MEASURING COMMODITY FLOWS IN CANADA: A CARRIER-BASED APPROACH

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INTRODUCTION

Transportation plays an instrumental role across the economy as a cost that must be incurred to complete almost any market transaction. As Winston (2013) asserts, transportation is so intertwined with almost every part of the economy that it is vital for government to continually assess system performance and to consider improvements. As a trade-reliant nation with its population spread over a vast landscape, Canada is particularly dependent on a transportation system that is efficient, reliable, innovative, responsive to change, and resilient to disruptions. However, it is evident that high quality statistical information is required to assess the national transportation system and its ability to move both people and goods.

A Freight Analysis Framework (FAF) is a method for estimating commodity origin and destination flows by mode over a network or system. While conventional, industry-based surveys of transportation provide data to meet national accounting needs, a FAF requires activity-based surveys to estimate commodity flows. This study begins by reviewing a possible Canadian FAF as well as the associated data considerations, such as geography and commodity detail. Then, it assesses the coverage of existing surface transportation surveys to estimate freight flows. By adding an assessment of rail coverage, this represents an extension of a previous work that assessed trucking coverage (Madar & McKeown, 2015).

A CANADIAN FREIGHT ANALYSIS FRAMEWORK

A FAF is used for assessing domestic and international trade flows, exploring patterns in freight movements, observing traffic volumes and network effects, and for analyzing impacts of transport policies (Schmitt and Tang, 2006). With commodity origin-destination (O-D) information benchmarked to a reference year and updated with annual data, a FAF can be used to determine network capacity required in future years or under different assumptions. In the Canadian context for example, a FAF can be used to determine if the transport network can handle the "surge capacity" of certain commodities (e.g. grain, potash, oil). However, among the many active datasets at Statistics Canada and Transport Canada, there is currently insufficient information to enable integrated freight analyses across all modes.

An earlier paper reviewed the methods and data for freight analysis in more detail (Madar & McKeown, 2015). There are five general data dimensions required to construct and maintain a FAF including shipment O-D information, commodity characteristics, mode of transportation, routing and timing, and vehicle type and related information (Allen, Browne, and Cherrett, 2012). In the United States (U.S.), the Bureau of Transportation Statistics (BTS) manages a FAF program that provides estimates of total volumes and values of freight moved among and within regions. Although the U.S. FAF relies on data from several sources, baseline data are provided by an establishment-based Commodity Flow Survey (CFS), undertaken every five years by the U.S. Census Bureau (USCB, U.S. Departments of Transportation and Commerce, 2012).

The Transportation Association of Canada has examined the American FAF and concluded that Canada would benefit immensely from acquiring a similar data program (Kriger, McCumber and Mucsi, 2009). A more recent study of best practices in freight transportation analysis conducted for Ontario proposed a modelling system that would allocate commodity flow forecasts by mode and assign them to networks (Parsons, Brinkerhoff & MMM Group, 2013). The study noted, however, that success of the modelling would depend on data availability and recommended a strong federal role in gathering the required commodity flow information.

In Canada, such a framework would consist of a series of matrices that model commodity flows, in terms of weight and value, by mode among a set of zones or districts within the country (Figure 1).

O/D	**ER_1**	**ER_2**	**...**		**ER_j**	**...**		**ER_{76}**	**EX**	$\sum$
ER_1										
ER_2										
⋮										
ER_i					$\boldsymbol{F_{xy}^{ij}}$					
⋮										
ER_{76}										
IM										
$\sum$										$\sum\sum$

where $\boldsymbol{F_{xy}^{ij}}$ = *flow (tonnes or $) of commodity* $\boldsymbol{x}$ *by mode* $\boldsymbol{y}$ *from origin* $\boldsymbol{i}$ *to destination* $\boldsymbol{j}$

Figure 1: A Canadian Freight Analysis Framework

This proposed framework starts with Canada's 76 Economic Regions (ER). Such regions, comprised of complete Census Divisions, are small enough to permit regional analysis yet large enough to release a broad range of statistics. Since Census Metropolitan Areas (CMAs) consist of Census Sub-divisions (or municipalities), ERs may not capture a CMA in its entirety. While the ER is the geographic unit for collection and estimation, some ERs may have to be grouped or collapsed for analysis and dissemination. It should be noted that imports and exports, depicted as a single respective row and column in Figure 1, would consist of multiple ports of entry and exit (i.e. the Ambassador Bridge) aligned with the American FAF.

