SmartWay®
Transport Partnership
U.S. Environmental Protection Agency

Shipper Partner 2.0.12 Tool: Technical Documentation 2012 Data Year - United States Version



EPA United States Environmental Protection Agency

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

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Office of Transportation and Air Quality
EPA-420-B-13-049
October 2013

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10-1-13

1.0 Overview

The SmartWay Shipper Tool is intended to help shippers estimate and assess their carbon, PM, and NOx emissions associated with goods movement in the U.S. freight rail and trucking sectors[1] with a greater degree of sophistication than was possible with previous SmartWay tools. 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 new SmartWay truck, logistics and multi-modal 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 more accurate emissions inventories. The new 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] While this Tool is primarily focused on freight movements in the rail and trucking sectors, our long-term vision is to provide shippers with tools to help them evaluate the emissions performance associated with other transport modes including marine and air.

2.0 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 whether they are entering basic or comprehensive data for them. If they have annual mileage-related activity data by carrier (miles or ton-miles), they may select the "Emissions Footprint and % SmartWay" option on the Basic or Comprehensive screen, and proceed to input activity data for each carrier. Otherwise, they must select the "% SmartWay" 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 "% SmartWay Only", 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. All shippers – regardless of whether they select the "Emissions Footprint" option or the "% SmartWay Only" option – will be able to see the ranking category-level emissions performance data for truck, logistics and multi-modal carriers as well as available industry average Class 1 rail emissions factors.

After identifying and selecting all of their SmartWay and non-SmartWay carriers, shippers can then optionally 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 in Section 3 below.

Emission Inventory and Performance Metric Calculations

If shippers choose the "Emissions Footprint" option, the Tool will calculate their total mass emissions (i.e., an emissions inventory) based on the mileage-related activity data they entered for each carrier, as well as various emission performance metrics (e.g., composite grams/mile and grams/ton-mile – see below) . The Tool offers two options for calculating mass emissions, based on either the annual mileage or ton-mileage data that shippers enter for each carrier. We encourage shippers to select the unit of activity data that is most appropriate for characterizing each truck carrier operation (e.g., use grams per mile for TL and grams per ton-mile for LTL and rail.)

The emissions inventory for each carrier/mode combination displayed on the **Emissions Summary, Carrier Performance** and **Ranking Category Details** screens is calculated by multiplying the appropriate unit of activity data (i.e., miles/railcar-miles, or ton-miles) by the corresponding carrier emissions performance data. To calculate composite, company-wide emissions performance metrics on the **Carrier Performance** screen (i.e., overall g/mile and g/ton-mile performance), the Tool weights the emissions performance of each of the shipper company's carriers by the percentage of the company's overall freight activity that the carrier moves. An example composite performance calculation is provided below.

Table 1. Example Compositing Calculation

	CO_2 g/mi	Mi/yr	Weighting Factor	Weighted CO_2 g/mi
Carrier 1	1,700	2,000,000	0.667	1,134 (0.667 x 1,700)
Carrier 2	1,500	1,000,000	0.333	500 (0.333 x 1,500)
		Weighted composite g/mi		**1,633 (1,134 + 500)**

This compositing process proceeds in an identical fashion for ton-miles. Weighted-average payloads are also calculated in this way, using the relative ton-miles for each carrier as the weighting factor. This value is displayed at the bottom of the Activity Data screen in the Tool.

Likewise, if a shipper selects one or more filters (e.g., inbound domestic carriers-only), the Tool adjusts the weighting factors to ensure that they sum to 100% for the selected subset of carriers. The following provides a simplified example calculation.

- Shipper selects three Truck carriers (T1, T2, T3)
- T1 has a CO_2 g/mile of 1,000
- T2 has a CO_2 g/mile of 2,000
- T3 has a CO_2 g/mile of 3,000
- T1 is Inbound
- T2 and T3 are both Outbound
- Shipper enters miles for the three carriers of 2,000, 4,000, and 2,000, respectively

- When Inbound/Outbound combo = All:
  - Composite CO_2 g/mile = [(1,000*2,000 + 2,000*4,000 + 3,000*2,000) / 8,000] = 2,000

- When Inbound/Outbound combo = Inbound:
  - Composite CO_2 g/mile = [1,000*2,000 / 2,000] = 1,000

- When Inbound/Outbound combo = Outbound:
  - Composite CO_2 g/mile = [(2,000*4,000 + 3,000*2,000) / 8,000] = 2,300

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 truck, 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

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

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, NOx and PM gram per mile, and gram per ton-mile emission factors for truck and rail freight transport providers. These data are provided in the SmartWayCarrierData2012.xls file, which are 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 marine and air transport providers, and gram per volume-mile emission factors for all modes, in the near future.

