Modal Shift:
Towards A Lower Carbon Economy

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Introduction

As party to the 2016 United Nations Framework Convention on Climate Change's (UNFCCC) Paris Agreement, Canada has committed to reducing its greenhouse gas (GHG) emissions to 30% below 2005 levels by 2030. According to one recent estimate, Canada's total GHG emissions output, including all industries and households, was 755 megatonnes (Mt) of carbon dioxide equivalent ($CO_{2\ eq}$) in 2015.[1] In the transportation sector – responsible for 66 Mt of $CO_{2\ eq}$ – there are two complementary approaches to help reduce the sector's carbon emissions. The first is to encourage more fuel efficient fleets within each mode. For instance, road motor vehicle manufacturers are introducing alternative fuels including electricity and the airline industry is employing lighter, more fuel efficient aircraft.[2]

The second approach to reducing transportation's GHG emissions is to introduce policies, pricing or otherwise, that encourage a modal shift. Previous research has indicated the potential emission reductions from shifting freight shipments from trucking to railways.[3] Our research compares estimates from surface commodity movements to identify the types of freight moved in Canada by distance. The paper begins by providing a context in terms of Canada's GHG emissions reduction targets and the economics of freight transportation. It then compares commodities transported by truck and rail by distance, using data assembled for the Canadian Freight Analysis Framework. This comparison may help to inform which commodities are relatively more susceptible to a potential modal shift.

Background

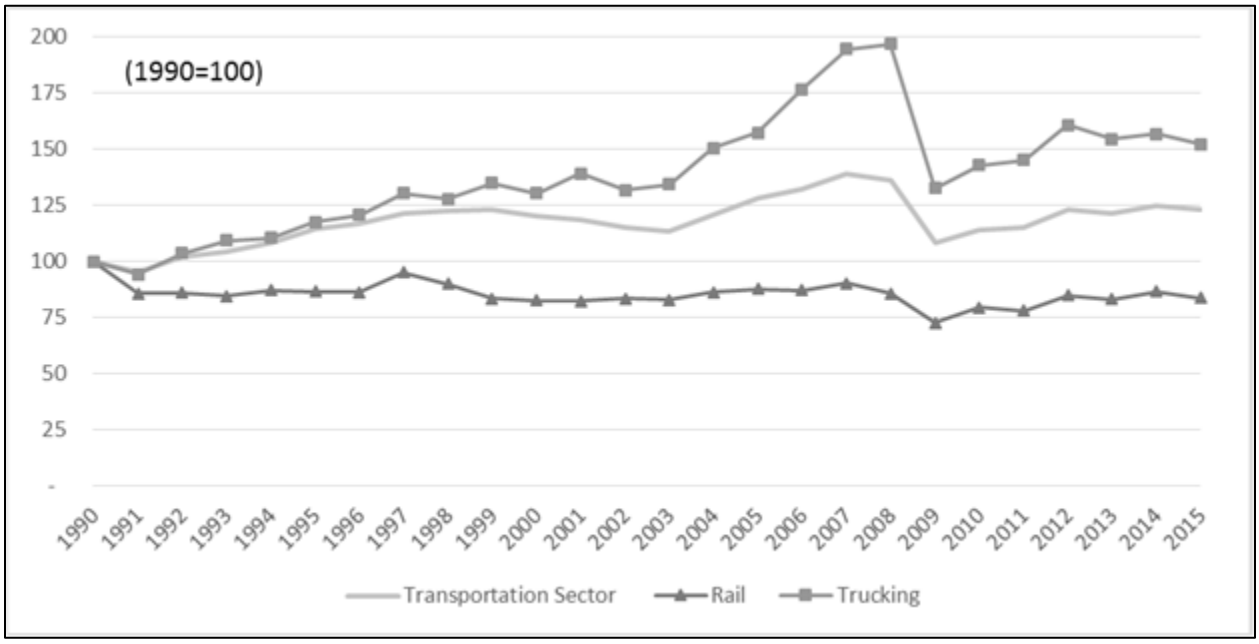
In order to reduce emissions to 30% below 2005 levels by 2030, the federal government worked with provincial and territorial governments to develop the Pan-Canadian Framework on Clean Growth and Climate Change.[4] The framework includes a federal-provincial approach to pricing carbon pollution, and measures to achieve emission reductions in all sectors of the economy, including transportation.

