indicate their participation level. If they have annual mileage-related activity data by carrier (miles or ton-miles), they should select Way 3 or Way 4, and proceed to input activity data for each carrier. Otherwise, they must select the Way 2 option, which only requires them to report the portion of goods they move with SmartWay carrier partners based on money spent, weight shipped, packages shipped, or another custom metric.

If shippers select the Way 2 option, they will not be eligible for a SmartWay Excellence Award, nor will they be able to calculate an emissions inventory or develop emissions performance metrics (e.g. g/mile or g/ton-mile) for their freight operations.[2]  All shippers – regardless of participation level – will be able to see the SmartWay Category-level emissions performance data for their truck, logistics and multimodal carriers as well as available industry average rail emissions factors. Emissions performance data for barge and air carriers are reported on a carrier-specific basis.

After identifying and selecting all of their SmartWay and non-SmartWay carriers, Way 4 shippers can then identify each carrier that they use for each company and the service that the carrier provides (e.g., Inbound or Outbound hauls, International and/or Domestic service, etc.). These optional parameters serve as "tags" which allows shippers to filter their emission data as desired using the screen tools discussed below.

## EMISSION INVENTORY AND PERFORMANCE METRIC CALCULATIONS

If shippers choose the Way 3 or 4 option, the Tool will calculate their total mass emissions (i.e., an emissions inventory) based on the mileage-related activity data entered for each carrier, as well as various emission performance metrics (e.g., grams/mile and grams/ton-mile – see below).

Carrier-specific emissions are first calculated either on a ton-mile basis (as ton miles x grams per ton-mile), or on a miles basis (miles x grams per mile), depending on the category as shown in Table 1.[3] Any modes/categories not listed have a limited data availability and their emissions are calculated using ton-miles.

---

[2] Shipper partners are encouraged to select the Way 3 or 4 reporting option for all their companies whenever possible. When a shipper has multiple companies the participation level chosen for the % SmartWay Value calculation must be the same for all companies in order for the Tool to calculate a Partner level % SmartWay Value.

[3] Note that the Tool doesn't need shippers to enter a payload or ton-mile estimate for SmartWay Categories whose emissions are based on Miles, as the payload estimate will not affect the overall emissions footprint. However, the calculated emission factors and average payload estimate are affected by the assigned payload.

## Table 1. Emissions Calculation Basis by SmartWay Category

| SmartWay Category | Activity Basis | $D_{tm}$ | $D_m$ |
|---|---|---|---|
| Refrigerated | Ton-miles | 1 | 0 |
| Mixed | Ton-miles | 1 | 0 |
| TL/Dry Van | Ton-miles | 1 | 0 |
| Flatbed | Miles | 0 | 1 |
| Moving | Miles | 0 | 1 |
| Dray | Miles | 0 | 1 |
| Non-SW Truck General | Ton-Miles | 1 | 0 |
| Specialized | Miles | 0 | 1 |
| Expedited | Miles | 0 | 1 |
| Auto | Miles | 0 | 1 |
| Tanker | Miles | 0 | 1 |
| Heavy/Bulk | Miles | 0 | 1 |

The Shipper partner's mass emissions are calculated by summing the individual carrier emissions. Then, fleet average emission factors are calculated by dividing mass emissions by total ton-miles and total miles to obtain grams per ton-mile and grams per mile, respectively. The fleet average payload is calculated by dividing total ton-miles by total miles.

Overall, carrier emissions are calculated using the following equations, where $D_{tm}$ and $D_m$ are dummy variables with values of either 0 or 1, as shown in Table 1 above.

$$E_c = D_{tm} * TonMiles * gtm + D_m * Miles * gm$$

Total emissions:

$$E_{tot} = \sum_c E_c$$

Emission factors and average payload (APL):

$$gtm = \frac{E_{tot}}{\sum_c TonMiles_c}$$

$$gm = \frac{E_{tot}}{\sum_c Miles_c}$$

$$APL = \frac{\sum_c TonMiles_c}{\sum_c Miles_c}$$

The emissions inventory for each carrier/mode combination displayed on the Emissions Summary, Carrier Performance and SmartWay Category Details screens is calculated using the equations show above. To

calculate composite emissions and associated performance metrics on the Carrier Performance screens (i.e., overall g/mile and g/ton-mile performance), the Tool weights simply sums the emissions, miles and ton-miles for the associated group ((e.g. all Inbound carriers) and divides the total emissions by total miles and ton-miles as appropriate.

## TON-MILE CALCULATION

Correctly calculating Ton-Miles is critically important for the accurate determination of your carbon footprint. You can calculate your company's ton-miles as follows.

Determine the ton-miles hauled per year attributable to each carrier. A ton-mile is one ton moving one mile. DO NOT ESTIMATE TON-MILES BY SIMPLY MULTIPLYING TOTAL MILES BY TOTAL TONS - this calculation effectively assumes your entire tonnage is transported on EACH AND EVERY shipment, and will clearly overstate your ton-miles.

Many companies track their ton-miles and can report them directly without further calculation. For example, shipper company systems are often set up to associate a payload with the mileage traveled on each trip by carrier, and are then summed at the end of the year. If such information is not available, there are two ways to calculate ton-miles:

1. Companies can determine their average payload per carrier, multiply the average payload by the total miles per carrier, and sum the results for all carriers for the reporting year; or

2. Set Ton-miles per carrier = $\dfrac{\text{(total miles per carrier x total tons per carrier)}}{\text{total \# of trips per carrier}}$

**NOTE:** In both ton-mile calculations, empty miles are not factored in while the fuel used to drive those empty miles is factored in.

To check your estimate, divide ton-miles by miles. The result is your fleet-average payload. If this number is not reasonable, (e.g., typically between 15 and 25 tons for Class 8b trucks), please check your calculations.

## CARRIER EMISSIONS PERFORMANCE DATA

The current SmartWay program provides $CO_2$, $NO_x$ and PM gram per mile, and gram per ton-mile emission factors for truck, rail, multimodal, logistics, air and barge freight transport providers. These data are provided in the SmartWayCarrierData2018ST.xls file, which is downloaded to the user's computer using the button on the Tool's Home screen.

It is envisioned that SmartWay will incorporate emission factors from ocean-going vessel transport providers in the future.

## TRUCK CARRIER PERFORMANCE

Truck carrier performance data utilized by the current Shipper Tool is based on 2019 Truck Partner Tool submittals for activity in 2018. Performance data includes g/mile and g/ton-mile for each truck carrier. Note that g/mile and g/ton-mile values represent midpoints for the appropriate SmartWay Category, rather than exact performance levels for a given carrier. Truck SmartWay Categories include:

- TL Dry Van
- LTL Dry Van
- Refrigerated
- Flatbed
- Tanker
- Dray
- Package

- Auto Carrier
- Expedited
- Heavy/Bulk
- Moving
- Specialized
- Mixed

Your fleet will be placed into a SmartWay Category and ranked with other SmartWay partner's fleet in that same category based on the following rules:

1. If 75% or more of fleet's Operation is Drayage your fleet will be categorized as a Drayage fleet, regardless of what you specify for fleet's Body Type.

Otherwise

1. If 75% or more of your fleet's Body Type is Moving, Heavy/Bulk, Refrigerated, Tanker, Auto Carrier, or Flatbed then your fleet will be categorized as that matching body type.

2. If the sum of your fleet's Utility Body Type and Special Hauler Body Type is 75% or more, then your fleet will be categorized as Specialized/Utility.

3. If 75% or more of your fleet's Body Type is Dry Van or Chassis then:

   a. If 75% or more of your fleet's Operation is Truckload then your fleet will be categorized as TL/Dry Van.

   b. If 75% or more of your fleet's Operation is Less than Truckload then your fleet will be categorized as LTL/Dry Van.

   c. If 75% or more of your fleet's Operation is Package then your fleet will be categorized as Package.

   d. If 75% or more of your fleet's Operation is Expedited then your fleet will be categorized as Expedited.

   e. If none of the above (a through d) are true, then your fleet will be categorized as Mixed.

4. Otherwise if none of the above conditions exist your fleet will be categorized as a Mixed fleet.

The following provides an overview of the process used to estimate the carrier-specific performance ranges.

## Truck Performance Categories

In the 2019 SmartWay Truck Tool, data is collected at the individual company fleet level. Fleets are characterized by a) business type: for-hire or private, b) operational type: truckload/expedited, less than truckload, dray, expedited, or package delivery, and c) equipment type: dry van, refrigerated van, flatbed, tanker, chassis (container), heavy/bulk, auto carrier, moving, or specialized (e.g., hopper, livestock, others.)

The possible categories are shown below.

| For-Hire | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Dry Van | Reefer | Flatbed | Tanker | Chassis | Heavy/Bulk | Auto Carrier | Moving | Specialized |
| TL | | | | | | | | | |
| LTL | | | | | | | | | |
| Dray | | | | | | | | | |
| Expedited | | | | | | | | | |
| Package | | | | | | | | | |
| Private | | | | | | | | | |
| | Dry Van | Reefer | Flatbed | Tanker | Chassis | Heavy/Bulk | Auto Carrier | Moving | Specialized |
| TL | | | | | | | | | |
| LTL | | | | | | | | | |
| Dray | | | | | | | | | |
| Expedited | | | | | | | | | |
| Package | | | | | | | | | |

Note that while Specialized fleets have disparate operations/equipment types and thus do not compare well, they are also unlikely to compete with one another, so it was deemed acceptable to aggregate these disparate fleets into one category.

For-hire and private fleets are combined in the SmartWay Categories. There are relatively few private fleets compared to for-hire fleets. Because owners of private fleets generally hire their own fleets exclusively, it was determined that grouping for-hire and private fleets together would not be detrimental to for-hire fleets, and the simplicity of one for-hire and private category outweighed the benefits of listing fleets separately. Grouping for-hire and private separately would have doubled the number of SmartWay Categories. Therefore, fleets can thus be categorized as shown below.

| For-Hire and Private | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Dry Van** | **Reefer** | **Flatbed** | **Tanker** | **Chassis** | **Heavy/Bulk** | **Auto Carrier** | **Moving** | **Specialized** |
| **TL** | | | | | | | | | |
| **LTL** | | | | | | | | | |
| **Dray** | | | | | | | | | |
| **Expedited** | | | | | | | | | |
| **Package** | | | | | | | | | |

To be categorized in a particular category, a fleet must have at least 75% of its mileage in a single category, otherwise it is classified as a "Mixed" fleet. Fleets may be mixed via their operational or equipment type. Fleets are generally segregated by their operational type, but some mixing does occur via equipment type, especially with smaller carriers that do not differentiate their fleet. Fleets that do not have 75% of their operations in a specific SmartWay Category are placed in the Mixed category.