<u>Truck Carrier Performance</u>

Truck carrier performance data utilized by the Shipper Tool is based on 2012 truck Partner Tool submittals. 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 ranking category, rather than exact performance levels for a given carrier. Truck ranking categories include:

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

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

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

Truck Performance Ranking

In the 2012 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									
rivate									
	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 possible to aggregate these disparate fleets into one category.

For-hire and private fleets are combined in 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 ranking 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. Ranking for-hire and private separately would have doubled the number of 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									

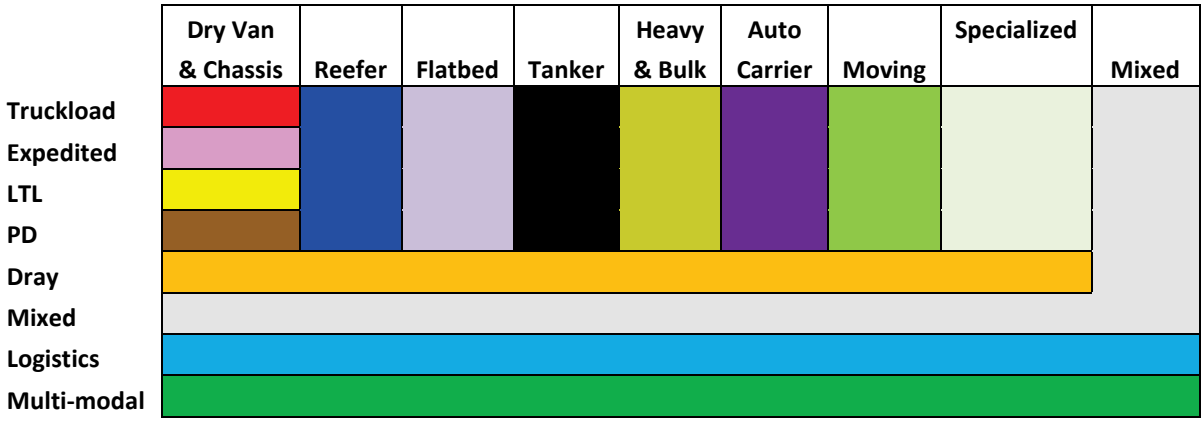
To be categorized in a particular category, a fleet must have at least 75% of its operations by mileage in a single category; otherwise it is classified as a "Mixed" fleet. Fleets may be mixed via their operational or equipment type. Fleets are generally segregated by their operational type, but some 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 category are placed in the Mixed category.

Individual fleets were then placed into 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		-	-	2	-	-	-			-
Mixed				-		-		-	-	-

SmartWay then looked at combining categories that exhibited 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 (intermodal container) 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 intersections would be left undefined. A similar situation was identified with flatbed, tanker, heavy/bulk, auto carrier, moving, and specialized fleets. All dray was collapsed into one category. Any fleet that had mixed operation and/or mixed equipment was placed into a single mixed category. Finally, logistics and multi-modal fleets were also included and retained as unique categories. This produces the final performance categories illustrated below.

SmartWay Carrier Categories: 2012 Data Year



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

Fleets *within a 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, NOx g/mile, NOx g/ton-mile, PM10 g/mile and PM10 g/ton-mile. When performance categories are first established, fleets within a category are separated into 5 groups such that an equal number of fleets were in each category. Each bin thus represents a range of emission factors. This range, and ranking cutpoints (transition points

from one rank to the next) were then modified so that each category had an equal range, and the new cutpoints remained as close to the originals as possible. The new range cutpoint is displayed as a number with significant digits appropriate to emission factors in that category. The midpoint of the range is used as the emission factor for all fleets in a category.

It would be simpler and more straightforward to use fleet-specific emission factors, however the trucking industry expressed concern with revealing exact data that 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 exact 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 (for example 0.001 g/mile of CO_2), SmartWay believes it is acceptable and appropriate to break truck fleets into 5 performance categories. The table below illustrates the bins in the For Hire/Private Truckload/Expedited Dry Van/Container category, using 2010 truck Partner data as an example.

Table 2. Example Binning Results for One Performance Category (2012 Data)

For-Hire/Private Truckload/Expedited Dry Van/Container CO_2 g/mile						
Bin 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	132	865	1,550	1,455	1,500	115
2	254	1,550	1,649	1,603	1,600	29
3	225	1,650	1,749	1,699	1,700	27
4	137	1,750	1,847	1,796	1,800	30
5	111	1,850	5,121	2,011	1,900	428

Similar tables have been developed for all performance 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 bin. Once the categories and bins have been established, the fleets of any new companies joining SmartWay will fall into one of the predefined categories/bins. SmartWay expects to update the category/bin structure approximately every three years.

Performance estimates for non-SmartWay truck carriers were calculated based on the lowest performing truck partners. Since no data exists 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 the standard performance range delta (max - min) for each range within each ranking 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 ranking categories, the worst performance value was selected to be the midpoint for all non-SmartWay Truck carriers. This approach does not require the shipper to identify the appropriate bin category for their non-SmartWay carrier(s), which they may not know.

