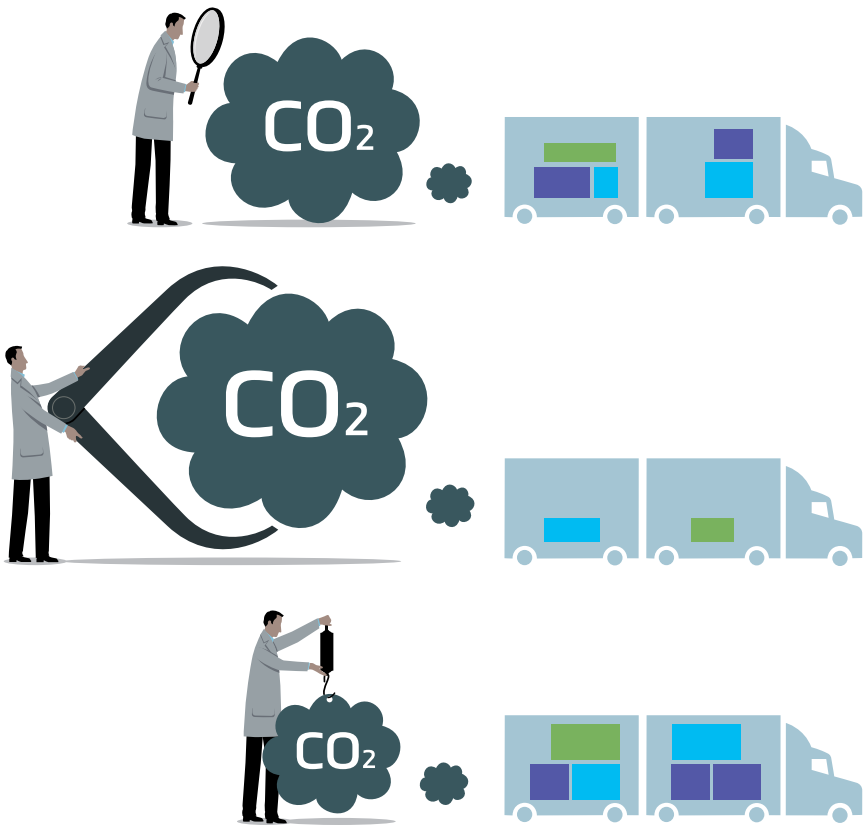
A New Model for Estimating Carbon Emissions from LTL Shipments

WHITE PAPER



MIT Center for Transportation & Logistics

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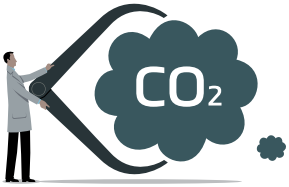
In brief

Calculating carbon emissions for less than truckload (LTL) is more challenging than for other modes of transportation. Each LTL truck combines a wide mix of freight from many shippers, with varying origin-destination pairs. Without visibility to the details about individual shipments on that truck, accurate carbon emission estimates at the shipment level can be difficult to obtain. Graduate students at the MIT Center for Transportation & Logistics (MIT CTL) examined this issue, using actual LTL shipment data from TMC, a division of C.H. Robinson, and a national LTL carrier. The models discussed in this paper were developed from this research. This white paper also includes an easy to use model derived from this research to help companies calculate their own LTL carbon emissions.



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Measuring the carbon emissions of various types of freight transportation has been a feature of logistics sustainability programs for some time. Yet, there is no widely accepted, accurate template for calculating emissions for individual LTL shipments.

In addition, there is inconsistency in how carbon emissions are calculated around the world. In the United States, most LTL methodologies are based on calculations for truckload service, using the well-known GHG Protocol and EPA SmartWay Program (see below). However, the macro-level data used in these programs cannot account for the unique characteristics of individual LTL shipments.

CARBON EMISSIONS STANDARDS

1. **The Greenhouse Gas Protocol Corporate Accounting and Reporting Standard (GHG Protocol)** was developed by the World Business Council for Sustainable Development and by the World Resources Institute and released in September 2001. Currently, this protocol is the most widely accepted tool for identifying, quantifying, and managing greenhouse gas emissions. It is written primarily from the perspective of an organization developing an inventory of emissions.

