SmartWay 2.0.10 Shipper Tool – Technical Documentation:

United States Version

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

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1-3-12

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 carrier emissions performance data that EPA has included in the tool, along with publically available 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.

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[1] While this tool is primarily focused on freight movements in the U.S. rail and trucking sectors, our long-term vision is to provide shippers with tools to help them evaluate the emissions performance of their full freight transportation supply chain.

2.0 Tool Inputs and Calculations

After shippers enter their company and contact information, they provide basic information about each company they operate, including name and NAICS code. Shippers 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 parameters serve as "tags" which allows shippers to filter their emission data as desired using the screen tools discussed in Section 3 below.

Next, if shippers have annual mileage-related activity data by carrier (miles or ton-miles), they select the "Emissions Footprint and % SmartWay" option on the second data entry screen, and proceed to input activity data for each carrier. Otherwise, they 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 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 bin-level emissions performance data for truck, logistics and multi-modal carriers as well as available Class 1 and rail-industry-wide emissions factors.

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** and **Carrier Performance** 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.

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
- T2 has a CO$_2$ g/mile of 2
- T3 has a CO$_2$ g/mile of 3
- 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*2,000 + 2*4,000 + 3*2,000) / 8,000] = 2

- When Inbound/Outbound combo = Inbound:

  - Composite CO$_2$ g/mile = [1*2,000 / 2,000] = 1

- When Inbound/Outbound combo = Outbound:

  - Composite CO$_2$ g/mile = [(2*4,000 + 3*2,000) / 8,000] = 2.3

> **For Future Tools: Addressing Empty Miles, Out-of-Route Miles, Return Miles**
>
> Ideally, total emissions should be adjusted to account for possible under-reporting of system miles. Shippers generally only see the miles they are invoiced by the carrier moving the freight, or use a point-to-point mileage calculation. In many cases, shippers may be charged for all miles traveled by the carrier, including empty miles and out-of-route miles, but shippers may only be aware of the point-to-point mileage. Therefore a shipper will base its emissions inventory calculations only on the miles of which they are aware, and will therefore not account for all of the emissions associated with their freight.
>
> EPA is investigating potential adjustment factors that can help ensure that shippers report their full emissions inventory. These factors may be specific to each carrier mode or possibly each carrier fleet type (e.g., distinguishing TL and LTL). While there are many ways to calculate this factor, it will likely follow this basic form:
>
> emissions adjustment factor = total carrier fleet odometer miles / miles invoiced to shippers

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 SmartWayCarrierData.xls file, which should be downloaded to the user's computer using the button on the tool's Home page.

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 2010 truck partner tool submittals. Performance data includes g/mile, g/ton-mile, and bin ranking (1-5) for each truck carrier, with a bin ranking of 1 indicating top 20 percent performance for a given pollutant/bin category. Note that g/mile and g/ton-mile values represent midpoints for the appropriate bin category, rather than exact performance levels for a given carrier. Truck bin categories include:

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

- Package
- Specialized
- Mixed

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

Truck Performance Binning

In the 2010 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, or package delivery, and C.) equipment type: dry van, refrigerated van, flatbed, tanker, chassis (container), or specialized (auto carrier, bulk, heavy haul, others.)[2] The possible categories are shown below.

For-Hire						
	Dry Van	**Refrigerated**	**Flatbed**	**Tanker**	**Chassis**	**Specialized**
TL & Exp						
LTL						
Dray						
PD						

Private						
	Dry Van	**Refrigerated**	**Flatbed**	**Tanker**	**Chassis**	**Specialized**
TL & Exp						
LTL						
Dray						
PD						

As originally developed, truckload and expedited were treated as separate categories, and specialized was broken out into bulk, auto, heavy haul, and moving. For purposes of simplification, truckload and expedited are treated as similar operations, and due to small numbers of trucking fleets, bulk, auto, heavy haul and moving were aggregated into one category. Specialized fleets will have disparate operations/equipment types and thus do not compare well, however they are also unlikely to compete with one another, so it was deemed possible to aggregate these into one bin.