As discussed in the **Shipper Tool User 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. Alternatively, freight density and cargo volume utilization information can also be used to estimate average payloads. For this reason, average payload and volume information are provided for each carrier in the SmartWayCarrierData2012.xls file. For non-SmartWay truck carriers, the values for average payload (18.7 tons) and average volume (3,260 cubic feet) were derived from the average values for all truck partners (2011 data), weighted by miles.

Logistics and Multi-modal Carrier Performance

Logistic and multi-modal carriers have their own performance categories based on the carrier Tool submittals.[2] The Shipper Tool modifies the Range 5 values for each of these categories (logistics and multi-modal) to estimate non-SmartWay carrier performance in the same way as was done for non-SmartWay Truck carriers (i.e., adding the standard range delta value to the Range 5 midpoints).

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 (10,084 g CO_2/gal diesel fuel), from publicly available data submitted in the 2010 railroad R-1 reports to the Department of Transportation. 2010 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. Specific rail companies may have an opportunity to provide company-specific data in the future. The R-1 data and corresponding CO_2 performance data are presented in Table 3 below.

Table 3. Rail Carrier Performance Metric Calculation Inputs and Results (2010 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	1,295,147	646,549,059	11,230,994	1,163	20.20
CSX Transportation	490,050	230,507,431	4,720,293	1,047	21.44
Grand Trunk	88,290	50,586,328	1,206,818	738	17.60
Kansas City Southern	62,354	31,025,588	609,929	1,031	20.76
Norfolk Southern*	440,159	183,104,320	4,081,893	1,087	24.24
Soo Line	65,530	33,473,544	771,033	857	19.74
Union Pacific	1,063,201	525,297,747	10,336,081	1,037	20.41
Total – Industry Average	**3,504,731**	**1,700,544,017**	**32,957,041**	**1,072**	**20.78**

* and combined subsidiaries

[2] As of this writing 2012 performance data is included for multi-modal carriers, and 2011 data for logistics carriers. 20121 logistics carrier data should be included in the carrier file by late summer/early fall of 2013.

NOx 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" section below for details regarding the calculation of industry average NOx and PM performance levels for different modes.

Average payload 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 4. 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 8 below. 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 5 below.

Table 5. Rail Carrier Average Volume Determination

		BNSF	
Freight Car Types (R1 - Schedule 755)	**Avg. Cu Ft.**	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

		BNSF	
Freight Car Types (R1 - Schedule 755)	**Avg. Cu Ft.**	Railcar Miles (x1K)	Cu Ft Miles (x1K)
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**

	CSX	
Freight Car Types (R1 - Schedule 755)	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

	CSX	
Freight Car Types (R1 - Schedule 755)	Railcar Miles (x1K)	Cu Ft Miles (x1K)
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**

	Grand Trunk	
Freight Car Types (R1 - Schedule 755)	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**

	Kansas City Southern	
Freight Car Types (R1 - Schedule 755)	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**

	Norfolk Southern	
Freight Car Types (R1 - Schedule 755)	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**

	Soo Line	
Freight Car Types (R1 - Schedule 755)	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**

	Union Pacific	
Freight Car Types (R1 - Schedule 755)	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**

	Total (for Industry Average)	
Freight Car Types (R1 - Schedule 755)	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 tracks 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:

- 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, and railcar-miles for rail;
- Total annual ton-miles (the Tool will automatically populate the **% SmartWay** screen with any truck or rail carrier activity data that shippers entered on the freight **Activity Data** screen);

- Total annual CO_2 emissions, based on the preferred calculation metric specified for each carrier on the **Activity Data** screen (miles or ton-miles)
- Custom Factors including –
    - Percent Spent;
    - Percent Weight Shipped;
    - Percent Packages Shipped;
    - Other Custom Metric (as defined by Shipper).

3.0 Calculator Tools

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

Shipper Operational Strategies[3]

The **Shipper Strategies** screen is optional and is intended for reference purposes only. On the **Shipper Strategies** 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 shipper strategy 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 text description of the strategy. The Tool assumes that total mass emissions are reduced in direct proportion with the specified mileage or weight reduction.[4] Mass emission reductions are calculated by using the appropriate emissions inventory for the **Emissions Summary** screen (based on reported activity data and associated carrier emissions performance data) as shown below:

[3] This "Shipper Strategies" calculation sheet cannot be used if shippers do not provide mileage-related activity data, since the Tool will be unable to determine the shippers' baseline mass emissions.

[4] 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.

S = EF x (1 / (1 – Reduction) - 1)

Where:

S = Savings (tons of CO_2, NOx, or PM)
EF = Emissions inventory value (tons of CO_2, NOx, or PM)
Reduction = the reduction in total miles or weight as a result of the strategy (expressed as fraction)

Fractional reduction estimates must be documented with 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 added 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 their Partner Account Manager.