Again, the transportation sector generates 66 Mt of emissions in Canada, with a significant portion (41%) from transit and ground passenger vehicles and from freight trucking. The Pan-Canadian Framework addresses the need to reduce emissions in the transportation sector and explicitly mentions supporting a shift from higher to lower-emitting types of transportation. This initiative contains specific provisions to encourage a modal shift with freight transportation; that is, designed to encourage shippers to choose lower GHG-emitting modes of transport.

Figure 1 highlights that rail freight transportation GHG emissions have grown less than both the total transportation sector as well as compared to the trucking industry. In 2015, rail freight emissions were 26% below 1990 levels for the total transportation sector (53.4 Mt of $CO_{2\ eq}$) despite the increased use of rail as a mode of transporting goods. Although trucking emissions declined temporarily following the 2008 economic downturn, they have risen to 52% above 1990 levels by 2015. Trucking makes up about one-third (34% or 22.7 Mt of $CO_{2\ eq}$) of the total emissions whereas rail accounts for 9% (6.2 Mt of $CO_{2\ eq}$).

[1] Presented at the 53rd Annual Meetings of the *Canadian Transportation Research Forum*, June 3-6, 2018 at Gatineau, Quebec

Figure 1 Index of GHG Emissions from Transportation, Rail and Trucking, 1990-2015

