THE TRANSSHIPMENT PROBLEM IN TRAVEL FORECASTING: PRELIMINARY ANALYSIS OF THE ONTARIO COMMERCIAL VEHICLE SURVEY

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National Center for Freight & Infrastructure Research & Education
College of Engineering
Department of Civil and Environmental Engineering
University of Wisconsin, Madison

Authors: William Melendez-Melendez and Alan J. Horowitz
Center for Urban Transportation Studies
University of Wisconsin – Milwaukee

Principal Investigator: Alan J. Horowitz
Professor, Civil Engineering and Mechanics Department, University of Wisconsin – Milwaukee

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Abstract: Transshipment has large implications for the provision of public infrastructure, and most of the available data on commodity shipments within a single country do not identity any transshipment points along their way. The Ontario Commercial Vehicle Survey (CVS) is one of the few databases that contain substantial transshipment information. The analysis of the Ontario CVS focused on the commodities of truck trips and trip origin/destination facilities. The Ontario CVS dealt with all commodities that are shipped by truck, with manufactured products leading the list of commodities shipped. Probable transshipment points within the Ontario CVS are terminals and warehouses. Chi-square tests demonstrated that the various commodities have differing trip length distributions and that trip origin/destination facility types also differ with respect to their trip length distributions. The Ontario Commercial Vehicle Survey proved to have useful data on transshipment that can suggest relationships that would be applicable to goods movements in the United States.

INTRODUCTION

The "transportation problem" is a very interesting, well known problem of operations research that can be formulated and solved as a linear program. Basically, it involves the minimization of total transportation costs for shipping goods by choosing the routes for supplying the amounts for a certain product, demanded by a set of customers (destinations), from a set of capacitated supply points (origins). The "transshipment problem", on the other hand, involves the choice of the routes on the same terms of the transportation problem but takes into account that the whole shipment is transported in two or more stages. In a two-stage process the first stage might consist of transporting a product from the point of production to a certain intermediate point, called a transshipment point, and the second stage consists of transporting the goods from an intermediate point to a point of consumption. A large number of shipments pass through transshipment points during their journey until they reach their final destination. In addition, a shipment from a producer might be split into multiple, smaller shipments with several destinations at a transshipment facility. Transshipment facilities include traditional warehousing and distribution centers as well as intermodal terminals, foreign trade zones and ports.

Most available data on commodity shipments within a single country identify the first origins and last destinations but not any transshipment points along the way. Transshipment has large implications for the provision of public infrastructure, because the routing of shipments on roads or other public facilities is not necessarily by the least-cost path between the first origin and last destination. Many shipments travel by farther, less direct routes. A better macroscopic understanding of transshipment is needed for transportation planning purposes. Within travel forecasting models the transshipment problem can be formulated as seeking the probability that a commodity with an origin at location A and a destination at location B has a transshipment point at location C.

This paper has the purpose of identifying and analyzing a dataset that includes transshipment information, either explicitly or implicitly. The Commercial Vehicle Survey, provided by the Ontario Ministry of Transportation, proved to have particularly useful data on transshipment, so this dataset is the presented in some depth.

LITERATURE REVIEW

Transshipment is the shipment of goods through intermediate destinations to a final destination. Reasons for transshipment could be to change the means of transport, to combine small shipments into a large shipment or vice versa, or to store a shipment for a period of time. Transshipment has been studied extensively by researchers in logistics, but almost all of these studies relate to improving the actions of an individual firm, rather than on the net effect of many firms acting within a whole economy. However, a few studies have addressed the broader societal implications of transshipment.

Boerkamps and van Binsbergen *(1)* (1999) developed a model to determine logistical performance and environmental effects of alternatives for urban goods distribution, emphasizing the concentration of goods flows, destinations and routes by using a distribution center just outside the city. They developed their model based on the conceptual framework that contains the relation between the four physical components of urban goods: spatial organization of activities; goods flows; traffic flows; and multimodal infrastructure. Takakuwa and Fujii *(2)* (1999) developed a method to generate simulation models for transshipment-inventory systems. They analyzed and developed their model considering any number of different kinds of items, any size of transportation trucks and the order by a demand node made toward the associated transshipment node. Iravani, Lien, Smilowitz and Tzurv *(3)* (2005) studied a concept in the transshipment context named chaining. They presented six configurations of network design: no transshipment; complete pooling; grouping; and chaining configurations. At the end of their evaluation, they proved that chaining configurations are more advantageous than grouping configurations, but then the benefits of the chaining decreases when the number of nodes increases, because every location is connected to only two other locations. Özdemir, Yücesan, and Herer *(4)* (2005) presented an incorporation of supply capacity into the traditional emergency transshipment model. Then they developed a solution procedure to solve a stochastic optimization problem, and analyzed the impact on the system behavior and on locations performance when a supplier fails to accomplish replenishment orders. Herer and Tzur *(5)* (2001) examined the transshipment in a dynamic and deterministic point of view. They considered two locations where transshipment between them are possible, and in their model they included fixed and variable replenishment cost, fixed and variable transshipment cost and holding costs. They provided a model to determine the replenishment and transshipment on each location, with the aid of structural policies that helped them to understand the most important transshipment issues.