Modal Shift

Overview

The **Modal Shift** 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** 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 and rail modes corresponding to the company-specific data from 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 rail and/or trucking 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 an alternative emissions factor of their choice (corresponding to the "User Input" selection).

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

While we have populated the Tool with illustrative modal average freight rail and truck 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 ranking 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 likely 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.

Partners may also evaluate modal shifts to and from the marine and aviation sectors by inputting an emissions factor of their choice ("User Input" option only). While we have not provided illustrative marine and aviation freight factors in the Tool, there are several external resources that partners can consult. We have included some selected sources of marine and aviation 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[5]

If the shipper is evaluating a mode shift between truck and rail, and if the available activity units are in miles rather than ton-miles, then an adjustment factor must be applied to the above equation converting railcar-miles (the activity unit for the rail mode) to equivalent truck miles (the unit for the truck mode).

The railcar-to-truck equivalency factor is calculated by first identifying the average cargo volume for a given carrier (see Table 5 above). These volumes estimates are contained in the Carrier Data File, and are weighted by the miles associated with each rail carrier on the **Activity Data** screen in order to estimate a single weighted-average railcar volume for the shipper company in question. Similarly, weighted average volumes are also calculated for the different truck carriers associated with the given shipping company. The weighting calculations involve all carriers used by the company if no filters are selected on the **Modal Shift** screen (only relevant for the "From" mode). Otherwise the weighted average calculation is only performed for the filtered subset (e.g., inbound domestic truck carriers).

Once the weighted average volumes are determined for both rail and truck modes, the Tool calculates

[5] 1.1023×10^{-6} short tons/gram

the ratio of the average railcar volume to the average truck volume (R). Next, the Tool converts the g/railcar-mile values (g/RC-mi) to g/truck-equivalent mile values by dividing g/RC-mi by the ratio R. The Tool then shows these values in the appropriate efficiency column, and uses these values to calculate emission changes as shown in the equation above. This approach does not require the shipper to develop and apply equivalency factors, relying on simple railcar-mile activity estimates.

Background on Illustrative (Modal Average) U.S. Truck and Rail Factors

Modal Average performance metrics have been developed for rail and truck modes (both gram per mile and gram per ton-mile), for estimating emission impacts using the **Modal Shift** screen. We developed the freight **truck g/ton-mile** factors with 2010 CO_2, NO_x, and PM2.5[6] inventory data on short-haul single unit, short-haul combination unit, long-haul single unit, and long-haul combination unit truck categories[7] in EPA's 2010a version of the Motor Vehicle Emissions Simulator (MOVES2010a) model[8]. MOVES does not contain ton-mile data, so we then divided the MOVES-based inventories by 2002 ton-mile data from the Federal Highway Administration's *2009 Freight Facts and Figures*[9], which we determined was the most recent, comprehensive national freight truck ton-mile dataset available.

For the freight **truck g/mile factors**, we used the same emissions inventory data as the g/ton-mile factors described above and divided them by the corresponding 2010 VMT data in MOVES2010a.

Table 6 presents the illustrative freight truck emissions factors in the tool and Table 7 presents the key underlying data. (Note that the modal average factors calculated for truck carriers were assumed valid for logistics carriers as well.)

Table 6: **Illustrative U.S. Freight Truck Industry Average Factors in Modal Shift**

	CO_2	NO_x	$PM_{2.5}$
gram/short ton-mile	161.8	1.114	0.0480
gram/mile	1,661	11.44	0.4925
gram/TEU-mile	597.4	4.113	0.1772

Table 7: Underlying Emissions Inventories and Activity Data for Illustrative U.S. Freight Truck Industry Average Factors in Modal Shift

CO_2 (grams)	341,986,421,100,000
NO_x (grams)	2,354,767,660,000
$PM_{2.5}$ (grams)	101,411,195,611
short ton-miles	2,114,115,022,573
miles	205,918,984,400

[6] Corresponding PM10 emission factors were estimated assuming PM2.5 values were 97% of PM10 values, based on MOVES model outputs for diesel fueled trucks.
[7] These four truck categories are coded as 52, 53, 61, and 62 in the MOVES model, respectively.
[8] EPA's MOVES model and accompanying resources, including technical documentation, are available at: www.epa.gov/otaq/models/moves/index.htm.
[9] U.S. DOT, Federal Highway Administration, 2009. *Freight Facts and Figures 2009*, FHWA-HOP-10-007, Ton Miles of Truck Shipments by State: 2002 (Table 3-10). Available at: http://ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/09factsfigures/table3_10.htm

We developed the freight **rail gCO_2/ton-mile** factors with 2008 inventory data from EPA's most recent *Inventory of U.S. Greenhouse Gas Emissions and Sinks (1990-2008)*[10], which is based on Class I rail fuel consumption data from the Association of American Railroads and estimates of Class II and III rail fuel consumption by the American Short Line and Regional Railroad Association. We divided this emissions inventory by the latest rail ton-mile data (2007) presented in Table 1-46b in the Bureau of Transportation Statistics' (BTS) *National Transportation Statistics*[11], which is intended to encompass all freight rail ton-miles, including Classes I, II, and III.