A key dimension of freight flows is the type of commodity. The American FAF models freight flows using the 2-digit Standard Classification of Transported Goods (SCTG). For the 2017 Economic Census, the Americans will be using the North American Product Classification System (NAPCS). While it is not entirely clear how this will affect the American CFS, it is imperative for a Canadian FAF to employ the same commodity classification. Other key dimensions include type of mode and routing. In the American FAF, shipments are assigned either a single or a multi-mode designation based on CFS or other data. Average distance, needed to estimate ton-miles, is derived using a program to calculate or impute the distance travelled by mode from shipper to customer.

There is an enormous volume of data necessary to develop a Canadian FAF. For example, with 10 modal categories (marine, rail, truck, air, pipeline, and multiple combinations) and 42 2-digit SCTG classifications, estimating freight flows – either by weight or by value – would require data to populate roughly 420 matrices of dimension 77 by 77 (corresponding to the number of economic regions). The principal data (i.e. commodity flows by mode) used to calibrate this FAF can be collected either directly from the shippers or indirectly from the carriers.

Since 2014, Statistics Canada has been working with Transport Canada on the feasibility of a shippers' survey, the Canadian CFS (CCFS). The CCFS would provide a set of freight flow O-D matrices for commodities transported for a base year (i.e. 2017). The base year flow matrices would then be updated annually using data sources such as output and employment by industry. CCFS data would consist of shipment characteristics including modes of transport from a sample of cross-economy business establishments. There are certain limitations such as excluding some economic sectors (e.g. agriculture) as well as shipments of imports.

This research, however, investigates how commodity flow O-D by mode could be gathered for a Canadian FAF using existing carrier-based surveys.

A CARRIER-BASED APPROACH

Currently, Statistics Canada gathers some commodity origin and destination data with carrier-based surveys. In this section, the trucking and rail surveys are assessed to determine if they can provide a reasonable coverage for a Canadian FAF.

Trucking

Previously, Madar & McKeown (2015) assessed the 2012 Trucking Commodity Origin and Destination (TCOD) survey which collects data on shipments (tonnage, distance, commodity, and revenue) from a sample of large for-hire trucking establishments (North American Industry Classification System, NAICS 484). It excludes shipments provided by ancillary units of non-trucking establishments (i.e. private trucking). For 2012, flows were extracted by weight for each of the 42 2-digit SCTG classifications among the 10 provinces and 3 territories and O-D matrices were created for each commodity type. A value of 1 was assigned if an O-D pair had flows present, regardless of volume, and a value of 0 was assigned if there were no flows. To summarize the 42 matrices, the values for each O-D pair were summed over all of the SCTG classes (Table 1).

The O-D pairs with the highest sum values are shaded darker indicating freight flows for a larger number of commodities, with a value of 42 indicating flows of all possible commodities. As expected, values along the principal diagonal (i.e. intra-provincial flows) are relatively high, as are international imports to, and exports from, many provinces. Also as expected, Ontario has the highest coverage as an origin (averaging 41 of 42 commodity types to all other provinces, excluding territories) and as a destination (averaging flows of 39 of 42 commodity types). Conversely, the fewest commodity flows occur to and from the territories, shaded lighter.