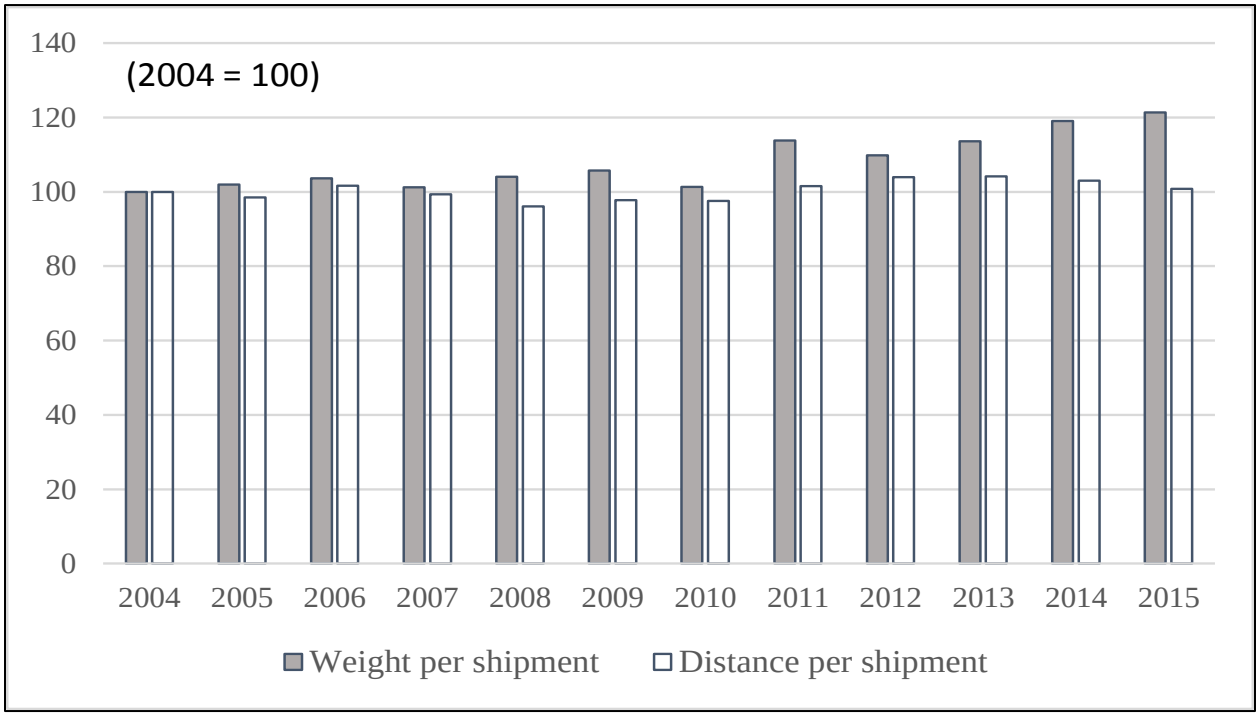


Source: Statistics Canada. CANSIM Table 153-0034 and 153-0114.

Higher prices on fuel are assumed to favour rail with its inherent line-haul efficiency, lower fuel consumption per tonne-kilometre compared to trucks. An American study analysing short-haul intermodal freight services and its potential to reduce highway congestion and emissions estimated the breakeven distance of 500 miles or roughly 800 kilometres.[5] That is, the distance at which rail becomes more economical than trucking to move a given shipment, all else being equal. The point reflects the large fixed costs (e.g. terminal) associated with rail that must be offset by sufficient length of haul (i.e. tapering).[6] In comparison, trucking has higher variable costs (e.g. labour, fuel) which makes it more competitive at shorter distances.

However, trucks appear to continue hauling freight over relatively long distances in Canada (Figure 2). For example, in 2004 the average shipment by truck consisted of 9,354 kilograms hauled an average of just over 600 kilometres. By 2015, it was estimated that for-hire trucking companies were hauling an average payload of 11, 349 kilograms, up 21% since 2004, over a slightly longer average distance.[7] More trucking shipments of this distance results in greater fuel consumption and, concomitantly, accounting for higher levels of GHG emissions (Figure 1). The remainder of the paper uses estimates from the first iteration of the Canadian Freight Analysis Framework to identify and compare selected commodity shipments over certain distances in Canada by the two modes.

Figure 2 – Index of average shipment weight and distance trucked in Canada, 2004-2015



Source: Statistics Canada. CANSIM Table 403-0004.

Data and Methods

The physical movement of goods plays a key role in many market transactions, making the transportation system an essential foundation for a national economy. As a trade-reliant nation, Canada is particularly dependent on an effective transportation system. A Freight Analysis Framework is a planning tool that can help assess the system's ability to move freight. The principal data required are a set of commodity origin-destination flows – monetary or volumetric or both – by mode. There are two basic approaches for estimating these flows and previous research has identified the strength and limitations of each.[8] As part of its strategic plan for transportation data, Transport Canada asked Statistics Canada in 2017 to construct a carrier-based Canadian Freight Analysis Framework (CFAF).

In constructing the CFAF, Statistics Canada started with its Surface Transportation File, a database containing commodity origin-destination flows by truck and rail in Canada.[9] This data file consists of assembling the most detailed shipment information by geography and commodity, then aggregating it into flows among Economic Regions.[10] In order to ensure comprehensive coverage, the CFAF is building on this existing file by adding estimates of other modes. The first iteration of the CFAF, released in March of 2018, included estimates of air freight flows in addition to trucking (for-hire) and rail for 2015.[11] While subsequent iterations of the CFAF will include pipelines, marine and private trucking, we are using the first iteration to estimate commodity flows by weight and distance for truck and rail.

A Modal Shift?

Again, the aim of this analysis is to examine distances over which selected commodities were transported in Canada by truck and rail during 2015. This would illustrate if policies to encourage a reduction in GHG emissions, such as carbon pricing, would be sufficient to nudge shipments of certain commodities to rail from truck. A range of commodities were selected for comparison; those were selected to show different patterns of weight and distances over both modes. The commodities were aggregated to 2-digit Standard

Classification of Transported Goods (SCTG, Table 1) and distance intervals were based on quartiles around the 800 kilometres breakeven point, for truck versus rail, as estimated by the American research cited previously.