2. **The SmartWay Transport Partnership** is a public-private initiative between the U.S. Environmental Protection Agency and more than 3,000 trucking and logistics companies, rail carriers, and other stakeholders. Launched in 2004, SmartWay aims to improve fuel efficiency, reduce the environmental impacts of freight transportation, and encourage overall supply chain sustainability. Shippers, carriers, and logistics companies use different reporting tools to benchmark their performance against the industry. SmartWay partners demonstrate to customers and investors that they are tracking emissions and working to improve overall efficiency and reduce their carbon footprint.

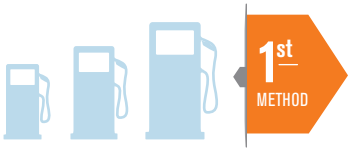
Compared to truckload, LTL is relatively complex. Smaller shipments from an average of 20 to 30 companies—a wide range of products in various packaging configurations, ranging from 100 to 10,000 pounds—may be consolidated onto a single truck. Delivery routes include extensive pickup and delivery (P&D) operations at multiple origins and destinations, compared to truckload services, where P&D activity is minimal. Determining the carbon emissions from one shipment on such a truck requires visibility to the details and data about the freight.

Guilherme Veloso de Aguiar and Mark Anderson Woolard, two graduates in the Supply Chain Master's program at the MIT Center for Transportation & Logistics (MIT CTL), decided to investigate. Directed by Dr. Edgar Blanco, MIT CTL's research director, the researchers teamed up with C.H. Robinson's TMC division and a national LTL carrier to gather comprehensive shipment- and route-level data about actual LTL movements.

The resulting thesis, *Estimating Carbon Emissions from LTL Shipments*, shows that current calculation models can be highly inaccurate. While the findings reveal that there is no magic bullet for calculating LTL carbon emissions, they lay the groundwork for future research. Some topics for further investigation include how to more accurately incorporate the dynamics of pickup and delivery operations, and how to take into account shipment class and density information when estimating carbon emissions.

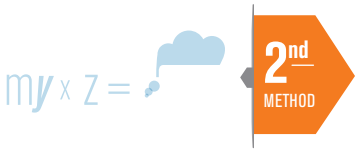
A LACK OF HARMONY RESULTS IN ESTIMATION, NOT MEASUREMENT

Freight transportation is a leading source of greenhouse gases across the globe, yet the methods used to calculate these emissions vary tremendously. Dr. Edgar Blanco, MIT CTL, explains how the methodologies for calculating freight emissions have evolved, why it's challenging to calculate freight emissions accurately, and how the different approaches might be harmonized.



There are two main methods for quantifying emissions from transportation.

Fuel-based approaches use fuel consumption data to estimate emissions levels, based on the fuel's content and assumptions regarding its combustion. This method has been adopted by the GHG Protocol, and relies on estimates of the amount of fuel consumed. This method is likely only applicable to carriers, because they have access to detailed fuel consumption data.

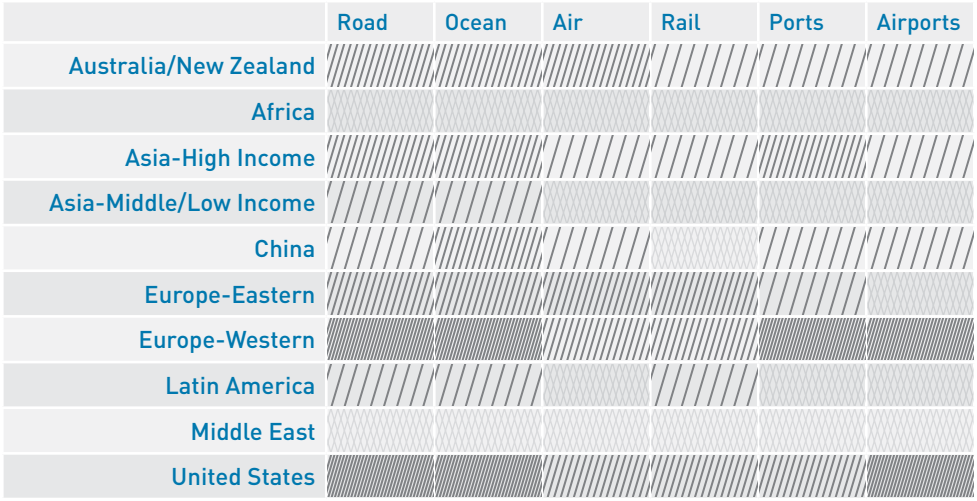


Activity-based approaches can be used when fuel data is not available. In this method, some measure of activity, such as vehicle miles traveled or ton miles moved, is multiplied by an emissions factor to estimate total emissions (the approach taken in the MIT CTL research). This method is commonly used by shippers and 3PLs because fuel consumption needs to be estimated from miles driven and estimated MPG.