For-hire and private fleets are combined in SmartWay categories/bins. 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

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[2] Additional operation and body type categories have been added to the 2011 Truck Tool and will be reflected in next year's Shipper Tool.

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. Fleets can thus be categorized as shown below.

For-Hire and Private Fleets						
	Dry Van	**Refrigerated**	**Flatbed**	**Tanker**	**Chassis**	**Specialized**
TL & Exp						
LTL						
Dray						
PD						

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 classed as a "Mixed" fleet. Fleets could 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 graphic illustrates the population of the various categories. The darker the shade of the intersection, the higher the number of fleets in that category.

For-Hire and Private							
	Dry Van	**Refrigerated**	**Flatbed**	**Tanker**	**Chassis**	**Specialized**	**Mixed**
TL & Exp							
LTL							
Dray							
PD							
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 two categories were combined. A similar situation was identified with flatbed, and flatbed truckload and less than truckload were combined. Although no less than truckload tanker fleets were identified, tanker truckload and less than truckload were combined into one category so that no intersections would be left undefined. All dray was collapsed into one category. Any fleet that had mixed operation and/or mixed equipment was placed into a single mixed category. This produces the final bin categories illustrated below.

For-Hire and Private						
	Dry Van/Chassis	**Refrigerated**	**Flatbed**	**Tanker**	**Specialized**	**Mixed**
TL & Exp						
LTL						
PD						
Dray/Package						
Mixed						

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.

Companies 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. Companies within a category were then separated into 5 groups (bins) such that an equal number of companies were in each bin. Each bin thus represents a range of emission factors. This range, and bin cutpoints (transition points from one bin to the next) were then modified so that each bin had an equal range, and the new bin 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 companies in a bin.

It would be simpler and more straightforward to use company-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 companies, and thus opportunity for companies 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 bins. The table below illustrates the bins in the For Hire/Private Truckload/Expedited Dry Van/Container category, using 2010 truck partner data.

Table 2. Example Binning Results for One Bin Category (2010 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	159	602	1,600	1,503	1,550	141
2	241	1,601	1,699	1,654	1,650	28
3	204	1,700	1,799	1,746	1,750	28
4	139	1,800	1,899	1,853	1,850	28

| 5 | 55 | 1,900 | 3,701 | 2,064 | 2,801 | 302 |

Similar tables were developed for all categories. The midpoint of each bin is the data that a Shipper will download 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 bin delta (min/max) for each bin category, and using the delta to calculate a non-SmartWay carrier midpoint for each bin category. This midpoint was the midpoint for Bin 5 plus the standard bin delta. For example, if the Bin 5 midpoint was 10.5 and the Bin Categories 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 Bin Categories, the worst performance value was selected to be the midpoint for the 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 SmartWayCarrierData.xls file. For Non-SmartWay truck carriers, the values for average payload (17.1 tons) and average volume (3,334 cubic feet) were derived from the average values for all truck partners (2010 data), weighted by miles.

Logistics and Multi-modal Carrier Performance

Logistic and multi-modal carriers have their own performance bins based on the carrier tool submittals for the 2010 calendar year. The Shipper Tool modifies the Bin 5 values for each of these bin 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 bin delta value to the Bin 5 midpoints).

<u>Rail Carrier Performance</u>

Rail carrier performance data are collected and displayed in the Shipper Tool at the individual company level for Class 1 rail companies. 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 each Class 1 carrier, in order to estimate gram per railcar-mile factors. Industry average values are used for non-class 1 and Non-SmartWay rail carriers. It is anticipated that Class 2 and 3 rail companies will 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
Non Class 1 and Non-SmartWay	3,504,731	1,700,544,017	32,957,041	1,072	20.78

* and combined subsidiaries

NOx and PM emission factors for rail carriers are 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 performance levels for different modes.