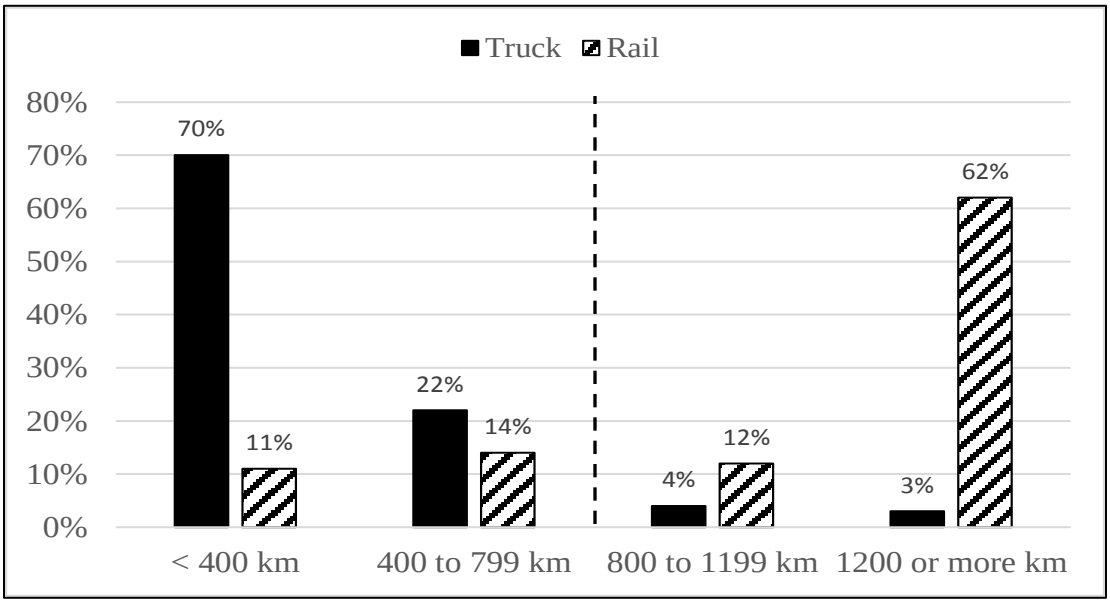
Table 1 Commodity Groupings Selected for Comparison

Standard Classification of Transported Goods	
SCTG 06	Milled grain products and preparations, bakery products
SCTG 07	Prepared foodstuffs n.e.c. and fats and oils
SCTG 09	Tobacco products
SCTG 16	Fuel oils and crude petroleum
SCTG 21	Pharmaceutical products
SCTG 26	Wood products
SCTG 29	Printed products
SCTG 33	Articles of base metal
SCTG 34	Machinery
SCTG 36	Automobiles and parts
SCTG 38	Precision instruments and apparatus
SCTG 39	Furniture, mattresses … lamps, lighting fittings, and signs

Using the CFAF database, queries were run to extract estimates of shipments for these twelve commodity groupings including total weight shipped. The total weight in tonnes for each selected commodity was then allocated into the four distance intervals (Figure 3 and Table 2). The proportions by weight for trucking and rail are concentrated in the shortest and longest distance interval respectively (Figure 3). While trucking handled over 90% of the total shipments by weight for these same commodities (Table 2), the comparison would be much more even using tonne-kilometres. In 2015 for example, the average distance for all shipment trucked was 613 kilometres while the average haul on each railway was 1,264 kilometres.[12]

Again, most of the commodities trucked by weight (92%) fall into the first two distance intervals (Figure 3). Exceptions include Tobacco products (SCTG 09), Precision instruments … (SCTG 38) and Furniture, mattresses, lamps … (SCTG 39) with 40%, 25% and 28% respectively by weight trucked more than 799 kilometres. However, these commodities collectively account for just a fraction of the weight. Conversely, the majority of Prepared foodstuffs (SCTG 07), Fuel oils and crude petroleum (SCTG 16) and Wood products (SCTG 26), collectively 83% of the total weight, was shipped less than 400 kilometres. Almost one-third (32%) of Fuel oil and petroleum products was trucked between 400 and 799 kilometres. However, transportation of crude oil has become a larger policy debate focussed on the safety of each mode rather than on emissions generated by each mode during shipping.[13]