Existing freight emissions methodologies and databases also lack consistency in the emissions factors they recommend. Overall, carbon emission measurement methods applied at the modal level are the least accurate. Shipment-level calculations generally offer more precision, and the methodology should specify how to calculate both emissions for a vehicle and assign emissions values to each shipment carried. This approach can be based on cube, weight, and distance, or some combination of these parameters.

Source: Blanco, Edgar, PhD, MIT CTL. "Assessing Global Freight Emission Methodologies." Prepared for the Global Emissions Council, September 2014.

TABLE 1 **STATE OF FREIGHT EMISSIONS METHODOLOGIES AROUND THE WORLD**[1]



KEY:

- No salient programs, methodologies, or tools exist in the region.
- Initial use of low precision and low depth methodologies and tools, mostly using European or U.S. based emission databases.
- Interest among freight stakeholders to develop regional programs. Methodologies and tools are still mostly low in depth and precision, but efforts are underway to achieve medium levels of comparability and add regional databases.
- Increased adoption and interest of stakeholders is observed toward medium to high precision methodologies, along with increasing levels of comparability and verifiability.

Worldwide, the precision levels and program types in use vary according to region (see Table 1). Variations in operating conditions and data assumptions mean that an emissions estimate carried out in one region might be much less precise when applied elsewhere.

Why estimate LTL's carbon footprint?

If evaluation methods for carbon emissions for freight transportation are generally inconsistent and LTL is a difficult measurement nut to crack, why go to the trouble of developing better models for estimating LTL's carbon footprint?

1. Last mile carbon efficiency is likely to become even more important as e-commerce in global retailing continues to grow. LTL is a significant and growing business, worth $32B in the United States alone. Exploring LTL's carbon footprint might yield important implications for last mile deliveries, where trucks carry a varied mix of loads for different destinations.

1 Blanco, Edgar, PhD, MIT CTL. "Assessing Global Freight Emission Methodologies." Prepared for the Global Emissions Council, September 2014.

DEFINITION:

GREAT CIRCLE MILES

Great circle miles are used in navigation and represent the shortest path between two points on the surface of a sphere, determined through the Haversine formula. It is important to understand that great circle miles are used in this model as a baseline for estimating actual shipped distances and do not mean that a shipment would actually move the same number of miles as the great circle distance.

2. Environmental sustainability is a high priority in the corporate sector. A McKinsey & Company survey of executives about sustainability reported, "Company leaders are rallying behind sustainability, and executives overall believe the issue is increasingly important to their company strategy."[2] Similar findings emerged in a Tompkins Supply Chain Consortium survey of 115 supply chain managers. Of the various categories of sustainability metrics, companies were focusing most on energy consumption and conservation, recycling and reuse of materials, disposal and waste management, transportation and logistics, and greenhouse gas footprint.[3]

3. More governmental mandates for carbon reduction are likely. The United States and China have recently come to an understanding about emissions targets,[4] and European governments are becoming more aggressive about enforcing carbon reduction targets. By actively obtaining detailed information on the carbon footprint of transportation, the industry can develop an accurate picture of sustainability performance. The industry may also use this information to help shape future emissions mandates and avoid unnecessary or damaging regulation.

4. There are questions about the effectiveness of existing sustainability measurement programs. In the McKinsey study, for example, respondents expressed doubts about the effectiveness of their current sustainability programs. Companies "struggle most with components of program execution, including employee motivation, capability building, and coordination of their sustainability work," said the study. Most companies in the Tompkins study also portrayed their capabilities in this area as either average or intermediate, and reported that their measuring efforts are hindered by the manual processes used to track target metrics.