Individual fleets were then placed into SmartWay Categories. The following shows the relative number of fleets for the various category intersections, with darker shadings indicating more fleets.

| | **Dry Van** | **Reefer** | **Flatbed** | **Tanker** | **Chassis** | **Heavy/Bulk** | **Auto Carrier** | **Moving** | **Specialized** | **Mixed** |
|---|---|---|---|---|---|---|---|---|---|---|
| **TL** | | | | | | | | | | |
| **LTL** | | | | - | - | - | | | - | |
| **Dray** | | | - | - | | - | - | - | | |
| **Expedited** | | - | - | - | - | | - | - | - | |
| **Package** | | - | - | - | - | - | - | | | - |
| **Mixed** | | | | - | | - | | - | - | - |

SmartWay then considered combining categories with similar characteristics for simplification purposes. One prerequisite was that there needed to be a minimum number of fleets in each category. SmartWay determined that a category needed a minimum of 25 fleets to be created. It was also determined that dry van and chassis (i.e. intermodal container) groups functioned primarily as dry van transport, so these categories were combined. While most refrigerated carriers were truckload, a few less than truckload refrigerated fleets exist, so these categories were combined. Although no expedited or package refrigerated fleets were identified, these categories were also combined into one overall refrigerated category so that no operation and equipment type intersections would be left undefined. A similar situation was identified with flatbed, tanker, heavy/bulk, auto carrier, moving, and specialized fleets. All dray fleets were collapsed into one category. Any fleet that had mixed operation and/or mixed equipment was placed into a single mixed category. Finally, logistics and multimodal fleets were also included and retained as unique categories.

The final performance categories for 2018 are illustrated below. The solid colors indicate how operation and equipment type assignments vary by performance category. For example, if 75% or more of a fleet's mileage is associated with reefer trucks, the fleet is assigned to the Reefer category *regardless* of the operation

percentage across truckload, expedited, LTL, and package categories.  However, the Reefer category assignment is overridden if the operation category is greater than or equal to 75% dray, logistics, or multimodal. Similar assignment rules apply to flatbed, tanker, heavy/bulk, auto carrier, moving, and specialized equipment types, as described above. Only the Dry Van/Chassis equipment category is subdivided by the truckload, expedited, LTL, and package operation categories, meaning that the 75% threshold must be met for *both* equipment and operation type in these cases. All other equipment/operation type percentage distributions are assigned to the Mixed category.

## Figure 1. SmartWay Carrier Categories and Data Specificity – 2018 Data Year

| TRUCK | Dry Van & Chassis | Reefer | Flatbed | Tanker | Heavy & Bulk | Auto Carrier | Moving | Specialized & Utility | Mixed |
|---|---|---|---|---|---|---|---|---|---|
| Dray | Dray — 5 Performance Levels | | | | | | | | |
| Truckload | Truckload DryVan 5 Performance Levels | Reefer 5 Performance Levels | Flatbed 5 Performance Levels | Tanker 5 Performance Levels | Heavy & Bulk 5 Performance Levels | Auto Carrier 5 Performance Levels | Moving 5 Performance Levels | Specialized & Utility 5 Performance Levels | Mixed 5 Performance Levels |
| Expedited | Expedited 5 Performance Levels | | | | | | | | |
| LTL | LTL 5 Performance Levels | | | | | | | | |
| Package | Package Delivery 5 Performance Levels | | | | | | | | Less than 75% in any category |
| Mixed | Mixed | | | | | | | | |

| Rail | Single Modal Average for All Rail (No company differentiation allowed per Association of American Railroads) |
|---|---|

| Barge | Company Specific Data |
|---|---|

| Air | Company Specific Data |
|---|---|

| Logistics | 5 Performance Levels |
|---|---|

| Multimodal | Emission Factor Data Only (No 5 Performance Level Ranking) |
|---|---|

| Marine | To Be Determined |
|---|---|

It is possible that SmartWay will expand these categories in the future based on in-use experience or as a result of further data analysis, and/or requests from industry.

Fleets *within a SmartWay Category* have been ranked from lowest emission factor (best) to highest emission factor (worst) for each of the following metrics: $CO_2$ g/mile, $CO_2$ g/ton-mile, $NO_x$ g/mile, $NO_x$ g/ton-mile, $PM_{10}$ g/mile and $PM_{10}$ g/ton-mile. When SmartWay Categories are first established, fleets within a category are separated into 5 ranges such that an equal number of fleets were in each range. Each range thus

represents a group of emission factors. These ranges, and associated ranking "cutpoints" (transition points from one rank to the next) were then modified so that each range had an equal difference between upper and lower bounds, and the new cutpoints remained as close to the originals as possible. The new range cutpoints are displayed as numbers with significant digits appropriate to emission factors in that range. The midpoint of the range is used as the emission factor for all fleets in that range.

It would be simpler and more straightforward to use fleet-specific emission factors, however the trucking industry expressed concern that revealing exact data could be used to back-calculate mile per gallon numbers. The above described methodology prevents a determination of an exact mpg figure, while at the same time attributing an emission factor much more precisely than a modal default number. Given the large number of trucking fleets, and thus opportunity for fleets to be very close to each other in performance, SmartWay believes it is acceptable and appropriate to break truck fleets into 5 performance ranges for each SmartWay Category.

The table below illustrates the ranges in the For Hire/Private Truckload/Expedited Dry Van SmartWay Category, using 2013 Truck Partner data as an example.

## Table 2. Emission Factor Ranges for One Performance Category (2013 Data)

| For-Hire/Private Truckload/ Dry Van $CO_2$ g/mile | | | | | |
|---|---|---|---|---|---|
| Group ID | Fleets Per Bin | Grams Per Mile Min | Grams Per Mile Max | Grams Per Mile Avg | Grams Per Mile Midpoint | Grams Per Mile Std Dev |
| 1 | 186 | 944 | 1,549 | 1,452 | 1,500 | 118 |
| 2 | 227 | 1,551 | 1,650 | 1,601 | 1,600 | 28 |
| 3 | 194 | 1,651 | 1,749 | 1,692 | 1,700 | 29 |
| 4 | 140 | 1,751 | 1,848 | 1,798 | 1,800 | 29 |
| 5 | 115 | 1,851 | 5,090 | 2,010 | 1,900 | 359 |

Similar tables have been developed for all performance SmartWay Categories. The midpoint of each performance range is the data that a shipper downloads into their SmartWay Shipper Tool to represent the emission performance of a specific fleet that is in the associated range. Once the categories and ranges have been established, the fleets of any new companies joining SmartWay will fall into one of the predefined categories/ranges for that reporting year. SmartWay expects to update the category/range structure periodically.

Performance estimates for non-SmartWay truck carriers were calculated based on the lowest performing truck partners. Since no data exist to define non-SmartWay fleets, SmartWay believes the prudent approach is to assign conservative emission factors to non-SmartWay companies. Also, this policy makes it likely that any company joining SmartWay will see better emission factors displayed than the non-SmartWay default emission factors.

The non-SmartWay performance metrics were calculated by taking a standard performance range delta (max - min) for each range within each SmartWay Category and using the delta to calculate a non-SmartWay carrier midpoint for each category. This midpoint was the midpoint for Range 5 plus the standard range delta. For example, if the Range 5 midpoint was 10.5 and the category's standard delta was 1, then the non-SmartWay midpoint was calculated to be 11.5. Once the non-SmartWay midpoints for each pollutant were calculated for all SmartWay Categories, the non-SmartWay performance metric was calculated by using the average value of these mid-points, weighted by the number of fleets in each category. This approach does not require the shipper to identify the appropriate SmartWay Category for their non-SmartWay carrier(s), which they may not know, while still ensuring that the performance of their non-SmartWay carriers reflects the distribution of the different categories within the truck population.

As discussed in the Shipper Tool Quick Start Guide, depending upon the type of data available for a given carrier, the user may input ton-miles or miles, and rely on carrier data to back-calculate the other value. For example, providing ton-miles and average payload allows the Tool to estimate total miles, by dividing the former by the latter.

## LOGISTICS AND MULTIMODAL CARRIER PERFORMANCE

Logistic and multimodal carriers have their own performance bins based on the carrier tool submittals for the most recent available calendar year (2017 for logistics, and 2018 for multimodal). Multimodal carrier categories are also differentiated by mode combinations, including Surface;[4] Surface-Air; Surface-Marine; and Surface-Air-Marine.  Multimodal composite fleets with 10% or more of their ton-miles coming from air or marine carriers are designated Surface-Air/Marine.[5] If a composite fleet does not meet the above Multimodal criteria, and if it has 75% of its ton-miles derived from one or more Logistics component fleets, it is binned as a Logistics fleet. If a composite fleet does not meet any of these criteria, it is binned as a Truck fleet.

Non-SmartWay carrier performance for the SmartWay Categories is estimated in the same way as is done for non-SmartWay Truck carriers (i.e., averaging the bin midpoints to calculate a fleet average value).

## AIR AND BARGE CARRIER PERFORMANCE

Air and barge carriers have agreed to have their actual emissions results made public, and, barge performance values used in the Shipper Tool are carrier-specific. The gram per mile performance values for barge carriers correspond to individual barge (nautical) miles travelled, rather than miles travelled by a string of barges or the associated tug(s).

Non-SmartWay barge carrier gram per mile and gram per ton-mile performance is set to be 25% higher than the worst performing SmartWay barge carrier.

---

[4] Surface multimodal carriers utilize road and rail modes.

[5] Air and/or marine carriers may be utilized directly by the multimodal carrier, or may be utilized indirectly by logistics business units hired by the multimodal carrier.

Since no air carrier data submittals have been approved as of this date, performance levels for non-SmartWay air freight are based on publicly available data. First upper bound estimates for grams of $CO_2$ per ton-mile were obtained for short and long-haul air freight (~4,236 g/t-mi and ~1,461 g/t-mi, respectively).[6,7] Values for $CO_2$ g/mile were calculated by multiplying the g/t-mi value by an average cargo payload value of 22.9 short tons. The average payload value was estimated by dividing total air freight tonnage in 2012 (15M tons)[8] by the total number of cargo departures in the same year (654,956 LTOs).[9] Corresponding performance metrics for $NO_x$ and $PM_{10}$ were based on the ratio of these pollutants to $CO_2$ from the EDMS 5.1.4.1 model (0.009 for $NO_x$ and 0.000059 for $PM_{10}$).[10] The resulting performance metrics are shown in Table 3.