We developed the freight **rail gNO_x/ton-mile and gPM2.5/ton-mile** factors with 2010 inventory data from Tables 3-82 and 3-83, respectively, in EPA's 2008 Regulatory Impact Analysis for a locomotive diesel engine rule[12]. 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 we determined would very closely align with the freight rail sector. We divided this emissions inventory data by the 2007 BTS ton-mile data described above.

We developed the freight **rail g/mile** factors 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[13]. We then converted the railcar-miles into "truck-equivalent" 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 very crude 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 truck-equivalent railcar miles. (As discussed above, carrier-specific volumes and truck-equivalent conversion factors can be applied by selecting the "Select Carriers" data source option on the **Modal Shift** screen, if available.)

To estimate the average volume capacity of Class I 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 8 to get 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) 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. (Note the 1.41 factor was also used to convert modal average g/truck-equivalent

[10] U.S. EPA, 2010. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2008* , Washington DC (EPA 430-R-10-006), available at: http://www.epa.gov/climatechange/emissions/usgginv_archive.html. Total freight rail GHG emissions are presented in Table A-110 of the inventory. Table 10 in this document presents CO_2-only data. In order to isolate the CO_2-only emissions data, we accessed spreadsheets that are not publically available.

[11] U.S. DOT, Research and Innovative Technology Administration, Bureau of Transportation Statistics, 2009. *National Transportation Statistics,* Table 1-46b - U.S. Ton-Miles of Freight (BTS Special Tabulation) (Updated September 2009). Available at: www.bts.gov/publications/national_transportation_statistics/html/table_01_46b.html

[12] 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: www.epa.gov/otaq/regs/nonroad/420r08001a.pdf

[13] 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

mile performance metrics to the g/railcar-mile factors displayed on the **Modal Shift** screen of the Shipper Tool.)

We developed the CO_2 inventory for the rail g/mile factors by using 2008 Class I rail fuel consumption reported in the R-1 reports and an emissions factor of 10,180 gCO_2/gallon, which corresponds to the diesel emissions factor in the current version of the SmartWay Truck Tool.[14] We developed the NO_x and PM inventories in a similar fashion using the average 2010 locomotive gPM10/gal and gNOx/gal factors from Tables 5 and 6, respectively, in EPA's 2009 *Technical Highlights: Emissions Factors for Locomotives*[15]. To calculate gPM2.5/gal, we assumed 95% of PM10 is PM2.5, which we determined was a good approximation of the share of overall PM10 emissions represented by particulate matter that is 2.5 micrometers in diameter or smaller.

Table 9 presents the illustrative freight rail emissions factors in the Tool and Table 10 presents the key underlying data.

Table 8: Railcar Volume Assumptions and Sources

Railcar Type	**Cubic Feet**	**Source/Method** ***Key:*** Norfolk Southern Railroad (NS)[16], Union Pacific Railroad (UP)[17], Burlington Northern Santa Fe Railroad (BNSF)[18], CSX Transportation Railroad (CSX)[19], World Trade Press Guide to Railcars (GTRC)[20], Chicago Rail Car Leasing (CRCL)[21], Union Tank Car Company (UTCC)[22], U.S Department of Agriculture (USDA)[23]
Boxcar 50 ft and longer including equipped boxcars	7,177	Based on the average of the following boxcar types: 50ft assumed to be 5694 [reflecting the average of 5355 (NS), 5431 (UP), 5238 (CSX), 6175 (BSNF), 6269 (GTRC)]. 60ft assumed to be 6,648 [reflecting the average of 6618 (NS), 6389 (UP), 6085 (CSX), 7500 (BNSF)]. 50ft high cube assumed to be 6,304 [reflecting the average of 6339 (NS) and 6269 (CSX)]. 60 ft high cube assumed to be 6917 [reflecting the average of 7499 (NS) , 6646 (CSX), and 6607 (GTRC)]. 86ft assumed to be 9999 (NS). Autoparts 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.

[14] The source of the diesel factor is the fuel economy calculations in 40 C.F.R 600.113 available at http://edocket.access.gpo.gov/cfr_2004/julqtr/pdf/40cfr600.113-93.pdf.

[15] 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: http://www.epa.gov/oms/regs/nonroad/locomotv/420f09025.pdf.