5. A green supply chain is often a more efficient one. Developing a more precise analysis of LTL's carbon output also makes good business sense. Exploring the true carbon efficiency of LTL is likely to highlight potential areas where performance can be improved, and enable shippers and carriers to make smarter operational and environmental decisions. Reductions in carbon emissions are likely linked to reduced costs of operation.

Research Methodology

This thesis research project develops a methodology for estimating carbon emissions from individual LTL shipments, while paying due regard to the complexities of a typical LTL network. The objectives:

- Develop a detailed method for the participating carrier's existing network
- Develop a simplified method using the carrier model that can be applied more generally where the freight network characteristics are unknown
- Identify the flaws in current estimation methods

Achieving these goals required calculating the distance that a given set of LTL shipments was transported from origins to destinations.

2 McKinsey & Company. "Sustainability's Strategic Worth: McKinsey Global Survey Results, Insights & Publications." July 2014.
3 Thompkins Supply Chain Consortium. "Sustainability Metrics Report: Measurement and Reporting." Benchmarking and Best Practices, July 2014.
4 The White House Office of the Press Secretary. "U.S.-China Joint Announcement on Climate Change." November 12, 2014.

The research team analyzed more than three million LTL shipments that were transported by the carrier between August and October 2013 while building the models. Using additional data supplied by TMC, the team tested the results of the models and compared the outputs of the different estimation methods. The data used for model testing was not part of the model building process.

Line haul emissions. First, the line haul distance was determined (i.e., the distance between the first and the last terminal that a shipment goes through). To calculate the total amount of fuel burned on this leg, divide the total distance by the fuel economy factor (miles per gallon, or MPG). The MPG is a parameter in the model based on one year of mileage and fuel consumption data, as supplied by the carrier. Using an emissions factor provided by the EPA Climate Leaders guidance material, the model calculated the total amount of line haul emissions.

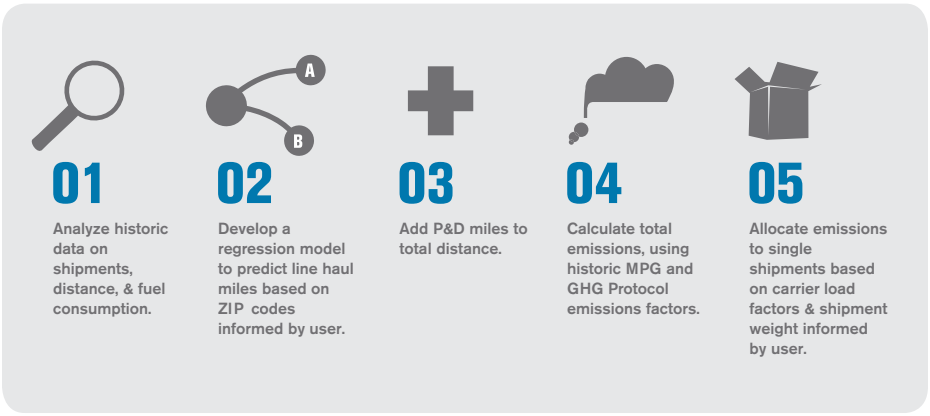
Next, line haul emissions were allocated to each shipment, based on unit weight and the load factor, which was derived from data provided by the carrier. Shipment cube, class, and load density information was not taken into account because weight data is generally accepted as more reliable.

P&D emissions. In the next stage of the model, emissions were added for the pickup and delivery (P&D) segments of the shipments. Values for the number of miles covered and amount of fuel burned were assigned to each shipment based on respective origins and destinations. An MPG value was applied for the P&D operations, also based on carrier data, and the model computed the emissions. The overall emissions number is the sum of the line haul emissions and the P&D emissions.

Modified approach. In addition to a detailed model based on carrier data, a simplified model was created for companies that do not have the detailed information on LTL shipment flows that is available to carriers. This model required the same three basic inputs as the detailed model described above (i.e., origin ZIP, destination ZIP, and shipment weight in pounds). However, there are two main differences in the way the low-precision model is structured.

1. Since the carrier's network is unknown, it is not possible to determine which terminals the shipments pass through. Therefore, the line haul distance is determined by a regression model based on the great circle distance between origin and destination ZIP codes.
2. P&D miles cannot be determined for each specific terminal. Instead, there are pre-determined values that change based on the origin and destination ZIP codes. All the other parameters (such as empty miles, MPG, emissions factors, and load factors) are equal to the values used in the detailed model. It should also be noted that these figures can be adjusted by the user.