## Table 3. Assumed Performance Metrics for Non-SmartWay Air Carriers

|  | $CO_2$/tmi | $CO_2$/mi | $NO_x$/mi | $NO_x$/tmi | PM/mi | PM/tmi |
|---|---|---|---|---|---|---|
| **Short-haul** | 4,236 | 96,998 | 873.2713 | 38.1341 | 5.743247 | 0.250797 |
| **Long-haul** | 1,461 | 33,448 | 301.1280 | 13.1497 | 1.980430 | 0.086482 |

## RAIL CARRIER PERFORMANCE

Rail carrier performance data are collected and displayed in the Shipper Tool at the industry average level derived from Class 1 rail company data. Gram per ton-mile factors were determined by dividing total fuel use by total ton-miles and multiplied by a rail diesel $CO_2$ factor (10,180 g $CO_2$/gal diesel fuel), from publicly available data submitted in the 2017 railroad R-1 reports to the Department of Transportation. 2017 R-1 data was also used to obtain total railcar-miles per year for all Class 1 carriers, in order to estimate gram per railcar-mile factors. *Industry average values are currently assumed for all rail carriers in the carrier data file, regardless of SmartWay Partnership status.* Specific rail companies may have the opportunity to provide company-specific data in the future. The R-1 data and corresponding $CO_2$ performance data are presented in Table 4 below.

---

[6] Short haul air freight assumed to be less than 3,000 miles, covering most domestic air routes in the U.S.

[7] Estimates from Figure 8.6 in Sims R., R. Schaeffer, F. Creutzig, X. Cruz-Núñez, M. D'Agosto, D. Dimitriu, M. J. Figueroa Meza, L. Fulton, S. Kobayashi, O. Lah, A. McKinnon, P. Newman, M. Ouyang, J. J. Schauer, D. Sperling, and G. Tiwari, 2014: Transport. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[8] U.S. DOT Bureau of Transportaion Statistics, Fregiht Facts and Figures 2013. Accessed 8-28-19.: http://www.ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/13factsfigures/pdfs/fff2013_highres.pdf

[9] U.S. DOT, Bureau of Transportation Statistics, U.S. Air Carrier Traffic Statistics, Accessed 8-28-19.: https://www.transtats.bts.gov/TRAFFIC/

[10] EDMS outputs for take-off mode, assumed to be equal to cruising mode. (Cruise emissions are not output by EDMS). Take-off mode emission rates were averaged across all aircraft/engine combinations in the Heavy (Max Takeoff Weight over 255,000 lbs) and Large (Max Takeoff Weight 41,001 to 255,000 lbs.) weight classes.

## Table 4. Rail Carrier Performance Metric Calculation Inputs & Results (2017 R-1 Data)

| Rail Company | Gal/Yr ('000) Sch. 750 Line 4 | Freight Ton-Mi/Yr ('000) Sch. 755 line 110 | Railcar-Mi/Yr ('000) Sch. 755 sum of lines 30, 46, 64 & 82 | g $CO_2$/railcar-mile | g $CO_2$/short ton-mile |
|---|---|---|---|---|---|
| BNSF Railway | 1,353,897 | 665,948,516 | 11,606,520 | 1,187 | 20.70 |
| CSX Transportation | 426,721 | 208,127,221 | 4,713,411 | 922 | 20.87 |
| Grand Trunk | 116,986 | 62,708,628 | 1,486,205 | 801 | 18.99 |
| Kansas City Southern | 68,873 | 34,582,626 | 724,012 | 968 | 20.27 |
| Norfolk Southern* | 458,179 | 201,451,969 | 4,383,081 | 1,064 | 23.15 |
| Soo Line | 65,299 | 35,244,079 | 745,550 | 892 | 18.86 |
| Union Pacific | 1,016,161 | 466,721,215 | 10,090,926 | 1,025 | 22.16 |
| Total/Industry Average | 3,506,116 | 1,674,784,254 | 33,749,705 | 980 | 20.72 |

* and combined subsidiaries

$NO_x$ and PM emission factors for rail carriers are also based on industry averages. Please see the "Background on Illustrative (Modal Average) U.S. Truck and Rail Factors" in Appendix A for further details.

Average payloads per loaded railcar were calculated for all Class 1 carriers by dividing the value for annual ton-miles hauled by an estimate for loaded railcar-miles, based on 2008 R-1 data. The calculation uses the Total Revenue and Non-Revenue Ton-Miles as listed In the R-1 Report on line 114 of schedule 755 divided by the Total loaded Railcar-Miles (the sum of lines 30 and 64 of schedule 755) along with the factor for fuel gallons consumed for loaded freight that is created based on the percentage of loaded freight to total freight multiplied by the total diesel fuel value listed on schedule 750 Line 4. The following table summarizes the estimated average payload per railcar, by carrier.

## Table 5. Rail Carrier Average Payload

| Carrier | Avg Payload/Loaded Railcar (tons) |
|---|---|
| BNSF Railway | 108 |
| CSX Transportation | 85 |
| Grand Trunk | 80 |
| Kansas City Southern | 91 |
| Norfolk Southern | 76 |
| Soo Line | 77 |
| Union Pacific | 91 |
| Industry Average | 93 |

Average railcar volumes were calculated for all carriers by first estimating an average volume for each major railcar type listed in the R-1 forms (schedule 755, lines 15-81). The assumptions used to estimate these volumes are provided in Table 6. The railcar-miles reported for each railcar type were multiplied by these average volumes to estimate annual cubic foot-miles travelled by car type for each company and for the industry average. The distribution of cubic foot-miles across car types was used as the weighting factor to estimate a single average railcar volume for each company. These values and the resulting volume estimates are presented in Table 7.

## Table 6. Railcar Volume Assumptions and Sources

| Railcar Type | Cubic Feet | Source/Method<br>**Key:** Norfolk Southern Railroad (NS)[11], Union Pacific Railroad (UP)[12], Burlington Northern Santa Fe Railroad (BNSF)[13], CSX Transportation Railroad (CSX)[14], World Trade Press Guide to Railcars (GTRC)[15], Chicago Rail Car Leasing (CRCL)[16], Union Tank Car Company (UTCC)[17], U.S Department of Agriculture (USDA)[18] |
|---|---|---|
| Boxcar 50 ft and longer including equipped boxcars | 7,177 | Based on the average of the following boxcar types:<br>50ft assumed to be 5694 [reflecting the average of 5355 (NS), 5431 (UP), 5238 (CSX), 6175 (BSNF), 6269 (GTRC)].<br>60ft assumed to be 6,648 [reflecting the average of 6618 (NS), 6389 (UP), 6085 (CSX), 7500 (BNSF)].<br>50ft high cube assumed to be 6,304 [reflecting the average of 6339 (NS) and 6269 (CSX)].<br>60 ft. high cube assumed to be 6917 [reflecting the average of 7499 (NS) , 6646 (CSX), and 6607 (GTRC)].<br>86ft assumed to be 9999 (NS).<br>Auto parts assumed to be 7499 (NS). |
| Boxcar 40ft | 4,555 | Based on estimate of 50ft boxcar volume described above. Assumed 40ft length would result in 20% reduction in volume. |

---

[11] Norfolk Southern Shipping Tools/Equipment Guide/Merchandise Equipment. http://www.nscorp.com/content/nscorp/en/shipping-tools/equipment-guide/merchandise-equipment.html. Accessed 8-28-19.

[12] UP Rail Equipment Descriptions, UP Rail Equipment Descriptions. https://www.uprr.com/customers/equip-resources/cartypes/index.shtml. Accessed 8-28-19.

[13] BNSF Individual Railcar Equipment. http://www.bnsf.com/ship-with-bnsf/ways-of-shipping/individual-railcar.html#subtabs-3. Accessed 5-25-18.

[14] CSX Railroad Equipment. https://www.csx.com/index.cfm/customers/resources/equipment/railroad-equipment/. Accessed 8-28-19.

[15] World Trade Press, World Trade Resources Guide to Railcars 2010.

[16] Chicago Freight Car Leasing Company, Railcar Types. http://www.crdx.com/Services/Railcar. Accessed 8-28-19.

[17] UTLX Tank Car Designs and Descriptions. https://www.utlx.com/tank-car-overview/. Accessed 8-28-19.

[18] U.S. Department of Agriculture (USDA), 1992, *Weights, Measures, and Conversion Factors for Agricultural Commodities and Their Products*, Agricultural Handbook Number 697, Economic Research Service, Washington, DC. Available at: https://www.ers.usda.gov/webdocs/publications/41880/33132_ah697_002.pdf?v=42487. Accessed 8-28-19.

# Table 6. Railcar Volume Assumptions and Sources

| Railcar Type | Cubic Feet | Source/Method<br>*Key:* **Norfolk Southern Railroad (NS)**[11]**, Union Pacific Railroad (UP)**[12]**, Burlington Northern Santa Fe Railroad (BNSF)**[13]**, CSX Transportation Railroad (CSX)**[14]**, World Trade Press Guide to Railcars (GTRC)**[15]**, Chicago Rail Car Leasing (CRCL)**[16]**, Union Tank Car Company (UTCC)**[17]**, U.S Department of Agriculture (USDA)**[18] |
|---|---|---|
| **Flat car – all types except for multi-level** | 6,395 | Based on the average of the following flat car types:<br>60ft assumed to be 6739 (BNSF).<br>89ft assumed to be 9372(BNSF).<br>Coil assumed to be 3387(NS).<br>Covered coil assumed to be 5294 [reflecting the average of 8328 (NS) and 2260 (BNSF)].<br>Center beam assumed to be 6546 [reflecting the average of 5857 (UP) and 7236 (BNSF)].<br>Bulkhead assumed to be 7030 (BNSF). |
| **Multi-level flat car** | 13,625 | Based on the average of the following multi-level flat car types:<br>Unilevel (that carry very large cargo, such as vehicles/tractors) assumed to be 12183 (NS).<br>Bi-level assumed to be 14381(NS).<br>Tri-level assumed to be 14313 (based on average of 15287 (NS) and 13339 (BNSF). |
| **Flat Car – all types- including multi-level** *[not used in analysis, except for estimating volume of "All Other Cars"]* | 7,428 | Based on the average volumes of the flatcar types described above including multi-level as a single flat car type. |
| **Gondola – all types Including equipped** | 5,190 | Based on the average of the following gondola car types:<br>52-53ft assumed to be 2626 [based on average of 2665 (NS), 2743 (CSX), 2400 (BNSF), and 2697(CRLC)].<br>60-66ft assumed to be 3372 [based on average of 3281 (NS), 3242 (CSX), 3350 (BNSF), CRCL-3670, and 3366 (GTRC)].<br>Municipal Waste assumed to be 7999 (NS).<br>Woodchip assumed to be 7781[based on average of 7862 (NS) and 7700 (CRCL)].<br>Coal assumed to be 4170 [based on average of 3785 (NS) and 4556 (BNSF)]. |
| **Refrigerated - Mechanical /non-Mechanical** | 6,202 | Based on the average of the following refrigerated car types:<br>48-72ft assumed to be 6963 [based on average of 6043 (UP) and 7883 (BNSF)].<br>50ft assumed to be 5167(GTRC).<br>40-90 ft. assumed to be 6476 [based on average of 6952 (UP) and 6000 (BNSF)]. |