Figure 3 Proportion of Weight Shipped for Selected Commodities by Distance, 2015



Source: Statistics Canada, Canadian Freight Analysis Framework

For rail, the distribution is less concentrated with about three quarters (74%) of these commodities by weight transported more than 800 kilometres. The overall distribution of weight by distance for rail is quite sensitive to Wood products (SCTG 26) which represents almost half of the total weight of these commodities moved. With the exception of Wood products, close to 90% or more by weight of all the commodities examined was transported more than 800 kilometres (Table 2).

Table 2 Commodities Shipped by Weight and Distance Interval, 2015

	Truck					**Rail**				
SCTG	Weight (tonnes)	< 400 km	400-799 km	800-1199 km	1200 + km	Weight (tonnes)	< 400 km	400-799 km	800-1199 km	1200 + km
06	2,099	71%	17%	5%	7%	578	2%	8%	23%	68%
07	43,739,118	67%	23%	4%	6%	2,299,237	3%	8%	3%	85%
09	18	26%	33%	30%	10%	9	0%	0%	0%	100%
16	53,644,807	63%	32%	4%	0%	3,890,577	2%	2%	4%	92%
21	735	68%	17%	11%	3%	8	0%	1%	0%	99%
26	42,999,364	81%	12%	4%	3%	7,846,910	21%	24%	19%	36%
29	513	76%	11%	3%	9%	15	0%	0%	0%	99%
33	9,513,846	56%	29%	8%	7%	767,766	0%	4%	18%	78%
34	9,460,579	71%	18%	3%	7%	78,241	4%	8%	1%	87%
36	9,440,458	91%	5%	1%	3%	968,658	0%	9%	12%	79%
38	91	60%	16%	8%	17%	42	0%	0%	0%	100%
39	692	50%	22%	10%	18%	64	0%	0%	3%	97%
Sum	168,802,321	**70%**	**22%**	**4%**	**3%**	15,852,104	**11%**	**14%**	**12%**	**62%**

Source: Statistics Canada, Canadian Freight Analysis Framework

At first glance, the commodities that appear to have some potential for a modal shift that could reduce GHG emissions include Articles of base metal (SCTG 33), Machinery (SCTG 34), and Automobiles and parts (SCTG 36). Based on this initial look at commodity shipments and the potential for a modal shift, it is apparent that more research is required to examine the operational aspects and distribution channels for these commodities. To some extent, these findings confirm the breakeven point of around 800 km as reported earlier.[14] However, by examining a range of goods we see some potential for a modal shift with certain commodities if, for example, tolling or other policies such as carbon pricing are implemented.

Summary and Next Steps

In order to meet Canada's Paris Agreement GHG emission reduction targets, there is a need to consider emissions from the transportation sector, particularly generated from freight movements. Indeed, this is an area in which the federal government is investigating options and policy tools. For instance, a Federal Greening Freight Working Group has been established, coordinated by Natural Resources Canada and by Environment and Climate Change Canada. With representatives from other federal departments including the National Research Council, Transport Canada, Statistics Canada and others, the Working Group is mandated to coordinate and examine federal government efforts to reduce GHG emissions generated by freight movements. [15]

To reiterate, one approach to reduce freight-generated carbon in transportation is by increasing energy efficiency within a mode. The National Research Council and Transport Canada are studying truck design and modifications such as full roof fairings, cab gap extenders, tractor fairings, trailer side skirts and boat tails and auto idle reduction. Other options being considered are more operational such as truck platooning. The second approach to reducing freight-generated carbon is to encourage more goods to be transported by less carbon-intensive modes of transport. Regardless of the approach – within or between modes – there is a need for statistical data to assess options and outcomes. The Canadian Freight Analysis Framework is a database designed to inform this as well as other policy matters such as network capacity.