ONTARIO COMMERCIAL VEHICLE SURVEY

The Commercial Vehicle Survey Program in Ontario involves surveys of intercity trucking activity, with the objective to obtain information on freight flows on the provincial highway system. The Commercial Vehicle Survey (CVS) is a roadside “intercept” survey of highway trucking activity. The survey collects information on origin/destinations, routes used, goods carried, weights (vehicle, axle and commodity), vehicle dimensions and driver characteristics. The survey is conducted at truck inspection stations (TIS), rest areas, road maintenance yards and at border crossing plaza areas. The last completed CVS was between 2005 and 2007, but this dataset has not yet been publicly released in sufficient detail for transshipment analysis. An earlier survey, between 1999 and 2001, is available upon request. That survey collected more than 40,000 samples.

The Ontario Commercial Vehicle Survey commodity coding is done by using the SCTG. The U.S. Department of Transpiration along with Transport Canada developed the SCTG to replace the STCC for the 1997 and subsequent Commodity Flow Surveys (CFS) and to integrate separate commodity classification systems used in Canada. This means that the Commercial Vehicle Survey is easily matched to data taken in the U.S.

The Commercial Vehicle Survey dataset contains the variables shown on Table 1.

DATA ASSEMBLY

Expansion Factor

The expansion factors for the 1999-2001 Ontario Commercial Vehicle Survey (CVS) were generated based on the methodology developed by Transport Canada to expand the 1999 National Roadside Study (NRS). The approach developed site-based hourly and weekly factors for trucks that would have passed a site regardless of the location of the survey. In order to account for double counting in this process, the weight of the survey associated with more than one station is adjusted down with a ratio based on the probability of a truck getting a survey at each of the other stations that the truck has potentially passed. This method of creating an expansion factor tends to correct for any bias due to haul length; that is, longer hauls are more likely to be sampled.

Commodities

The difference between commodities is important to the analysis of the possible transshipment points made during a journey. While the Commercial Vehicle Survey contains more than 40,000 samples, just 29,822 samples are for trucks that contain commodities. As mentioned earlier, the Commercial Vehicle Survey commodities are coded by SCTG, but Ontario also produced more aggregated categories of the commodities, as follows.

1. Agricultural Products
2. Food
3. Minerals & Products
4. Petroleum & Products
5. Chemicals & Products
6. Wood & Products
7. Metals & Products
8. Machinery & Electrical
9. Manufactured Products
10. Transportation
11. Waste & Scrap
12. Shipping Containers Returning Empty

The aggregated categories are still also consistent with the Commodity Flow Survey. Table 2 summarizes the 12 aggregated categories with their corresponding 2-digit SCTG codes.

TABLE 1 Variables of the Ontario Commercial Vehicle Survey

Variable	Description
Trip Origin Jurisdiction	The jurisdiction at which the trip origin is located
Trip Origin Place	Name of the place at which the trip origin is located
Trip Origin Longitude	Longitude of the place
Trip Origin Latitude	Latitude of the place
Trip Origin Zone	Trip origins were coded to a zoning system
Trip Origin Commodity Status	1st largest commodity is available
Commodity Origin Jurisdiction	Jurisdiction at which the shipment origin is located
Commodity Origin Placename	Name of the place at which the shipment origin is located
Commodity Origin Longitude	Longitude of the place
Commodity Origin Latitude	Latitude of the place
Trip Destination Jurisdiction	Jurisdiction at which the trip destination is located
Trip Destination Placename	Name of the place at which the trip destination is located
Trip Destination Longitude	Longitude of the place
Trip Destination Latitude	Latitude of the place
Trip Destination Zone System	Trip destinations were coded to a zoning system
Trip Destination Commodity Status	1st largest commodity is available
Commodity Destination Jurisdiction	Jurisdiction at which the shipment destination is located
Commodity Destination Placename	Name of the place at which the shipment destination is located
Commodity Destination Longitude	Longitude of the place
Commodity Destination Latitude	Latitude of the place
Commodity SCTG Group Code	The SCTG Codes were 12 aggregated categories
Commodity SCTG Commodity Code	Commodities are coded to the 5-digit SCTG
Cargo	Whether the truck is carrying cargo
Capacity used	How much of the truck's capacity of used
Space	Truck is fully loaded because the space limit has been reached
Weight	Truck is fully loaded because the weight limit has been reached
Pickup	Whether the cargo was picked up at one location
Delivered	Whether the cargo will be delivered to one location
Shipment Status	Whether the number of shipments on-board is available
Shipments	Number of Shipments
Weight of All Cargo Status	Whether the weight of all cargo on-board is available