# Table 6. Railcar Volume Assumptions and Sources

| Railcar Type | Cubic Feet | Source/Method<br>*Key:* **Norfolk Southern Railroad (NS)[11], Union Pacific Railroad (UP)[12], Burlington Northern Santa Fe Railroad (BNSF)[13], CSX Transportation Railroad (CSX)[14], World Trade Press Guide to Railcars (GTRC)[15], Chicago Rail Car Leasing (CRCL)[16], Union Tank Car Company (UTCC)[17], U.S Department of Agriculture (USDA)[18]** |
|---|---|---|
| **Open Top Hopper** | 4,220 | Based on the average of the following open top hopper car types:<br>42ft assumed to be 3000 (UP).<br>54ft assumed to be 3700 (UP).<br>60ft assumed to be 5188 [based on average of 5125 (UP) and 5250 (GTRC)]. 45ft+ assumed to be 4105 [based on average of 4500 (UP) and 3710 (BNSF).<br>Woodchip assumed to be 7075 [based on average of 7525 (NS), 5999 (UP), and 7700 (CRCL)].<br>Small Aggregate assumed to be 2252 [based on average of 2150 (NS), 2106 (BNSF), and 2500 (CRCL)]. |
| **Covered Hopper** | 4,188 | Based on the average of the following covered top hopper car types:<br>45ft assumed to be 5250 (GTRC).<br>Aggregate assumed to be 2575 [based on average of 2150 (NS) and 3000 (CRCL)].<br>Small Cube Gravel assumed to be 2939 [based on average of 2655 (NS), 3100 (CSX), and 3063 (BNSF).<br>Med-Large Cube Ores and Sand assumed to be 4169 [based on average of 3750 (NS) and 4589 (BNSF)].<br>Jumbo assumed to be 5147 [based on average of 4875 (NS), 4462 (CSX), 5175 (BNSF), and 6075 (CRCL)].<br>Pressure Differential (flour) assumed to be 5050 [based on average of 5124 (NS) and 4975 (CRCL)]. |
| **Tank Cars under 22,000 gallons** | 2,314 | Assumes 1 gallon=0.1337 cubic foot (USDA).<br>Based on small tank car average volume of 17304 gallons, which is the average of the following currently manufactured tank car volume design capacities of 13470, 13710, 15100, 15960, 16410, 17300, 19900, 20000, 20590, and 20610 gallons (GTRC). |
| **Tank Cars over 22,000 gallons** | 3,857 | Assumes 1 gallon=0.1337 (USDA).<br>Based on large tank car volume of 28851 gallons, which is the average of the following currently manufactured tank car volume design capacities of 23470, 25790, 27200, 28700, 30000, 33000, and 33800 gallons (GTRC). |
| **All Other Cars** | 5,014 | Based on average volume presented above for each of the nine railcar types (all flatcars are represented by the line item that includes multi-level flatcars - 7428). |

## Table 7. Rail Carrier Average Volume Determination

| Freight Car Types (R1 - Schedule 755) | Avg. Cu Ft. | BNSF | |
|---|---|---|---|
| | | Railcar Miles (x1K) | Cu Ft Miles (x1K) |
| Box-Plain 40-Foot | 4,555 | 1 | 4,555 |
| Box-Plain 50-Foot & Longer | 7,177 | 9,338 | 67,018,826 |
| Box-Equipped | 7,177 | 147,226 | 1,056,641,002 |
| Gondola-Plain | 5,190 | 379,762 | 1,970,964,780 |
| Gondola-Equipped | 5,190 | 75,894 | 393,889,860 |
| Hopper-Covered | 4,188 | 758,442 | 3,176,355,096 |
| Hopper-Open Top-General Service | 4,220 | 65,077 | 274,624,940 |
| Hopper-Open Top-Special Service | 4,220 | 137,449 | 580,034,780 |
| Refrigerator-Mechanical | 6,202 | 19,272 | 119,524,944 |
| Refrigerator-Non-Mechanical | 6,202 | 32,910 | 204,107,820 |
| Flat-TOFC/COFC | 6,395 | 520,521 | 3,328,731,795 |
| Flat-Multi-Level | 13,625 | 38,624 | 526,252,000 |
| Flat-General Service | 6,395 | 357 | 2,283,015 |
| Flat-All Other | 6,395 | 71,826 | 459,327,270 |
| All Other Car Types-Total | 5,772 | 20,146 | 116,282,712 |
| Average Railcar Cubic Feet | | | 5,811 |

| Freight Car Types (R1 - Schedule 755) | CSX | |
|---|---|---|
| | Railcar Miles (x1K) | Cu Ft Miles (x1K) |
| Box-Plain 40-Foot | - | - |
| Box-Plain 50-Foot & Longer | 6,987 | 50,145,699 |
| Box-Equipped | 144,631 | 1,038,016,687 |
| Gondola-Plain | 137,256 | 712,358,640 |
| Gondola-Equipped | 64,532 | 334,921,080 |
| Hopper-Covered | 153,315 | 642,083,220 |
| Hopper-Open Top-General Service | 78,412 | 330,898,640 |
| Hopper-Open Top-Special Service | 35,451 | 149,603,220 |
| Refrigerator-Mechanical | 17,117 | 106,159,634 |
| Refrigerator-Non-Mechanical | 11,923 | 73,946,446 |
| Flat-TOFC/COFC | 125,828 | 804,670,060 |
| Flat-Multi-Level | 29,956 | 408,150,500 |
| Flat-General Service | 162 | 1,035,990 |
| Flat-All Other | 31,913 | 204,083,635 |
| All Other Car Types-Total | 19,861 | 114,637,692 |
| Average Railcar Cubic Feet | | 6,389 |

| Freight Car Types (R1 - Schedule 755) | Grand Trunk | |
|---|---|---|
| | Railcar Miles (x1K) | Cu Ft Miles (x1K) |
| Box-Plain 40-Foot | 0 | - |
| Box-Plain 50-Foot & Longer | 2,119 | 15,208,063 |
| Box-Equipped | 66,110 | 474,471,470 |
| Gondola-Plain | 6,467 | 33,563,730 |
| Gondola-Equipped | 19,201 | 99,653,190 |
| Hopper-Covered | 44,239 | 185,272,932 |
| Hopper-Open Top-General Service | 9,114 | 38,461,080 |
| Hopper-Open Top-Special Service | 32,621 | 137,660,620 |
| Refrigerator-Mechanical | 312 | 1,935,024 |
| Refrigerator-Non-Mechanical | 205 | 1,271,410 |
| Flat-TOFC/COFC | 2,779 | 17,771,705 |
| Flat-Multi-Level | 4,831 | 65,822,375 |
| Flat-General Service | 20 | 127,900 |
| Flat-All Other | 31,744 | 203,002,880 |
| All Other Car Types-Total | 4,755 | 27,445,860 |
| Average Railcar Cubic Feet | | 6,309 |

| Freight Car Types (R1 - Schedule 755) | Kansas City Southern | |
|---|---|---|
| | Railcar Miles (x1K) | Cu Ft Miles (x1K) |
| Box-Plain 40-Foot | 0 | - |
| Box-Plain 50-Foot & Longer | 3,383 | 24,279,791 |
| Box-Equipped | 39,792 | 285,587,184 |
| Gondola-Plain | 16,628 | 86,299,320 |
| Gondola-Equipped | 11,150 | 57,868,500 |
| Hopper-Covered | 50,346 | 210,849,048 |
| Hopper-Open Top-General Service | 626 | 2,641,720 |
| Hopper-Open Top-Special Service | 943 | 3,979,460 |
| Refrigerator-Mechanical | 21 | 130,242 |
| Refrigerator-Non-Mechanical | 52 | 322,504 |
| Flat-TOFC/COFC | 10,736 | 68,656,720 |
| Flat-Multi-Level | 629 | 8,570,125 |
| Flat-General Service | 12 | 76,740 |
| Flat-All Other | 2,321 | 14,842,795 |
| All Other Car Types-Total | 247 | 1,425,684 |
| Average Railcar Cubic Feet | | 5,938 |

| Freight Car Types (R1 - Schedule 755) | Norfolk Southern | |
|---|---|---|
| | Railcar Miles (x1K) | Cu Ft Miles (x1K) |
| Box-Plain 40-Foot | 0 | - |
| Box-Plain 50-Foot & Longer | 7,622 | 54,703,094 |
| Box-Equipped | 136,745 | 981,418,865 |
| Gondola-Plain | 193,214 | 1,002,780,660 |
| Gondola-Equipped | 111,320 | 577,750,800 |
| Hopper-Covered | 116,848 | 489,359,424 |
| Hopper-Open Top-General Service | 84,557 | 356,830,540 |
| Hopper-Open Top-Special Service | 30,078 | 126,929,160 |
| Refrigerator-Mechanical | 3,512 | 21,781,424 |
| Refrigerator-Non-Mechanical | 5,392 | 33,441,184 |
| Flat-TOFC/COFC | 114,928 | 734,964,560 |
| Flat-Multi-Level | 20,349 | 277,255,125 |
| Flat-General Service | 145 | 927,275 |
| Flat-All Other | 24,563 | 157,080,385 |
| All Other Car Types-Total | 212,408 | 1,226,018,976 |
| Average Railcar Cubic Feet | | 6,065 |

| Freight Car Types (R1 - Schedule 755) | Soo Line | |
|---|---|---|
| | Railcar Miles (x1K) | Cu Ft Miles (x1K) |
| Box-Plain 40-Foot | 0 | - |
| Box-Plain 50-Foot & Longer | 725 | 5,203,325 |
| Box-Equipped | 17,972 | 128,985,044 |
| Gondola-Plain | 1,203 | 6,243,570 |
| Gondola-Equipped | 8,856 | 45,962,640 |
| Hopper-Covered | 94,146 | 394,283,448 |
| Hopper-Open Top-General Service | 3,077 | 12,984,940 |
| Hopper-Open Top-Special Service | 20 | 84,400 |
| Refrigerator-Mechanical | 159 | 986,118 |
| Refrigerator-Non-Mechanical | 742 | 4,601,884 |
| Flat-TOFC/COFC | 11,178 | 71,483,310 |
| Flat-Multi-Level | 2,973 | 40,507,125 |
| Flat-General Service | 12 | 76,740 |
| Flat-All Other | 10,068 | 64,384,860 |
| All Other Car Types-Total | 428 | 2,470,416 |
| Average Railcar Cubic Feet | | 5,667 |