Acknowledgements

The authors would like to recognize the valuable comments and insights provided on this paper by Jenifer Johnston of Natural Resources Canada and by Mike Scrim and Carolyn Cahill of Statistics Canada.

Endnotes

[1] Statistics Canada, CANSIM Tables 153-0114 & 153-0034. Carbon dioxide equivalent emissions are estimated using global warming potentials (i.e. multipliers) for methane and nitrous oxide of 25 and 298 respectively.

[2] See, Hagag, A. and McKeown, L (2017). The greening of Canada's road motor vehicles: An assessment. Canadian Transportation Research Forum, *Proceedings*, p. 273-279. Winnipeg (May). Olsheskie, M., Larmour, R. and McKeown, L. (forthcoming). Making cents of reducing aviation greenhouse gas emissions. Canadian Transportation Research Forum, *Proceedings*. Ottawa (June).

[3] Gullo, M. and Rosales, E. (2016). Part of the problem or the solution? How Canada's railways can help address climate change. Canadian Transportation Research Forum Proceedings. Toronto (May), p. 65-75.

[4] Pan Canadian framework https://www.canada.ca/en/services/environment/weather/climatechange/technical-paper-federal-carbon-pricing-backstop.html (accessed 20/01/2018).

[5] Harder, F. and Smith, D. (2018). Learning from short-haul intermodal success. Paper presented at the 97th annual meeting of the Transportation Research Board. Washington D.C. (January).

[6] Prentice, B. and Prokop, D. (2016). Concepts of Transportation Economics. New Jersey: World Scientific, p. 78.

[7] Trucking Commodity Origin and Destination, 2015 http://www.statcan.gc.ca/daily-quotidien/170512/dq170512b-eng.htm.

[8] Data can be collected from the shipper, for example the manufacturer which sends the shipments or, data can be obtained from the carrier, such as the railway, which delivers the shipments. See, Madar, G., and L. McKeown (2016). Measuring Commodity Flows in Canada: A Carrier-Based Approach. Canadian Transportation Research Forum *Proceedings*. Toronto, p. 322-329.

[9] An Industry Canada initiative to assess inter-provincial barriers to trade in Canada, see Statistics Canada (2016). Domestic regional trade flows in Canada: Experimental estimates from the new Surface Transportation File, 2004 to 2012. *The Daily*: August 22, 11-001. http://www.statcan.gc.ca/daily-quotidien/160922/dq160922b-eng.htm.

[10] Canada's 76 Economic Regions (ER) are comprised of complete Census Divisions (CDs), small enough to permit regional analysis yet large enough to release a broad range of statistics. For the exercise, some ERs were aggregated into Greater ER.

[11] The CFAF is a series of modal-based origin-destination matrices of commodity movements classified according to the Standard Classification of Transported Goods. The first iteration consists of trucking (for-hire only), rail and air freight flows. Subsequent iterations will add pipeline flows (2019), marine commodities (2020) and private trucking shipments (2021).

[12] As such, it was estimated that trucking output was 277.4 billion tonne-kilometres (CANSIM Table 403-0004) compared to rail's revenue-freight 4.11.6 billion tonne-kilometres (CANSIM Table 404-0016) during 2015.

[13] And examination of emissions from energy have tended to focus on extraction rather than distribution. See, McKeown, L. (2016). Canada's shifting sands: Oil production, distribution and implications, 2005 to 2014, in *EnviroStats*. Statistics Canada: 16002.

[14] Harder and Smith (2018).

[15] See, Natural Resources Canada (*forthcoming*). Low Carbon Pathways for On-Road Freight. Draft Discussion Paper prepared for a February 20, 2018 Workshop. Ottawa. Please contact. nrcan.greenfreight-transportecologique.rncan@canada.ca.