Average payload per loaded railcar were calculated for each Class 1 carrier by dividing the value for annual ton-miles hauled by an estimate for <u>loaded</u> 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
Non Class 1 and Non-SmartWay	93

Average railcar volumes were calculated for each carrier 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. 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

| 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**

	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**

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**

	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**

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**

	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
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)
- 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 they provide mileage-related activity data under the "Emissions Footprint" option.

Shipper Operational Strategies[3]

The **Shipper Strategies** screen is optional and is intended for scoping 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

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[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.

- o Package weight reduction
- o 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:

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

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 your 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.

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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.

Modal Shift

<u>Overview</u>

The **Modal Shift** screen in the tool is optional and is intended for scoping 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 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 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 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,

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[5] 1.1023 x 10^{-6} short tons/gram
[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.

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

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

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[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
[10] U.S. EPA, 2010. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 200*8 , 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.

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

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[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

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.

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[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.

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.
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),

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[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]
		3350 (BNSF), CRCL-3670,and 3366 (GTRC)]. <u>Municipal Waste</u> assumed to be 7999 (NS). <u>Woodchip</u> assumed to be 7781[based on average of 7862 (NS) and 7700 (CRCL)]. <u>Coal</u> 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: <u>48-72ft</u> assumed to be 6963 [based on average of 6043 (UP) and 7883 (BNSF)]. <u>50ft</u> assumed to be 5167(GTRC). <u>40-90 ft</u> 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: <u>42ft</u> assumed to be 3000 (UP). <u>54ft</u> assumed to be 3700 (UP). <u>60ft</u> assumed to be 5188 [based on average of 5125 (UP) and 5250 (GTRC)]. <u>45ft+</u> assumed to be 4105 [based on average of 4500 (UP) and 3710 (BNSF). <u>Woodchip</u> assumed to be 7075 [based on average of 7525 (NS), 5999 (UP), and 7700 (CRCL)]. <u>Small Aggregate</u> 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: <u>45ft</u> assumed to be 5250 (GTRC). <u>Aggregate</u> assumed to be 2575 [based on average of 2150 (NS) and 3000 (CRCL)]. <u>Small Cube Gravel</u> assumed to be 2939 [based on average of 2655 (NS), 3100 (CSX), and 3063 (BNSF). <u>Med-Large Cube Ores and Sand</u> assumed to be 4169 [based on average of 3750 (NS) and 4589 (BNSF)]. <u>Jumbo</u> assumed to be 5147 [based on average of 4875 (NS), 4462 (CSX), 5175 (BNSF), and 6075 (CRCL)]. <u>Pressure Differential (flour)</u> 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). 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

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[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

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
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 + 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

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	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. Validation messages are presented for the following conditions:

- Average truck/logistics/multi-modal payloads are less than 9.4 tons (error – red)
- Average truck/logistics payloads are greater than 33.8 tons (error – red)
- Average multi-modal payloads are greater than 90 tons (error – red)
- Average railcar payloads are less than 9.4 tons or greater than 125 tons (error – red)
- Average truck/logistics/multi-modal payloads are between 9.4 and 15.5 tons (warning – yellow)
- Average truck/logistics payloads are between 27.7 and 33.7 tons (warning – yellow)
- Average multi-modal payloads are between 60 and 90 tons (warning – yellow)
- Payload is less than or equal to zero (error)

The cutpoints for Truck and Logistics carriers (and the lower bound cutpoints for mult-modal and rail carriers) are based on the payload validation ranges used in the Truck Tool for Class 8b trucks. (See the **Truck Tool Technical Documentation** for additional information.) The upper bound cutpoints for multi-modal payloads are based on a qualitative review of 2010 multi-modal carrier tool submittals. The upper bound cutpoints for rail payloads are based on the distribution of average values estimated for Class 1 carriers (see Table 4 above). These 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).