| Freight Car Types (R1 - Schedule 755) | Union Pacific | |
| --- | --- | --- |
| | Railcar Miles (x1K) | Cu Ft Miles (x1K) |
| Box-Plain 40-Foot | 0 | - |
| Box-Plain 50-Foot & Longer | 12,311 | 88,356,047 |
| Box-Equipped | 238,241 | 1,709,855,657 |
| Gondola-Plain | 206,370 | 1,071,060,300 |
| Gondola-Equipped | 91,775 | 476,312,250 |
| Hopper-Covered | 370,929 | 1,553,450,652 |
| Hopper-Open Top-General Service | 188,027 | 793,473,940 |
| Hopper-Open Top-Special Service | 104,969 | 442,969,180 |
| Refrigerator-Mechanical | 82,874 | 513,984,548 |
| Refrigerator-Non-Mechanical | 27,009 | 167,509,818 |
| Flat-TOFC/COFC | 1,026,251 | 6,562,875,145 |
| Flat-Multi-Level | 46,889 | 638,862,625 |
| Flat-General Service | 350 | 2,238,250 |
| Flat-All Other | 72,371 | 462,812,545 |
| All Other Car Types-Total | 16,769 | 96,790,668 |
| Average Railcar Cubic Feet | | 6,248 |

| Freight Car Types (R1 - Schedule 755) | Total (for Industry Average) | |
| --- | --- | --- |
| | Railcar Miles (x1K) | Cu Ft Miles (x1K) |
| Box-Plain 40-Foot | 1 | 4,555 |
| Box-Plain 50-Foot & Longer | 42,485 | 304,914,845 |
| Box-Equipped | 790,717 | 5,674,975,909 |
| Gondola-Plain | 940,900 | 4,883,271,000 |
| Gondola-Equipped | 382,728 | 1,986,358,320 |
| Hopper-Covered | 1,588,265 | 6,651,653,820 |
| Hopper-Open Top-General Service | 428,890 | 1,809,915,800 |
| Hopper-Open Top-Special Service | 341,531 | 1,441,260,820 |
| Refrigerator-Mechanical | 123,267 | 764,501,934 |
| Refrigerator-Non-Mechanical | 78,233 | 485,201,066 |
| Flat-TOFC/COFC | 1,812,221 | 11,589,153,295 |
| Flat-Multi-Level | 144,251 | 1,965,419,875 |
| Flat-General Service | 1,058 | 6,765,910 |
| Flat-All Other | 244,806 | 1,565,534,370 |
| All Other Car Types-Total | 274,614 | 1,585,072,008 |
| Industry Average Railcar Cubic Feet | | 6,091 |

## % SMARTWAY VALUE

The % SmartWay screen presents the portion of goods that shippers move with SmartWay Partners (expressed as a percentage between 0 and 100). Shippers select the basis for calculating the percentage shipped with SmartWay Partners, including the following options for Way 3 and 4 participants:

- Total annual miles (the Tool will automatically populate the % SmartWay screen with any carrier activity data that shippers entered in the freight Activity Data screen). Miles correspond to truck-miles for trucks, aircraft-miles for air, barge-miles for barge, and railcar-miles for rail;

- Total annual ton-miles (the Tool will automatically populate the % SmartWay screen with any carrier activity data that shippers entered on the freight Activity Data screen);

Shippers participating at the Way 2 level must characterize their carrier activity using one of the following metrics:

- Percent Spent;

- Percent Weight Shipped;

- Percent Packages Shipped;

- Other Custom Metric (as defined by Shipper).

## PUBLIC DISCLOSURE REPORTS

The Shipper Tool now provides a report summarizing Scope 3 emissions for public disclosure purposes. Mass emissions are presented in metric tons for $CO_2$ (biogenic and non-biogenic), $NO_x$, and PM[19] for all carriers NOT specifically designated as "Shipper Carriers" on the Tool's Activity screen.[20] The percent of $CO_2$ attributable to SmartWay Carriers is also provided, again excluding any Shipper Carriers. Biogenic $CO_2$ emissions estimates are assumed to equal 2 percent of total $CO_2$ emissions, as per U.S. requirements for biomass-based diesel from the EPA Renewable Fuel Standard program final volume requirements.[21]

---

[19] Emissions from $CH_4$, $N_2O$, HFC's, PFC's, $SF_6$ and $NF_3$ have been deemed immaterial, comprising less than 5% of overall GHG emissions and are therefore EXCLUDED for reporting purposes.

[20] "Shipper Carriers" refer to fleets directly operated by the Shippers themselves. These fleets are associated with Scope 1 emissions which are not reported in the Shipper Tool. For purposes of developing a corporate inventory using the SmartWay Shipper Tool, the relevant Scope 3 category only includes upstream transportation and distribution and therefore excludes downstream transportation and distribution as falling outside of the system boundary.

[21] As stated in the Final Rule (Table I.B.7-1 – see https://www.gpo.gov/fdsys/pkg/FR-2017-12-12/pdf/2017-26426.pdf, Accessed 8-28-19.), the volume requirements for biomass-based diesel in 2018 is 1.74%, rounded to equal 2% for calculation purposes. The percentage will be updated annually in the Tool.

# 2.0 Calculator Tools

In addition to estimating a shipper's emissions inventory and performance metrics, the Shipper Tool also allows shippers to estimate the emissions impact of system activity strategies as well as modal shifts, if the user provides mileage-related activity data under the Way 4 option.

## MILE AND WEIGHT IMPROVEMENTS

The Mile & Weight Improvements screen is optional and is intended for reference purposes only. On this screen, shippers may estimate emission reduction benefits for the following options:

- Miles Removed from the System

  - Distribution center relocation

  - Retail sales relocation

  - Routing optimization

  - Cube optimization

  - Larger vehicles and/or multiple trailers

- Weight Removed from System

  - Product weight reduction

  - Package weight reduction

  - Vehicle weight reduction

For each activity selected, shippers must provide an estimate of the percentage reduction in freight activity (in miles or weight), for each mode of interest, along with a detailed text description of the strategy. The Tool assumes that total mass emissions are reduced in direct proportion with the specified mileage or weight reduction.[22]

---

[22] This assumption should be accurate for weight reduction strategies when applied to truckload shipments that weigh out. Additional uncertainty arises in the case of LTL and package delivery shipments, where weight reductions may not result in one-to-one reductions in miles hauled. Uncertainties are even greater for non-truck modes, where the shipper commonly does not control the entire content of the container. Likewise, this assumption may not hold if shippers reduce freight by loading more products (i.e., more weight) on trucks that were previously cubing out, since the increase in payload will negatively impact the truck's fuel economy and g/mile emissions performance.

Mass emission reductions are calculated by using the appropriate emissions inventory from the Emissions Summary screen (based on reported activity data and associated carrier emissions performance data) as shown below:

$$S = EM \times (1 / (1 - Reduction) - 1)$$

Where:

| | | |
|---|---|---|
| S | = | Savings (tons of $CO_2$, $NO_x$, or PM) |
| EM | = | Emissions inventory value (tons of $CO_2$, $NO_x$, or PM from Emissions Summary screen) |
| Reduction | = | the reduction in total miles or weight as a result of the strategy (expressed as fraction) |

Fractional reduction estimates must be documented in the Shipper Tool. An example calculation is provided below:

A shipper changes the shape of its milk cartons from round to square. As a result, the shipper can pack 20% more milk cartons per truck trailer than the rounded milk cartons. This reduces 20% of the loads associated with that product line (corresponding to the "Cube Optimization" activity selection for the "Miles removed from system" category). However, the company sells many products, and the total truckloads associated with milk shipments is 1,000 out of 50,000 overall truckloads. The efficiency gain is thus 20% x (1,000/50,000), or a 0.4% system improvement. Therefore, the shipper would enter "0.4" in the Percent Improvement column. This assumes that all loads on average travel an equivalent distance. If milk loads were significantly shorter than other loads, then a mileage-based weighting per trip would need to be applied to arrive at a percent improvement. The burden of proof on demonstrating an accurate percent reduction and modal allocation is the shipper's. The data sources and methodology should be briefly described in the Tool under Data Source/Methodology. The shipper should, at a minimum, keep detailed records electronically within the company to document the estimate upon EPA request. The shipper can also submit any documentation in electronic text format along with the Tool to its Partner Account Manager.

## MODAL SHIFT IMPACTS

### Overview

The Modal Shift Impacts screen in the Tool is optional and is intended for reference purposes only. Shippers should develop their carrier emissions inventories (and associated emissions factors for their companies) by inputting activity data in the Activity Data screen.

Shippers wishing to conduct scenario analyses can use the Modal Shift Impacts screen to estimate the emissions impacts associated with modal shifts by specifying the mode from which they are considering shifting their freight ("From Mode"), as well as the target mode ("To Mode"). Shippers have several options for selecting an emissions factor for both the "From Mode" and "To Mode". First, the Tool automatically

calculates and displays the average emission factors for truck, barge, air and rail modes corresponding to the carrier data file values used on the Activity Data screen (corresponding to the "Shipper's Carrier Average" Emission Factor Source selection). In this case partners can also adjust their estimates of emission impacts from modal shifts by applying different filters for the "From" Mode (e.g., just considering inbound international freight). Second, partners may select illustrative industry average emission factors (discussed in the section below) from the drop-down menu (corresponding to the "Modal Average" selection). Third, the shipper can input a set of alternative emissions factors of their choice (corresponding to the "User Input" selection). In this instance the user must also provide a description of the source of the information used to develop the alternate factors (by selecting the "User Input Data Source" button).

Some modal shifts may include some form of drayage activity. To properly account for all emissions in these cases, you may need to add additional lines - the first line will be for the main leg of the trip, while a second or third may account for changes in drayage miles. Additionally, due to the location of infrastructure (roads, rail lines, etc.) the distances across the different modal shifts my not be the same; for example, the mileage for trucks will very likely be different from the mileage for rail.

Note: the emissions factors that automatically appear on the Modal Shift Impacts screen do not include all potential emissions impacts; for example, the factors do not include emissions specifically associated with drayage (i.e., short-distance trips often required to move freight from one mode to another), or operations at intermodal facilities.

While EPA has populated the Tool with illustrative modal average freight emission factors, we recommend that partners use more representative emission factors to analyze scenarios whenever possible. For example, partners may wish to evaluate the emissions impact from moving freight from rail to a specific truck fleet by consulting the SmartWay Category average emissions factors associated with the fleet (available on the SmartWay website), or by inputting data that partners receive directly from a carrier. For better estimates of emission impacts from modal shifts, partners are encouraged to use a factor that reflects the full emissions impact (e.g., including anticipated drayage emissions) and that best represents the fleet equipment and operational type that they are most likely to work with for their unique freight movement.