[16] http://www.nscorp.com/nscportal/nscorp/Customers/Equipment_Guide

[17] http://www.uprr.com/customers/equip-resources/cartypes/index.shtml

[18] http://www.bnsf.com/customers/how-can-i-ship/individual-railcar/#%23subtabs-3

[19] http://www.csx.com/index.cfm/customers/equipment/railroad-equipment/#boxcar_specs

[20] http://www.worldtraderef.com/WTR_site/Rail_Cars/Guide_to_rail_Cars.asp

[21] http://www.crdx.com/railcar.html

[22] http://www.utlx.com/bdd_tank.html

[23] 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: http://www.ers.usda.gov/publications/ah697/ah697.pdf

Railcar Type	**Cubic Feet**	**Source/Method** ***Key:*** Norfolk Southern Railroad (NS)[16], Union Pacific Railroad (UP)[17], Burlington Northern Santa Fe Railroad (BNSF)[18], CSX Transportation Railroad (CSX)[19], World Trade Press Guide to Railcars (GTRC)[20], Chicago Rail Car Leasing (CRCL)[21], Union Tank Car Company (UTCC)[22], U.S Department of Agriculture (USDA)[23]
Flat car – all types except for multi-level	6,395	Based on the average of the following flat car types: 60ft assumed to be 6739 (BNSF). 89ft assumed to be 9372(BNSF). Coil assumed to be 3387(NS). Covered coil assumed to be 5294 [reflecting the average of 8328 (NS) and 2260 (BNSF)]. Centerbeam assumed to be 6546 [reflecting the average of 5857 (UP) and 7236 (BNSF)]. Bulkhead assumed to be 7030 (BNSF).
Multi-level flat car	13,625	Based on the average of the following multi-level flat car types: Unilevel (that carry very large cargo, such as vehicles/tractors) assumed to be 12183 (NS). Bi-level assumed to be 14381(NS). 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 gondala car types: 52-53ft assumed to be 2626 [based on average of 2665 (NS), 2743 (CSX), 2400 (BNSF), and 2697(CRLC)]. 60-66ft assumed to be 3372 [based on average of 3281 (NS), 3242 (CSX), 3350 (BNSF), CRCL-3670,and 3366 (GTRC)]. Municipal Waste assumed to be 7999 (NS). Woodchip assumed to be 7781[based on average of 7862 (NS) and 7700 (CRCL)]. 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: 48-72ft assumed to be 6963 [based on average of 6043 (UP) and 7883 (BNSF)]. 50ft assumed to be 5167(GTRC). 40-90 ft assumed to be 6476 [based on average of 6952 (UP) and 6000 (BNSF)].
Open Top Hopper	4,220	Based on the average of the following open top hopper car types: 42ft assumed to be 3000 (UP). 54ft assumed to be 3700 (UP). 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). Woodchip assumed to be 7075 [based on average of 7525 (NS), 5999 (UP), and 7700 (CRCL)]. 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: 45ft assumed to be 5250 (GTRC). Aggregate assumed to be 2575 [based on average of 2150 (NS) and 3000 (CRCL)]. Small Cube Gravel assumed to be 2939 [based on average of 2655 (NS), 3100 (CSX), and 3063 (BNSF). Med-Large Cube Ores and Sand assumed to be 4169 [based on average of 3750 (NS) and 4589 (BNSF)]. Jumbo assumed to be 5147 [based on average of 4875 (NS), 4462 (CSX), 5175 (BNSF), and 6075 (CRCL)]. Pressure Differential (flour) assumed to be 5050 [based on average of 5124 (NS) and 4975 (CRCL)].

Railcar Type	Cubic Feet	Source/Method ***Key:*** Norfolk Southern Railroad (NS)[16], Union Pacific Railroad (UP)[17], Burlington Northern Santa Fe Railroad (BNSF)[18], CSX Transportation Railroad (CSX)[19], World Trade Press Guide to Railcars (GTRC)[20], Chicago Rail Car Leasing (CRCL)[21], Union Tank Car Company (UTCC)[22], U.S Department of Agriculture (USDA)[23]
Tank Cars under 22,000 gallons	2,314	Assumes 1 gallon=0.1337 cubic foot (USDA). 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). 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 9: Illustrative U.S. Freight Rail Industry Average Factors in Modal Shift

	CO_2	NO_x	PM2.5
gram/short ton-mile	22.94	0.4270	0.0120
gram/truck-equivalent mile	813.8	13.19	0.3569
gram/TEU-mile	292.8	4.745	0.1284

Table 10: Underlying Emissions Inventories and Activity Data for Illustrative U.S. Freight Rail Industry Average Factors in Modal Shift

CO2 (grams)	41,736,353,990,153
short ton-miles	1,819,633,000,000
Class I-only diesel fuel consumption (gallons)	3,905,310,865
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*

Note that NOx and PM emission factors were not available at the carrier level for the rail mode. Accordingly, the modal average emission factors for NOx and PM were assumed to apply equally for all rail carriers, even though the corresponding factors for CO_2 emissions are company-specific. Also, note that the g/truck-equivalent mile factors for NOx and PM were converted back to a g/railcar mile basis for inclusion in the carrier file, to be consistent with the **Modal Shift** calculation methodology described above.