Table 1: Number of SCTG Commodity Flows by Truck between Provinces

Province of Origin		Province of Destination													Exports	Total
		10	11	12	13	24	35	46	47	48	59	60	61	62		
		NL	PE	NS	NB	QC	ON	MB	SK	AB	BC	YT	NT	NU		
10	NL	39	18	33	32	39	37	19	15	27	19	2	1	2	34	317
11	PE	23	34	32	35	29	34	14	13	18	19	1	0	0	29	281
12	NS	37	34	39	38	37	37	28	23	33	28	12	10	2	37	395
13	NB	37	35	36	39	38	40	27	25	29	25	10	1	1	40	383
24	QC	41	35	39	40	41	41	37	38	39	37	20	21	16	42	487
35	ON	42	36	42	41	42	42	41	39	42	41	24	31	12	42	517
46	MB	30	22	29	26	37	39	40	40	39	40	21	21	6	38	428
47	SK	16	11	21	20	33	37	40	42	41	36	11	7	4	39	358
48	AB	30	25	30	28	39	39	39	41	42	41	26	31	14	41	466
59	BC	30	24	35	30	38	41	37	39	41	42	30	26	11	41	465
60	YT	0	0	1	0	7	6	6	0	10	10	25	1	1	10	77
61	NT	9	1	8	1	11	8	2	1	10	5	2	10	1	10	79
62	NU	1	0	1	1	0	2	0	1	1	1	0	1	3	3	15
Imports		41	39	42	42	42	42	42	41	42	42	19	16	11		461
Total		376	314	388	373	433	445	372	358	414	386	203	177	84	406	

Source: Statistics Canada, TCOD Survey, 2012

Next, at the ER level, a series of 77 by 77 matrices were created for the same commodities. Another way to view coverage is by commodity. For each 2-digit SCTG, the proportion of for-hire trucking flows by economic region pairings are summarized in Table 2. The percentage ranges in the table represent the proportion of O-D pairs with flows of that particular commodity, among the total of 5,929 possible O-D pairs. Certain commodity classes, such as SCTG 26, 34 and 40 (wood products, machinery, and miscellaneous manufactured products respectively), score higher, with flows present among at least half of the ER-level O-D pairs. Other classes, such as SCTG 15 (coal) and SCTG 16 (crude petroleum), do not, since they are only produced in certain regions of the country and are not generally shipped long distances by truck.

Table 2: Proportions of ER O-D Pairs with Trucking Flows by Commodity Categories

SCTG category	% with flows	SCTG category	% with flows	SCTG category	% with flows
1	10 to 19%	***15***	***< 5%***	29	20 to 39%
2	10 to 19%	***16***	***< 5%***	30	20 to 39%
3	20 to 39%	17	5 to 9%	31	20 to 39%
4	20 to 39%	18	5 to 9%	32	20 to 39%
5	20 to 39%	19	10 to 19%	33	40% and over
6	10 to 19%	20	20 to 39%	***34***	***40% and over***
7	20 to 39%	21	20 to 39%	35	40% and over
8	10 to 19%	22	10 to 19%	36	40% and over
9	< 5%	23	20 to 39%	37	10 to 19%
10	5 to 9%	24	40% and over	38	20 to 39%
11	5 to 9%	25	10 to 19%	39	20 to 39%
12	5 to 9%	***26***	***40% and over***	***40***	***40% and over***
13	10 to 19%	27	20 to 39%	41	10 to 19%
14	< 5%	28	20 to 39%	42	40% and over

Source: Statistics Canada, TCOD Survey, 2012

Rail

The same exercise was undertaken for the rail industry (NAICS 483) with data from the Monthly Railway Carloadings (MRC) survey. This survey collects the number of cars, tonnage and carloads of revenue freight, and commodities carried based on 7-digit Standard Transportation Commodity Classification (STCC), which is then converted to SCTG classes[1]. Commodity flows were extracted for the 2012 reference year by carloads for each of the 42 2-digit SCTG classifications among the 10 provinces and 3 territories. The number of carloads was used instead of the reported shipment weight because some records included weights under one tonne that were rounded to zero, whereas at least one carload would be present each time a flow exists, regardless of the tonnage[2].