While we have not provided modal average ocean-going vessel factors in the Tool, there are several external resources that partners can consult. We have included some selected sources of ocean-going vessel factors in the following section.

In order to calculate the emissions impact associated with a modal shift, shippers input the activity data corresponding with their modal shift scenario expressed in a given unit (miles or ton-miles) and the Tool combines that data with a corresponding emission factor (described above) in the same unit. The Tool then displays the change in emissions (as calculated below) in tons per year.

Total Emission Impact (tons/yr) =
[(Efficiency Before x "From Mode" Amount) –
(Efficiency After x "To Mode" Amount)] x grams to short tons conversion factor[23]

---

[23] 1.1023 x 10$^{-6}$ short tons/gram

If the shipper is evaluating a mode shift between truck and rail or barge, and if the available activity units are in miles rather than ton-miles, then the activity data entered must be expressed in terms of railcar-miles or barge-miles, as appropriate in order to be consistent with the g/mile factors included in the carrier data file. Determination of railcar and barge-miles for any particular container/commodity type and route should be made in consultation with carriers or logistics service providers in order to account for volume differences compared to truck carriers.

If you need to convert truck-miles to railcar and/or barge-mile equivalents for your assessment, a railcar-to-truck equivalency factor can be calculated by first identifying the average cargo volume for a given rail carrier (see Table 5 above). These volumes estimates should be weighted by the miles associated with each rail carrier in order to estimate a single weighted-average railcar volume for the carrier company in question. Similarly, weighted average volumes can also be calculated for the different truck carriers associated with the given shipping company. (Company-specific volume data is contained within the carrier data file for SmartWay truck carriers.) The weighting calculations should involve all carriers used by the company if no filters are selected on the Modal Shift Impacts screen (only relevant for the "From" mode). Otherwise the weighted average calculation should only be performed for the filtered subset (e.g., inbound domestic truck carriers).

Once the weighted average volumes are determined for both rail and truck modes, you can calculate the ratio of the average railcar volume to the average truck volume (R). Using industry average volume estimates as described in Appendix B, we estimate R to equal approximately 1.41, meaning that the average railcar has 1.41 times the volume of an average truck trailer/container. Next, you can convert your truck-equivalent mile estimates to railcar equivalent miles by dividing truck miles by the ratio R.[24] Enter the corresponding railcar-mile activity estimate in the "Amounts" column.

The same process is used to convert truck-miles to barge-mile equivalents, although national average barge volume information was not identified for this analysis. In this case volume estimates may be used for specific barge carriers from the carrier data file. In addition, the value for truck miles should also be divided by 1.15 to convert from statute to nautical miles.[25]

## BACKGROUND ON ILLUSTRATIVE U.S. MODAL AVERAGE FACTORS

Modal Average performance metrics were estimated for rail, truck and multimodal modes (both gram per mile and gram per ton-mile), as well as for barge and air modes (gram per ton-mile only) in order to estimate emission impacts using the Modal Shift Impacts screen. We developed the truck g/mile factors for $CO_2$, $NO_x$, and $PM_{2.5}$[26] using EPA's 2014b version of the Motor Vehicle Emissions Simulator model (MOVES2014b). The model was run at the national level for calendar year 2019, with emissions estimated and summed across the diesel short-haul single unit, short-haul combination unit, long-haul single unit, and long-haul combination

---

[24] Any route mileage differences must be adjusted for separately.

[25] Barge performance values are expressed in grams per nautical mile, to be consistent with barge carrier reporting practices.

[26] Corresponding $PM_{10}$ emission factors were estimated assuming $PM_{2.5}$ values were 97% of $PM_{10}$ values, based on MOVES model outputs for diesel fueled trucks.

unit truck categories.[27] [28] MOVES does not contain ton-mile data, so we divided the MOVES-based mass emission estimates by national freight truck ton-mile estimates from the Bureau of Transportation Statistics (BTS) to obtain the truck g/ton-mile factors.[29] The most recent BTS ton-mile data were for 2017, so estimates for 2019 were based on a linear interpolation of the 2012 and 2017 values.

Table 8 presents the illustrative freight truck emissions factors in the tool and Table 8 presents the key underlying data. (Note that the modal average factors calculated for truck carriers were assumed valid for logistics carriers as well.)

### Table 8. U.S. Freight Truck Industry Average Factors Used in Modal Shift

| Units | $CO_2$ | $NO_x$ | $PM_{2.5}$ |
|---|---|---|---|
| gram/short ton-mile | 210 | 0.744 | 0.027 |
| gram/mile | 1,578 | 5.586 | 0.199 |

### Table 9. Underlying Data for Freight Truck Industry Average Factors (2019)

| | |
|---|---|
| $CO_2$ (grams) | 436,853,902,968,783 |
| $NO_x$ (grams) | 1,547,043,757,414 |
| $PM_{2.5}$ (grams) | 55,183,809,776 |
| Miles | 276,927,898,414 |
| short ton-miles | 2,078,299,600,000 |

We developed the freight rail g $CO_2$/ton-mile and g $CO_2$/mile factors using the 2017 data summarized in Table 4 above. We then developed the freight rail $NO_x$ and PM g/mile and g/ton-mile factors as described in Appendix A.

The modal average barge emissions factors presented in Table 10 are from a study prepared by the Texas Transportation Institute (TTI) for the U.S. Maritime Administration[30] and reflect inland waterway towing operations in the U.S. We converted the $PM_{10}$ factor in the TTI study into $PM_{2.5}$ by assuming 95% of $PM_{10}$ is $PM_{2.5}$, which we determined was a good approximation of the share of overall $PM_{10}$ emissions represented by particulate matter that is 2.5 micrometers in diameter or smaller.

---

[27] These four truck categories are coded as 52, 53, 61, and 62 in the MOVES model, respectively.

[28] EPA's MOVES model and accompanying resources, including technical documentation, are available at: www.epa.gov/otaq/models/moves/index.htm. Accessed 8-28-19.

[29] Bureau of Transportation Statistics, U.S. Ton-Miles of Freight, https://www.bts.gov/us-ton-miles-freight Accessed 8-28-19.

[30] U.S. Maritime Administration and the National Waterways Foundation (U.S. MARAD), amended January 2017. *A Modal Comparison of Domestic Freight Transportation Effects on the General Public*. Prepared by Center for Ports & Waterways, Texas Transportation Institute, Table 10. Available at: http://www.portsofindiana.com/wp-content/uploads/2017/06/Final-TTI-Report-2001-2014-Approved.pdf, Accessed 8-28-19.

## Table 10. Modal Average Barge Emission Factors

| | CO$_2$ | NO$_x$ | PM$_{2.5}$ |
|---|---|---|---|
| **gram/short ton-mile** | 17.48 | 0.4691 | 0.0111 |

Estimates of average g/mi performance metrics were not identified for barge carriers.

Modal average estimates for air freight are based on EDMS outputs, presented in Table 3 above.

Modal average estimates for multimodal carriers were calculated for intermodal truck/rail freight movements by estimating the average length of haul for rail freight (990 miles)[31] and truck drayage carriers (398 miles).[32] Based on these estimates we assume a "typical" intermodal container shipment will travel 71% by rail, and 29% by truck. These percentages are applied as weights to the modal average rail and truck mode values calculated above in order to estimate modal average performance metrics for intermodal shipments (see Table 11).

## Table 11. Modal Average Performance Metric Estimates for Rail, Truck, Barge, Air, and Intermodal

| Mode | g/mi | | | | g/ton-mi | | | |
|---|---|---|---|---|---|---|---|---|
| | CO$_2$ | NO$_x$ | PM$_{10}$ | PM$_{2.5}$ | CO$_2$ | NO$_x$ | PM$_{10}$ | PM$_{2.5}$ |
| **Rail** | 666.1 | 11.558 | 0.322 | 0.313 | 15.7 | 0.292 | 0.014 | 0.024 |
| **Truck** | 960.6 | 5.251 | 0.214 | 0.208 | 143.9 | 0.784 | 0.032 | 0.031 |
| **Intermodal** | 751.5 | 9.7 | 0.3 | 0.3 | 52.9 | 0.4 | 0.02 | 0.01 |
| **Barge** | | | | | 12.0 | 0.321 | 0.008 | 0.008 |
| **Air** | | | | | 817 | 2.702 | 0.082 | 0.082 |
| **Air - long haul** | 20,784 | 187.0 | 1.230 | 1.230 | 1,001 | 8.974 | 0.059 | 0.059 |
| **Air - short haul** | 60,272 | 542.5 | 3.567 | 3.567 | 2,902 | 26.099 | 0.172 | 0.172 |

## OUTSIDE SOURCES OF OCEAN-GOING MARINE EMISSION FACTORS

There are many sources of marine emission factors available in research literature and other GHG estimation tools. For reference, we have included below the g CO$_2$/ton-mile marine factors from the Business for Social Responsibility's (BSR) Clean Cargo Tool as well as factors from a study prepared for the International Maritime Organization (IMO).[33]

---

[31] Class I Rail average length of haul for 2013 - https://transportgeography.org/?page_id=2735, accessed 8-28-19.

[32] Harrison, R. et al, Characteristics of Drayage Operations at the Port of Houston, University of Texas Center for Transportation Research, Table 4, September 2008. Available at https://static.tti.tamu.edu/swutc.tamu.edu/publications/technicalreports/473700-00075-1.pdf. Accessed 8-28-19.

[33] Buhaug, et al. for the International Maritime Organization (IMO), 2009. Second IMO GHG Study 2009, International Maritime Organization (IMO), London, UK, April 2009. Available at: http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/SecondIMOGHGStudy2009.pdf, Accessed 8-28-19.

Note that the factors from BSR and IMO are published in units of kg $CO_2$/metric ton-km, so we converted this data into g $CO_2$/ton-mile by first multiplying by 1,000 (to convert from kilograms to grams), then multiplying by 0.9072 (to convert from metric tonnes to short tons), and then multiplying by 1.609 (to convert from kilometers to miles) to prepare the tables below.

BSR developed average 2009 marine emission factors for various shipping corridors, as well as global defaults that are applicable outside those corridors, based on surveys from marine carriers. The BSR marine factors in Table 12 below are from the "Emission Factors & Distances" tab in their tool.