Outside Sources of Marine and Air Emission Factors

There are many sources of marine and aviation emission factors available in research literature and other GHG estimation tools. For reference, we have included below:

- gCO_2/ton-mile marine and aviation factors from the Business for Social Responsibility's (BSR) Clean Cargo Tool gCO_2/ton-mile marine and aviation factors from a study prepared for the International Maritime Organization (IMO)[24]
- multi-pollutant g/ton-mile barge factors from a study prepared by the Texas Transportation Institute (TTI) for the U.S. Maritime Administration[25]

Note that the factors from BSR and IMO are published in units of $kgCO_2$/metric ton-km, so we converted this data into gCO_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. BSR also included two aviation factors in their tool from DEFRA for short and long international trips, which reflect higher CO_2 emissions rates from shorter trips because landing and take-off operations consume more fuel than cruising at altitude. The BSR aviation and marine factors in Tables 11 and 12 below are from the "Emission Factors & Distances" tab in their tool.

Table 11: BSR Marine Emission Factors (gCO_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

[24] Buhaug, Ø., 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/OurWork/Environment/PollutionPrevention/AirPollution/Documents/GHGStudyFINAL.pdf

[25] U.S. Maritime Administration and the National Waterways Foundation (U.S. MARAD), amended March 2009. *A Modal Comparison of Domestic Freight Transportation Effects on the General Public* . Prepared by Center for Ports & Waterways, Texas Transportation Institute. Available at: www.waterwayscouncil.org/study/public%20study.pdf

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

Table 12: BSR Air Emission Factors (gCO_2/short ton-mile)

Air_freight_long_>3700km	**International**	**868.3227**
Air_freight_short_<3700km	**International**	**2049.9959**

The marine and aviation factors in the **IMO** study reflect commonly-used equipment sizes and types. The factors in Tables 13 and 14 below come from Table 9.1 and 9.4 in the IMO study, respectively.

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 + m^3	46,656	48%	16.6	2,411,297,106	7.59	13.14
LPG tanker	0-49,999 m^3	3,120	48%	14	89,631,360	39.41	63.50
LNG tanker	200,00 + m^3	97,520	48%	19.6	5,672,338,333	7.88	13.58
LNG tanker	0-199,999 m^3	62,100	48%	19.6	3,797,321,655	12.26	21.17

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)
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
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.							

Table 14: IMO Air Emission Factors (gCO2/short ton-mile)

Boeing 747F	**high**	**691.89**
Boeing 747F	**low**	**634.96**
Ilyushin IL 76T	**high**	**2,627.43**
Ilyushin IL 76T	**low**	**1,605.65**

The barge emissions factors presented in Table 15 are from Table 10 in the **TTI** study and reflect inland waterway towing operations in the U.S. We converted the PM10 factor in the TTI study into PM2.5 by assuming 95% of PM10 is PM2.5, which we determined was a good approximation of the share of

overall PM10 emissions represented by particulate matter that is 2.5 micrometers in diameter or smaller.

Table 15: TTI Barge Emission Factors

	CO_2	NO_x	PM2.5
gram/short ton-mile	17.48	0.4691	0.0111

4.0 Data 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

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 2, 3, 5, and 6, where payloads are either entered by the user, or calculated based on other inputs. Checks are applied at the carrier (row) level. Both direct payload inputs and indirect payload (derived from density and load % calculators) are checked, using the same criteria for each. If Data Availability Options 3 or 6 are used, the following equation is used to calculate inferred payload:

Payload (tons) = (density/2000) x carrier average volume x (average load percent/100)

Payload checks are specific to the truck performance ranking category, which is available for each carrier from the Carrier Data File. For Truck carriers, the payload checks are consistent with the Class 8b payload checks currently in the Truck Tool, and are shown below in Table 16. (See the **Truck Tool Technical Documentation** for additional information.) Note that Ranges 1 and 5 are colored red, and require explanations before proceeding. Ranges 2 and 4 are colored yellow, and explanations are optional.