FIGURE 1 **FIVE-STEP METHODOLOGY ADOPTED IN THE MIT CTL RESEARCH**



Summary of Research Findings

The research compared five LTL carbon emissions models. Researchers used a new sample of 2,700 shipments moved by the participating carrier that had not been used to build the detailed and simplified models. The methods compared were:

- A detailed model for the participating carrier's existing network
- A simplified model where the characteristics of the LTL network are unknown
- Model 1: A standard, commonly accepted method in the freight transportation industry, not designed specifically for LTL (in this case, the GHG Protocol Freight Transportation method).
  CO_2 = Road Distance x Shipment Weight x Road Emissions Factor
- Model 2: A common approach adopted in the industry for LTL.
  CO_2 = (Miles/MPG) x (Weight/40,000) x Emissions Factor
- Model 3: A revised version of Model 2 with a load factor adjustment.
  CO_2 = (Miles/MPG) x (Weight/25,000) x Emissions Factor

OUTPUT DISPARITIES

The results, which use the detailed model as the base, are depicted in Table 2. Model 2 underestimates the emissions by 62 percent, on average. Adjusting the formula's load factor (the average cargo weight hauled by a truck) from 40,000 pounds (traditionally associated with full truckload shipments) to 25,000 pounds (more representative of the LTL mode) reduces the difference to 39 percent. Model 1, the standard GHG Protocol approach for freight transportation, yielded an estimate that is 31 percent higher than the base model. The difference between the detailed and simplified models is only 3 percent, in aggregate.

TABLE 2 **EMISSIONS COMPARISON—2,700 SAMPLE SHIPMENTS (POUNDS OF CO_2)**

	Detailed Model	Simplified Model	Model 1	Model 2	Model 3
Total Emissions	370,285	382,692	486,425	140.435	224,697
Total Line Haul Emissions	268,359	266,355	486,425	140,435	224,697
Total P&D Emissions	101,925	116,338	0	0	0
P&D Percentage	28%	30%	0%	0%	0%
Difference (Total Emissions)	**BASE**	**3%**	**31%**	**-62%**	**-39%**

IMPACT OF P&D OPERATIONS

P&D activities—a segment of the LTL supply chain that established methods tend to neglect—account for roughly 30% of total carbon emissions. A more detailed analysis at the individual shipment level reveals more about the influence of P&D moves on carbon emissions. P&D emissions were assigned to a shipment irrespective of its weight, but rather based on the average mileage for P&D operations. Line haul emissions did take the weight into account, so

that heavier shipments were assigned more emissions. This explains why, if two shipments are moved the same distance, the heavier one will have a smaller percentage of its emissions coming from P&D and more coming from line haul (Table 3).

TABLE 3 **COMPARISON OF THE IMPACT OF P&D EMISSIONS**

Shipment 1		Shipment 2	
Origin ZIP	28206	Origin ZIP	28206
Destination ZIP	37213	Destination ZIP	37213
Weight (lbs.)	**100**	**Weight (lbs.)**	**3,000**
Line haul emissions (lbs. CO_2)	7.3	Line haul emissions (lbs. CO_2)	219
P&D emissions (lbs. CO_2)	32.2	P&D emissions (lbs. CO_2)	32.2
Total emissions (lbs. CO_2)	39.5	Total emissions (lbs. CO_2)	251.2
% P&D	**82%**	**% P&D**	**13%**

Notice how miles are the same (i.e., the same ZIP codes). But because weights are different, P&D percentages are 82% and 13%, even though absolute P&D emissions are the same at 32.2 pounds. Line haul emissions are very different though, due to the allocation based on weight.

DETAILED VERSUS SIMPLIFIED MODELS

The researchers analyzed the difference between the detailed and simplified models using the same sample of 2,700 shipments, to find out more about how each model can be applied. This analysis sought to understand how detailed information about a carrier's network infrastructure affects the emissions estimations.

Although there was only a 3 percent difference between the total emissions recorded by each model (see Table 2), there were much wider differences at the estimates of individual shipments. In some specific cases, the simplified model yielded results that were as much as 3.5 times higher in emissions than the detailed model. This happened primarily because the simplified model utilized network averages from across all terminals, while the detailed model calculated emissions based on the characteristics of each terminal.