### Table 12. BSR Marine Emission Factors (g $CO_2$/short ton-mile)

| | | |
|---|---|---|
| Ship_general | International | 13.0678 |
| Ship_Barge | International | 29.1937 |
| Ship_Feeder | International | 29.1937 |
| Ship_inland_Germany | Germany | 41.5280 |
| Ship_inland_China | China | 35.0578 |
| Ship_Asia-Africa | Asia--Africa | 11.9227 |
| Ship_Asia-South America (EC/WC) | Asia--South America (EC/WC) | 13.1897 |
| Ship_Asia-Oceania | Asia--Oceania | 13.4028 |
| Ship_Asia-North Europe | Asia--North Europe | 10.8586 |
| Ship_Asia-Mediterranean | Asia--Mediterranean | 12.1358 |
| Ship_Asia-North America EC | Asia--North America EC | 12.9854 |
| Ship_Asia-North America WC | Asia--North America WC | 12.0818 |
| Ship_Asia-Middle East/India | Asia--Middle East/India | 13.5459 |
| Ship_North Europe-North America EC | North Europe--North America EC (incl. Gulf) | 14.1823 |
| Ship_North Europe-North America WC | North Europe--North America WC | 13.0642 |
| Ship_Mediterranean-North America EC | Mediterranean--North America EC (incl. Gulf) | 12.6788 |
| Ship_Mediterranean-North America WC | Mediterranean--North America WC | 10.1433 |
| Ship_Europe (North & Med)-Middle East/India | Europe (North & Med)--Middle East/India | 13.4276 |
| Ship_Europe (North & Med)-Africa | Europe (North & Med)--Africa | 15.8361 |
| Ship_Europe (North & Med)-Oceania (via Suez / via Panama) | Europe (North & Med)--Oceania (via Suez / via Panama) | 14.4056 |
| Ship_Europe (North & Med)-Latin America/South America | Europe (North & Med)--Latin America/South America | 12.6146 |
| Ship_North America-Africa | North America--Africa | 17.4549 |
| Ship_North America EC-Middle East/India | North America EC--Middle East/India | 12.8788 |
| Ship_North America-South America (EC/WC) | North America--South America (EC/WC) | 13.4379 |
| Ship_North America-Oceania | North America--Oceania | 15.0552 |
| Ship_South America (EC/WC)-Africa | South America (EC/WC)--Africa | 11.7432 |
| Ship_Intra-Americas (Caribbean) | Intra-Americas (Caribbean) | 15.9222 |
| Ship_Intra-Asia | Intra-Asia | 15.2012 |
| Ship_Intra-Europe | Intra-Europe | 17.1790 |

The marine factors in the IMO study reflect commonly-used equipment sizes and types. The factors in Tables 13 below come from Table 9.1 4 in the IMO study.

## Table 13. IMO Marine Emission Factors

| TYPE | SIZE | AVERAGE CARGO CAPACITY (metric tonne) | Average yearly capacity utilization | Average service speed (knots) | Transport work per ship (tonne NM) | Loaded efficiency (g of $CO_2$/ ton-mile) | Total efficiency (g of $CO_2$/ton-mile) |
|---|---|---|---|---|---|---|---|
| Crude oil tanker | 2000,000+dwt | 295,237 | 48% | 15.4 | 14,197,046,742 | 2.34 | 4.23 |
| Crude oil tanker | 120,000-199,99 dwt | 151,734 | 48% | 15 | 7,024,437,504 | 3.21 | 6.42 |
| Crude oil tanker | 80,000-119,999 dwt | 103,403 | 48% | 14.7 | 4,417,734,613 | 4.38 | 8.61 |
| Crude oil tanker | 60,000-79,999 dwt | 66,261 | 48% | 14.6 | 2,629,911,081 | 6.28 | 10.95 |
| Crude oil tanker | 10,000-59,999 dwt | 38,631 | 48% | 14.5 | 1,519,025,926 | 7.59 | 13.28 |
| Crude oil tanker | 0-9,999 dwt | 3668 | 48% | 12.1 | 91,086,398 | 30.22 | 48.61 |
| Products tanker | 60,000+ dwt | 101,000 | 55% | 15.3 | 3,491,449,962 | 4.82 | 8.32 |
| Products tanker | 20,000-59,999 dwt | 40,000 | 55% | 14.8 | 1,333,683,350 | 10.51 | 15.03 |
| Products tanker | 10,000-19,999 dwt | 15,000 | 50% | 14.1 | 464,013,471 | 16.49 | 27.30 |
| Products tanker | 5,000-9,999 dwt | 7,000 | 45% | 12.8 | 170,712,388 | 21.60 | 42.62 |
| Products tanker | 0-49,999 dwt | 1,800 | 45% | 11 | 37,598,072 | 38.68 | 65.69 |
| Chemical tanker | 20,000 + dwt | 32,200 | 64% | 14.7 | 1,831,868,715 | 8.32 | 12.26 |
| Chemical tanker | 10,000-19,999 dwt | 15,000 | 64% | 14.5 | 820,375,271 | 10.66 | 15.76 |
| Chemical tanker | 5,000-9,999 dwt | 7,000 | 64% | 14.5 | 382,700,554 | 15.62 | 22.04 |
| Chemical tanker | 0-4,999 dwt | 1,800 | 64% | 14.5 | 72,147,958 | 27.15 | 32.41 |
| LPG tanker | 50,000 + m³ | 46,656 | 48% | 16.6 | 2,411,297,106 | 7.59 | 13.14 |
| LPG tanker | 0-49,999 m³ | 3,120 | 48% | 14 | 89,631,360 | 39.41 | 63.50 |
| LNG tanker | 200,00 + m³ | 97,520 | 48% | 19.6 | 5,672,338,333 | 7.88 | 13.58 |
| LNG tanker | 0-199,999 m³ | 62,100 | 48% | 19.6 | 3,797,321,655 | 12.26 | 21.17 |
| Bulk carrier | 200,000 +dwt | 227,000 | 50% | 14.4 | 10,901,043,017 | 2.19 | 3.65 |
| Bulk carrier | 100,000-199,999 dwt | 163,000 | 50% | 14.4 | 7,763,260,284 | 2.63 | 4.38 |
| Bulk carrier | 60,000-99,999 dwt | 74,000 | 55% | 14.4 | 3,821,361,703 | 3.94 | 5.98 |
| Bulk carrier | 35,000-59,999 dwt | 45,000 | 55% | 14.4 | 2,243,075,236 | 5.55 | 8.32 |
| Bulk carrier | 10,000-34,999 dwt | 26,000 | 55% | 14.3 | 1,268,561,872 | 7.74 | 11.53 |
| Bulk carrier | 0-9,999 dwt | 2,400 | 60% | 11 | 68,226,787 | 33.43 | 42.62 |
| General cargo | 10,000 + dwt | 15,000 | 60% | 15.4 | 866,510,887 | 11.09 | 17.37 |
| General cargo | 5,000-9,999 dwt | 6,957 | 60% | 13.4 | 365,344,150 | 14.74 | 23.06 |

## Table 13. IMO Marine Emission Factors

| TYPE | SIZE | AVERAGE CARGO CAPACITY (metric tonne) | Average yearly capacity utilization | Average service speed (knots) | Transport work per ship (tonne NM) | Loaded efficiency (g of $CO_2$/ ton-mile) | Total efficiency (g of $CO_2$/ton-mile) |
|---|---|---|---|---|---|---|---|
| General cargo | 0-4,999 dwt | 2,545 | 60% | 11.7 | 76,645,792 | 15.91 | 20.29 |
| General cargo | 10,000+ dwt, 100+ TEU | 18,000 | 60% | 15.4 | 961,054,062 | 12.55 | 16.06 |
| General cargo | 5,000-9,999 dwt, 100+TEU | 7,000 | 60% | 13.4 | 243,599,799 | 20.14 | 25.54 |
| General cargo | 0-4,999 dwt, dwt+TEU | 4,000 | 60% | 11.7 | 120,938,043 | 22.63 | 28.90 |
| Refrigerated cargo | All | 6,400 | 50% | 20 | 392,981,809 | 18.83 | 18.83 |
| Container | 8000+TEU | 68,600 | 70% | 25.1 | 6,968,284,047 | 16.20 | 18.25 |
| Container | 5,000-7,999 TEU | 40,355 | 70% | 25.3 | 4,233,489,679 | 22.19 | 24.23 |
| Container | 3,000-4,999 TEU | 28,784 | 70% | 23.3 | 2,280,323,533 | 22.19 | 24.23 |
| Container | 2,000-2,999 TEU | 16,800 | 70% | 20.9 | 1,480,205,694 | 26.71 | 29.19 |
| Container | 1,000-1,999 TEU | 7,000 | 70% | 19 | 578,339,367 | 42.91 | 46.86 |
| Container | 0-999 TEU | 3,500 | 70% | 17 | 179,809,363 | 48.61 | 52.99 |
| Vehicle | 4000 +ceu | 7,908 | 70% | 19.4 | 732,581,677 | 36.78 | 46.71 |
| Vehicle | 0-3999 ceu | 2,808 | 70% | 17.7 | 226,545,399 | 68.90 | 84.08 |
| Ro-Ro | 2,000 + lm | 5,154 | 70% | 19.4 | 368,202,021 | 66.12 | 72.25 |
| Ro-Ro | 0-1,999 lm | 1432 | 70% | 13.2 | 57,201,146 | 80.57 | 88.02 |

Note: "Loaded efficiency" is the theoretical maximum efficiency when the ship is fully loaded at service speed/85% load. Since engine load at the fully loaded condition is higher than the average including ballast and other voyages, the difference between the columns "loaded efficiency" and "total efficiency cannot be explained by differences in utilization only.

# 3.0 Shipper Payloads and Data Validation

The Shipper Tool contains data validation checks designed to identify missing and potentially erroneous data. At this time the only validation involves payload checks and total ton-mile checks, on the Activity Data screen.

## PAYLOAD VALIDATION

The Shipper Tool also contains data validation checks designed to identify missing and potentially erroneous data. At this time the only validation involves payload checks and total ton-mile checks, on the Activity Data screen. `

Payload validation cutpoints were set with the intention of identifying those payloads that are somewhat outside typical industry values (yellow flag warnings) and those that are far outside industry averages (red flag warnings). The payload check only apples to Data Availability selections a, b, and c where payloads are either entered by the user, or calculated based on other inputs. Checks are applied at the carrier (row) level.

Payload checks are specific to the truck carrier fleet's SmartWay Category, which is available for each carrier category from the Carrier Data File. Note that payload Ranges 1 (very low) and 5 (very high) are colored red on the Activity screen and require explanations before proceeding. Ranges 2 (low) and (high) 4 are colored yellow, and explanations are optional.