Rail movements are classified using one of the following four traffic types:

1. Local, referring to traffic moving between stations located on the same railway network;
2. Interline forwarded, where the origin of goods was shipped from a specific railway, but the destination of the goods was carried out by another railway;
3. Interline received, where the destination of goods was carried out by a specific railway but that the shipments originated from another railway; and
4. Bridged, where the carrier of interest receives the goods from one carrier and deliver them to another carrier.

This analysis only used those records with traffic types 1 and 2, in order to avoid double counting of any shipments, since the ultimate origins and destinations would be given by these. Since each rail carrier utilizes a unique geographic coding system, the records from each were linked to economic regions[3]. All records that had both origin and destination outside of Canada were excluded. While both Prince Edward Island and Newfoundland and Labrador have abandoned their rail systems, among the territories only the North West Territories (NT) has rail service, albeit very limited. Any flows in these regions have been excluded from the analysis.

A value of 1 was assigned if an O-D pair had flows present, regardless of volume, and a value of 0 was assigned to all O-D pairings that did not record any commodity flows. Similarly to trucking, in order to summarize the 42 matrices (i.e. one for each SCTG code) the values for each O-D pair were summed over all of the SCTG classes (Table 3). Again, the O-D pairs with the highest sum values are shaded darker, indicating that the freight flows were observed for the O-D pair for a larger number of commodities. Conversely, O-D pairs with low values are shaded lighter.

Unlike trucking, the principal diagonal (i.e. intra-provincial flows) does not necessarily represent the highest value for each province. Rail freight transport tends to consist of relatively longer distance shipments of specific commodity types, such as heavier raw materials. With the Quebec City to Windsor corridor, Ontario and Quebec constitute the most densely used potion of the national rail network, representing the origin for approximately 80% of the 42, 2-digit commodity flows. It can be seen that some other rail corridors present in the west, namely to/from/within Alberta and British Columbia, also record flows of more commodities by rail. For imports from the United States, Ontario and Quebec represent destinations for most (37 of 42) of the types of commodities.

Table 3: Number of SCTG Commodity Flows by Rail between Provinces

Origin ER		Destination ER													Exports	Total
		10	11	12	13	24	35	46	47	48	59	60	61	62		
		NL	PE	NS	NB	QC	ON	MB	SK	AB	BC	YT	NT	NU		
10	NL	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
11	PE	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
12	NS	x	x	4	6	21	29	8	5	15	5	x	x	x	15	108
13	NB	x	x	8	9	23	26	11	6	14	9	x	x	x	15	121
24	QC	x	x	30	34	27	33	34	30	39	38	x	x	x	38	303
35	ON	x	x	31	30	36	27	36	32	36	38	x	x	x	37	303
46	MB	x	x	7	11	29	34	23	15	25	29	x	x	x	27	201
47	SK	x	x	5	9	24	30	14	17	21	21	x	x	x	25	167
48	AB	x	x	17	20	33	37	28	25	29	34	x	x	x	36	262
59	BC	x	x	11	16	36	36	31	31	34	29	x	x	x	36	261
60	YT	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
61	NT	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
62	NU	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Imports		x	x	25	29	37	37	33	33	39	36	x	x	x		269
Total		x	x	138	164	266	289	218	194	252	240	x	x	x	229	

Source: Statistics Canada, MRC Survey, 2012

where x = suppressed for confidentiality

As with trucking, we can also view the coverage according to type of commodity at the ER level. Again, some regions were excluded from the analysis due to an absence of rail service or to preserve confidentiality[4]. For each 2-digit SCTG, the proportion of rail commodity flows by economic region pairings is summarized in Table 4. The percentage ranges in the table represent the proportion of O-D pairs with recorded flows of each commodity with respect to the total number of possible O-D pairs.