In conclusion, the simplified model was effective for estimates of total emissions across a portfolio of shipments, but detailed route and carrier information proved to be important when estimating emissions of shipments individually.

How to Apply the New Methodology

The LTL carbon emissions research provides two methods for calculating LTL's carbon footprint.

1. LTL carriers will be most interested in the detailed model; many shippers will not have the dimensional information required for the calculations. More information about the detailed model that was developed for the participating carrier can be found at the MIT CTL website: http://ctl.mit.edu/library/estimating_carbon_emissions_less_than_truckload_ltl_shipments.
2. Most shippers, government agencies, and researchers can use the simplified model if they don't have detailed information about a carrier's network. The simplified model considers region averages and does not require specific information about lanes and terminal infrastructure, but still utilizes coefficients and regression models that were developed for the detailed approach. More information about this model can also be found at the MIT CTL website mentioned above.

As an additional takeaway, Appendix 1 describes an easy-to-apply formula that was derived from the simplified model and is intended to provide baseline estimates of LTL emissions of multiple shipments, including both the line haul and the pickup and delivery sections.

Implications for LTL Carbon Emissions

The models revealed much about the dynamics of LTL operations and the accuracy of existing methods to calculate the carbon footprint of this mode. Here are the main findings.

- **Low-ball estimates.** Existing tools tend to underestimate the emissions associated with LTL shipments, especially for short distances and light freight; the methods rely on over the road distances, rather than actual LTL distances. In addition, the methods fail to factor in P&D operations that account for as much as 28 percent to 31 percent of total emissions in the models.
- **Established methods flawed.** Established initiatives (e.g., the GHG Protocol and SmartWay) provide general guidance on how to estimate the carbon emissions generated by freight transportation. They do not address the complexities of LTL, especially the need to assign emissions to individual shipments. As a result, these measurement methods are not precise enough when applied to LTL shipments. In addition, there is a wide disparity between the LTL emissions levels calculated by the thesis models and the methods commonly used by freight companies. The disparity reflects that the logistics industry generally uses flawed approaches when evaluating LTL's carbon footprint. As Blanco points out in his analysis of carbon footprint evaluations in the LTL mode, "These programs have adopted methodologies with varying degrees of breadth, depth, precision, and verifiability."[5]
- **The detailed model is superior.** Aggregate results from the detailed and simplified models were very similar (see Table 2 on page 8). However, at the shipment level, the detailed model takes a more granular view of LTL movements and is more accurate.

5 Blanco, Edgar, PhD, MIT CTL. "Assessing Global Freight Emission Methodologies." Prepared for the Global Emissions Council, September 2014..

APPENDIX 1

This Appendix presents an easy-to-apply formula that was derived from the simplified model developed in this research. While the formula below was not included in the original MIT CTL research project, it could provide a quick way to obtain baseline estimates of CO_2 emissions from LTL shipments. It provides better results when used to obtain aggregate emissions of multiple shipments (as opposed to when applied to individual movements); this is analogous to the way that this research's simplified model performed.

EASY-TO-APPLY FORMULA FOR CALCULATING LTL CARBON EMISSIONS

$$\text{LTL EMISSIONS (LBS OF } CO_2) = \left(\frac{1.1 \times \text{MILES}}{5.9} \times 22.38\right) \times \left(\frac{\text{WEIGHT}}{25{,}000}\right) + \left(\frac{6.07}{6.3}\right) \times 2 \times 22.38$$

About this Model:

- 1.1 – This multiplier of Miles accounts for empty miles (10% was the average number for empty miles obtained in this research).
- 5.9 - Miles per gallon for the line haul portion of the movement (a network average for the data used in this research).
- 22.38 - GHG Protocol-suggested emissions factor, expressed in pounds of CO_2 per gallon of diesel fuel.
- 25,000 - Load factor for the line haul part of the movement, expressed in pounds.
- 6.07 - Network average for the number of miles driven on the pickup side, as well as on the delivery side of the movement; the value is multiplied by two to account for both sides.
- 6.3 - Miles per gallon for the pickup and delivery portions of the movement (a network average, considering the data was used in this research).