Reported Shipper payloads were compiled for each shipper carrier for the 2014 – 2016 reporting years. The data was broken down for each SmartWay carrier category. Next, for every category a histogram was developed and the distribution of the data was reviewed. By adjusting the size of the bins outliers were identified and the histograms adjusted to exclude those points. In most cases specific cutpoints were then selected for each SmartWay Category to represent 5, 10, 90, and 95 percentiles. (Certain highly skewed distributions such as that for package carriers did not define low end cutpoints). The resulting cutpoints used to establish the "red" and "yellow" validation ranges are provided below.

### Table 14. Shipper Payload Validation Ranges

| Carrier Category | low red | low yellow | high yellow | high red |
|---|---|---|---|---|
| Dray | 2.90 | 6.47 | 22.00 | 23.00 |
| Expedited | N/A | N/A | 20.16 | 21.61 |
| Specialized | 1.00 | 4.95 | 24.00 | 28.00 |
| LTL[34] | 4.10 | 6.30 | 15.40 | 17.70 |
| Auto Carrier | 4.10 | 4.60 | 20.95 | 21.83 |
| Heavy Bulk | 5.45 | 10.24 | 25.03 | 25.20 |

---

[34] Values for LTL carriers are based on average weight per load and average number of loads per shipment reported by LTL Truck Partners for 2017.

## Table 14. Shipper Payload Validation Ranges

| Carrier Category | low red | low yellow | high yellow | high red |
|---|---|---|---|---|
| TL | 4.00 | 7.33 | 22.00 | 24.00 |
| Moving | N/A | N/A | 20.13 | 20.54 |
| Flatbed | 4.34 | 7.59 | 23.00 | 26.00 |
| Mixed | 1.00 | 4.43 | 22.50 | 23.93 |
| General | 10.00 | 14.45 | 21.00 | 28.00 |
| Package | N/A | N/A | 2.20 | 11.00 |
| Tanker | 7.86 | 14.06 | 24.56 | 26.28 |
| Reefer | 3.87 | 9.33 | 22.00 | 24.00 |
| Logistics | 0.40 | 1.16 | 22.00 | 24.00 |

Validation cutoffs for rail and surface multimodal carriers are summarized below. The upper bound cutpoints for surface multimodal payloads are based on a qualitative review of 2011 Multimodal carrier Tool submittals. The upper bound cutpoints for rail payloads are based on the distribution of average values estimated for all Class 1 carriers (see Table 5 above).

- Average surface multimodal payloads less than 9.4 tons (error – red)
- Average surface multimodal payloads greater than 95 tons (error – red)
- Average railcar payloads less than 9.4 tons or greater than 125 tons (error – red)
- Average surface multimodal payloads between 9.4 and 15.5 tons (warning – yellow)
- Average surface multimodal payloads between 60 and 95 tons (warning – yellow)

In addition, the absolute upper bound for rail and surface multimodal carriers have both been set at 200 tons.

Multimodal carriers with an air component have their maximum average payload set to 220,000 lbs., corresponding to the maximum payload capacity for the largest aircraft make/model specified by SmartWay partners in 2017. Payloads above this amount will trigger a "red" out of range error that must be explained by the partner in order to proceed, although no value has been set for a maximum allowable payload at this time. Payloads between 110,000 and 220,000 lbs. will receive a "yellow" warning which may be explained if the partner chooses. Any payload value less than or equal to zero will be flagged as an error and must be changed.

Finally, barge carrier payloads are flagged for verification if their density is greater than 0.6 tons per cubic foot or less than 0.003 tons per cubic foot, consistent with the payload validation used in the Barge Tool.

## TON-MILE VALIDATION

2011 Logistics Partner data was evaluated to establish absolute upper bounds for ton-mile inputs. The ton-mile validation applies at the carrier (row) and total fleet (summation of rows) level, with the same values

applied to both. The maximum allowable ton-mile value was set to twice the observed maximum value in the 2011 data set: 209,207,446,000 ton-miles.

# Appendix A: Background on Industry Average U.S. Rail Factors

Industry average freight rail g $NO_x$/ton-mile and g $PM_{2.5}$/ton-mile factors were developed using 2010 inventory data from Tables 3-82 and 3-83, respectively, in EPA's 2008 Regulatory Impact Analysis for a locomotive diesel engine rule.[35] This inventory data represents 2010 emission projections for all U.S. rail except for passenger and commuter rail (i.e., large line-haul, large switch, and small railroads), which was determined to closely align with the freight rail sector. The emissions inventory data was then divided by the 2007 BTS ton-mile data described above.

The freight rail g/mile factors for $NO_x$ and $PM_{2.5}$ were estimated by using 2008 railcar mileage data from lines 15 through 81 of R-1 forms that Class I railroad companies submitted to the Surface Transportation Board.[36] The $NO_x$ and PM inventories were developed using the average 2010 locomotive g $PM_{10}$/gal and g NOx/gal factors from Tables 5 and 6, respectively, in EPA's 2009 *Technical Highlights: Emissions Factors for Locomotives*.[37] To calculate g $PM_{2.5}$/gal, it was assumed that 95% of $PM_{10}$ is $PM_{2.5}$, which was determined to be a good approximation of the share of overall $PM_{10}$ emissions represented by particulate matter that is 2.5 micrometers in diameter or smaller.

Table A-1 presents the average freight rail emissions factors used by the SmartWay Tools and Table A-2 presents the key underlying data.

## Table A-1. U.S. Freight Rail Industry Average Factors (2010)

|  | $NO_x$ | $PM_{2.5}$ |
|---|---|---|
| **gram/short ton-mile** | 0.4270 | 0.0120 |
| **gram/railcar mile** | 18.6 | 0.503 |

---

[35] U.S. EPA, Office of Transportation and Air Quality, 2008. Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters Per Cylinder, EPA420-R-08-001a, Washington DC. Available at: https://nepis.epa.gov/Exe/ZyNET.exe/P10024CN.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2006+Thru+2010&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C06thru10%5CTxt%5C00000005%5CP10024CN.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL. Accessed 5-21-19.

[36] Surface Transportation Board (STB), *Industry Data, Economic Data, Financial and Statistical Reports, Class 1 Annual Report, Form R-1*. Available at: http://www.stb.dot.gov/stb/industry/econ_reports.html, Accessed 5-21-19.

[37] U.S. EPA, Office of Transportation and Air Quality, 2009. *Technical Highlights: Emission Factors for Locomotives*, EPA-420-F-09-025, Washington DC. Available at: https://nepis.epa.gov/Exe/ZyNET.exe/P100500B.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2006+Thru+2010&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C06thru10%5CTxt%5C00000010%5CP100500B.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL Accessed 5-21-19.

## Table A-2. Underlying Data Used to Estimate U.S. Rail Industry Average Factors

| | |
|---|---|
| **short ton-miles** | 1,819,633,000,000 |
| **Class I-only railcar miles (total)** | 34,611,843,000 |
| **50' and Larger Box Plain + Box Equipped** | 2,223,402,000 |
| **40' Box Plain** | 22,000 |
| **Flat TOFC/COFC, General, and Other** | 5,057,466,000 |
| **Flat Multi Level** | 1,725,998,000 |
| **Gondola Plain and Equipped** | 7,893,684,000 |
| **Refrigerated Mechanical and Non-Mechanical** | 495,311,000 |
| **Open Top Hopper General and Special Service** | 5,913,012,000 |
| **Covered Hopper** | 7,210,656,000 |
| **Tank under 22,000 gallons** | 1,295,482,000 |
| **Tank 22,000 gallons and over** | 2,394,565,000 |
| **All Other Car Types** | 402,245,000 |

$NO_x$ and PM emission factors are not available at the carrier level for the rail mode. Accordingly, the industry average emission factors for $NO_x$ and PM are assumed to apply equally for all rail carriers.

**NOTE:** EPA updated the rail industry average g/ton-mile and g/mile factors for NOx and PM included in the Modal Shift Calculator using data released in August of 2019 for EPA's 2017 National Emission Inventory (NEI).[38] The factors were developed using emission estimates specifically for Class I (line-haul and yard switching) locomotives – 534,847 tons $NO_x$, and 15,058 tons $PM_{2.5}$. These data were then divided by railcar-mile and ton-mile data for 2017 Class I rail carriers shown in Table 4 to obtain the corresponding $NO_x$ and PM performance metrics. Table A-3 presents the industry average freight rail emissions factors used in the Modal Shift section of the Tool. These factors will also be used in the Carrier Data File starting in 2020.[39]

## Table A-3. Updated U.S. Freight Rail Industry Average Factors in Modal Shift (2017)

| | $CO_2$ | $NO_x$ | $PM_{2.5}$ |
|---|---|---|---|
| **gram/short ton-mile** | 20.72 | 0.2897 | 0.0082 |
| **gram/railcar mile** | 980 | 14.38 | 0.405 |

---

[38] Emissions Modeling Platform Collaborative, Specification Sheet: Rail 2017 National Emissions Inventory, August 2019 – Table 1.

[39] The updated rail $NO_x$ and PM performance factors are not being used to calculate Shipper rail carrier emissions for Data Year 2018 in order to be consistent with the Multimodal and Logistics carrier tools, which still use the earlier rail performance factors.

# Appendix B: Calculation of Truck-Equivalent Mileage Factors for Rail

Truck-equivalent can be converted into railcar-miles, so that partners can more readily estimate emissions impacts from shifting freight between truck and rail modes, by estimating the average volume capacity of Class I railcars and dividing it by an average freight truck volume capacity. This results in a rough estimate that does not take into consideration the utilized volume of railcars or the comparative freight truck, but we determined that this was the best available data and method to estimate modal average railcar-equivalent miles.

To estimate the average volume capacity of railcars, we multiplied the railcar miles reported by each company for each railcar type in their respective 2008 R-1 reports (lines 15-81) by the volume-per-railcar assumptions in Table 6 to obtain total Class I TEU-miles. We then divided the total railcar TEU-miles by the total railcar-miles to estimate the average railcar volume capacity. We then divided this average railcar volume capacity (3.92 TEUs) by the average freight truck volume capacity that we developed for the truck g/TEU-mile factor discussed above (2.78 TEUs) to develop the conversion factor - 1.41 railcar-miles-to-truck-miles. In the absence of more specific data, this factor can be used to convert truck miles to railcar miles for use on the Modal Shift screen of the Shipper Tool. Note that no equivalent information was identified for the estimation of industry-average barge or air volumes.

For more information:

U. S. Environmental Protection Agency
Office of Transportation and Air Quality
1200 Pennsylvania Ave. NW
Washington, DC 20460
(734) 214-4333

www.epa.gov/transportation-air-pollution-and-climate-change

U. S. Environmental Protection Agency
National Vehicle and Fuel Emissions Laboratory
2565 Plymouth Rd.
Ann Arbor, MI 48105
(734) 214-4200

www.epa.gov/aboutepa/about-national-vehicle-and-fuel-emissions-laboratory-nvfel