Certain commodity classes, such as SCTG 26 and 37 (wood products, and transportation equipment) are most prominent with flows covering at least 10% of these SCTG commodities at the ER-level O-D pairs. Other classes, such as SCTG 19 and 20 (products of petroleum refining and coal products, and basic chemicals) are also more discernible. On balance, most other commodities have only limited flows by economic region (i.e. < 5%). However, this does not imply that flows of these commodities are not significant in terms of weight, frequency or value; rather such flows may be heavily concentrated in certain market segments. This analysis assesses the presence and absence rather than the volume or value of these shipments.

Table 4: Proportions of ER O-D Pairs with Rail Flows by Commodity Categories

SCTG category	% with flows	SCTG category	% with flows	SCTG category	% with flows
1	***< 5%***	15	< 5%	29	< 5%
2	< 5%	16	< 5%	30	< 5%
3	< 5%	17	< 5%	31	< 5%
4	< 5%	18	< 5%	32	< 5%
5	< 5%	***19***	***5 to 9%***	33	< 5%
6	< 5%	***20***	***5 to 9%***	34	< 5%
7	5 to 9%	21	< 5%	35	< 5%
8	< 5%	22	5 to 9%	36	< 5%
9	< 5%	23	< 5%	***37***	***10 to 19%***
10	< 5%	24	< 5%	38	< 5%
11	< 5%	25	< 5%	39	< 5%
12	< 5%	***26***	***10 to 19%***	40	< 5%
13	< 5%	27	< 5%	41	< 5%
14	< 5%	28	< 5%	42	< 5%

Source: Statistics Canada, MRC Survey, 2012

SUMMARY

This paper assesses the ability of existing surface transport carrier surveys of trucking and rail to provide a set of commodity origin and destination flows by mode for Canada's economic regions. These commodity flow estimates represent the principal data required for developing and maintaining a Canadian FAF. As expected, the for-hire trucking industry (NAICS 484) provides, geographically, more granulation of freight movements by commodity than does the rail industry (NAICS 483), which operates on a fixed network. However, while the former consists of a sample-based collection effort, the rail commodity information can be available for all carriers.

A strength of the carrier-based approach is the inclusion of import shipments. A limitation of this approach the exclusion of private trucking activity. However, the existing TCOD survey is currently being studied with an aim of identifying establishments with own-account or private trucking in the target population as it is not always apparent from industry classification. Another FAF consideration is an alternative geography to ERs, a grouping based on CMAs and rest-of-province[5]. While this would still provide granularity for analysis, it would reduce the size of the O-D matrix and perhaps cover a portion of the gaps at the ER level.

In summary, this research is part of a larger effort to develop a Canadian FAF. Such a framework represents a tool that can be used to inform policy and investment decisions aimed at ensuring that the Canadian transportation system continues to have the capacity and resiliency to meet freight transport demand. Statistics Canada is also using a similar surface transportation database to assess border thickness and interprovincial trade barriers (Brown & Anderson, 2015). Based on these assessments of trucking and rail data, it is apparent that the carrier-based approach to measuring commodity flows in Canada should be given further consideration.

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ENDNOTES

[1] For this initial analysis, data from a subset of the rail carriers responding to this survey, representing a majority of movements, were used since some rail carriers report their data in very different formats and some provide incomplete records.

[2] The number of cars was used rather than tonnages to simplify the assessment of coverage. However, a FAF would require consistency across modes and tonnages would be used since it also allows for data imputation if necessary.

[3] In the process of this conversion, those records for which the geographic codes found no ER code match were excluded from the dataset.

[4] The eight economic regions from Newfoundland and Labrador, Prince Edward Island, and the three territories were excluded, leaving a total of 4761 cells to be populated.

[5] Another alternative is the aggregation of regions into a set of 31 "Greater Economic Regions," which allows for more reliable estimates than would the 76 smaller ERs.