It is important to understand that this formula considers network averages from the entire dataset that was used to develop the models in this research; it includes shipments that were moved across the entire U.S. This differs from the simplified model, for example. The simplified model divided the U.S. into six regions, then assigned P&D miles based on the origin and destination ZIP codes, which were matched to one of those six regions. In contrast, the formula presented in this appendix assumes that P&D miles are always going to be the same and equal to the national average. There could be significant impacts to the resulting emissions based on the specifics of each movement, which this formula is not intended or able to account for.

In conclusion, a perfect carbon estimation methodology for the individual shipment has yet to be developed. Still, approaches like the ones developed in this research provide insights into the dynamics of LTL shipments and offer increased accuracy for estimates of carbon emissions when compared to other currently used estimation methods.

3 TOP INSIGHTS FOR **LTL CARBON EMISSIONS**

1. **Current models for calculating LTL carbon emissions are highly inaccurate.** Many current approaches are based on truckload CO_2 emissions protocols, but LTL is far more complex than full truckload. Small shipments from an average of 20 to 30 companies—a wide range of products in various packaging configurations, ranging from 100 to 10,000 pounds—may be consolidated on a single truck. Load factors from LTL operations are often significantly lower than those associated with truckload transportation, and this disparity can have a notable impact on emissions estimates.
2. **Two new approaches offer more accurate estimates.** The research led to two new methods of calculating LTL carbon emissions. The detailed model, largely of interest to the LTL carrier community, requires detailed dimensional data about the freight that shippers often do not gather , as well as information about a carrier's network infrastructure (terminals, lanes). Instructions for using the detailed model are available at the MIT CTL website: http://ctl.mit.edu/library/estimating_carbon_emissions_less_than_truckload_ltl_shipments. The simplified model can be applied to most shipper operations to provide baseline estimates considering network averages obtained in this research (see page 11 for more information).
3. **The models developed by the MIT CTL research are freely available to every logistics player.** The work cited in this white paper provides a platform for future research and makes a significant contribution to our understanding of freight transportation's carbon footprint. If adopted, these models can help the industry to create a more precise account of LTL carbon emissions.

Greg West, vice president North America LTL for C.H. Robinson, manages LTL and consolidation sales, operations, carrier management, training, and more. He has a BBA degree in Finance from the University of Iowa.

Steve Raetz, director of Supply Chain Integration at C.H. Robinson, has 25 years of logistics experience. Steve holds a B.S. in Mathematics and Teaching from Minnesota State University, Mankato.

Chris Brady, general manager, Latin America for C.H. Robinson's TMC division, holds a Business Administration degree in from the Richard T. Farmer School of Business at Miami University.

Guilherme Veloso, project manager at TMC, a division of C. H. Robinson, has been in the logistics industry for six years. Originally from Curitiba, Brazil, he received his master's degree in supply chain management from MIT in 2014.

Mark Woolard, is a supply chain consultant for AT&T, where he focuses on supply chain strategy. Mark joined AT&T in 2014 after earning his Master of Engineering degree from MIT's Supply Chain Management program.

About C.H. Robinson

C.H. Robinson helps companies simplify their global supply chains and understand their landed costs. To help build smarter, more competitive supply chains, skilled supply chain engineers and logistics professionals combine a deep knowledge of market conditions, practical experience, and proven processes. From local truck transportation to global supply chain management systems, from produce sourcing to consulting to logistics outsourcing, C.H. Robinson supplies a competitive advantage to companies of all sizes.

For more information, please visit www.chrobinson.com or our Transportfolio® blog at www.chrobinson.com/blog.

About TMC

TMC is a division of C.H. Robinson, one of the world's largest providers of global freight services. Their global Managed TMS® solution offers TMS technology combined with managed services. Through Control Towers® in Chicago, Amsterdam, Shanghai, Mumbai, San Paulo, and Wroclaw, Poland, TMC coordinates complex, global, multi-leg shipments, using all forms of transportation. With the Managed TMS solution—delivered through TMC—clients are provided a single global platform for shipment optimization and visibility, freight payment, and business intelligence. C.H. Robinson employs hundreds of transportation experts to support Managed TMS clients in North and South America, Europe, Asia, Africa, and the Middle East.

Learn more at www.mytmc.com.

14701 Charlson Road, Eden Prairie, MN 55347 | 800.323.7587 | **www.chrobinson.com**

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