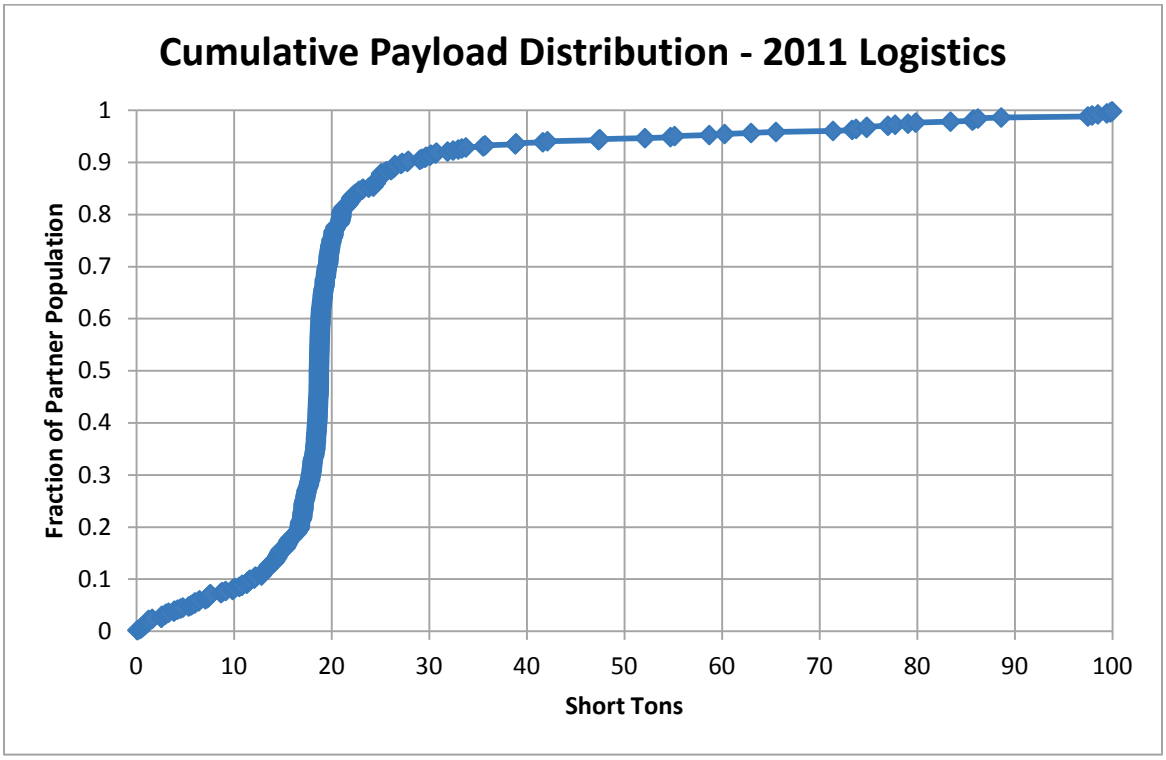
Table 16. Truck Carrier Payload Validation Ranges

Truck Bin Category	Range 1 Low	Range 1 High / 2 Low	Range 2 High / 3 Low	Range 3 High / 4 Low	Range 4 High / 5 Low	Range 5 High (Max)
LTL Dry Van (from Dry Van Single - LTL-Moving-Package)[26]	0.0	0.0	11.0	19.1	23.2	83.7
Package (from Dry Van Single - LTL-Moving-Package)	0.0	6.9	11.0	19.1	23.2	83.7
TL Dry Van (from Dry Van Single - other bins)	0.0	10.5	14.5	22.4	26.4	150.0
Refrigerated	0.0	14.5	17.3	22.9	25.7	82.5
Flatbed	0.0	14.0	18.3	26.7	31.0	99.9
Tanker	0.0	19.1	22.0	27.8	30.7	103.8
Moving (from Dry Van Single – LTL-Moving-Package)	0.0	6.9	11.0	19.1	23.2	83.7
Specialized (from Specialty - Other bins)	0.0	20.2	22.9	28.3	31.1	111.0
Dray (from Chassis)	0.0	11.2	16.5	27.1	32.4	73.5
Auto Carrier	0.0	5.7	11.0	21.4	26.6	73.5
Heavy-Bulk	0.0	2.7	16.5	44.0	57.8	120.0
Utility (from Specialty – Other bins)	0.0	20.2	22.9	28.3	31.1	111.0
Mixed (from Other - Heavy-Flatbed-Mixed bins)	0.0	14.7	21.1	33.8	40.1	99.3
Expedited (from Dry Van Single - other bins)	0.0	10.5	14.5	22.4	26.4	150.0

Logistic carrier payload validations are based on 2011 Logistics Partner data, and use simple cutoffs from the cumulative payload distribution shown in Figure 1 below.

[26] Since LTL shipments can be very small, no lower-bound "red/yellow" ranges are designated for LTL carrier payloads.

Figure 1. Logistics Partner Payload Distribution



As can be seen in the figure, the payload distribution is highly non-normal, so use of validation cutoffs based on standard deviation is not appropriate. However, rough inflection points appear at approximately 10%, 20%, 80%, and 90%. As such, these values were used to specify the following payload validation cutoffs for logistics carriers.

- Range 1 Red: 0 – 12.0 tons
- Range 2 Yellow: 12.0 – 16.7 tons
- Range 3: 16.7 – 21.0 tons
- Range 4 Yellow: 21.0 – 27.2 tons
- Range 5 Red: 27.2 – 150 tons (150 absolute max)

Validation levels for rail and multi-modal carriers are summarized below. The upper bound cutpoints for multi-modal payloads are based on a qualitative review of 2011 multi-modal 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 4 above).

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

In addition, the absolute upper bound for rail and multi-modal carriers have both been set at 200 tons.

Finally, any payload value less than or equal to zero will be flagged as an error and must be changed.

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.