TABLE 1 Variables of the Ontario Commercial Vehicle Survey (continuation)

Variable	Description
Weight of All Cargo	The weight of all cargo on-board
Amount of All Cargo Units	Units at which the amount of cargo was measured
One Commodity	Whether the cargo consists of one commodity
Trip Type	Whether the trip is linehaul or peddle run
Trip Stop Status	Number of stops on the peddle run is available
Trip Stops	Number of Stops on the peddle run
Configuration of Truck	Configuration
Vehicle Configuration Code	Summarizes the axle groupings
Trip Start Facility Type	Type of facility at which the trip started
Trip Start Facility Description	Description
Trip End Facility Type	Type of facility at which the trip ended
Trip End Facility Description	Description
D.T. in each of the Canadian Provinces	Distance in Kilometers
D.T. in each U.S. State	Distance in Kilometers
D.T. in Mexico	Distance in Kilometers
Daily D.T. in Canada	Distance in Kilometers
Daily D.T. in the U.S.	Distance in Kilometers
Daily D.T. in Mexico	Distance in Kilometers
Daily Total Distance Traveled	Distance in Kilometers

TABLE 2 SCTG 2-digit commodities and Aggregated Ontario CVS Categories

Aggregate Categories	SCTG 2-digit	Description
Agricultural	1	Live Animals and Fish
	2	Cereal Grains (including seed)
	3	Other Agricultural Products, except Animal Feed
	4	Animal Feed and Products of Animal Origin, n.e.c.
Food	5	Meat, Fish, and Seafood, and Their Preparations
	6	Milled Grain Products and Preparations, Bakery Products
	7	Other Prepared Foodstuffs, and Fats and Oils
	8	Alcoholic Beverages
	9	Tobacco Products
Minerals & Products	10	Monumental or Building Stone
	11	Natural Sands
	12	Gravel and Crushed Stone
	13	Non-Metallic Minerals, n.e.c.
	14	Metallic Ores and Concentrates
	15	Coal
Petroleum & Products	16	Crude Petroleum Oil
	17	Gasoline and Aviation Turbine Fuel
	18	Fuel Oils
	19	Coal and Petroleum Products, n.e.c.
Chemicals & Products	20	Basic Chemicals
	21	Pharmaceutical Products
	22	Fertilizers
	23	Chemical Products and Preparations, n.e.c.
	24	Plastics and Rubber

TABLE 2 SCTG 2-digit commodities and Aggregated Ontario CVS Categories (continuation)

Aggregate Categories	SCTG 2-digit	Description
Wood & Products	25	Logs and Other Wood in the Rough
	26	Wood Products
	27	Pulp, Newsprint, Paper, and Paperboard
	28	Paper or Paperboard Articles
Manufactured Products	29	Printed Products
	30	Textiles, Leather, and Articles or Textiles or Leather
Minerals & Products	31	Non-Metallic Mineral Products
Metals & Products	32	Base Metal Primary or Semi-Finished Forms and in Finished Basic Shapes
	33	Articles of Base Metal
Machinery & Electrical	34	Machinery
	35	Electronic and Other Electrical Equipment and Components, and Office Equipment
Transpor-tation	36	Motorized and Other Vehicles (including parts)
	37	Transportation Equipment, n.e.c.
Manufactured Products	38	Precision Instruments and Apparatus
	39	Furniture, Mattresses and Mattress Supports, Lamps, Lighting Fittings, and Illuminated Signs
	40	Miscellaneous Manufactured Products
Waste & Scrap	41	Waste and Scrap
Other	43	Mixed Freight

Two other key factors for transshipment analysis are the facilities at which the trip starts and ends. The Commercial Vehicle Survey uses the following trip facilities:

1. Truck Terminal – Your Carrier
2. Truck Terminal – Another Carrier
3. Rail Terminal
4. Marine Terminal
5. Airport Terminal
6. Primary Producer
7. Manufacturer
8. Warehouse/Distribution Center
9. Retail Outlet
10. Commercial/Office Building
11. Construction Sites
12. Residences
13. Home

14. Waste Facilities
15. Recreational Sites

FIRST CUT DATA ANALYSIS

Commodities

The Commercial Vehicle Survey provides 29,822 trips which contain commodities, out of more than 40,000 surveys taken. The following tables show number of trips made that contain any of the different commodities, organized by the 12 aggregated categories.

TABLE 3 Trips by Each Commodity

Commodities	Total	Percent of Total Trips
Agricultural Products	1776	5.96%
Food	3267	10.95%
Minerals & Products	1909	6.40%
Petroleum & Products	831	2.79%
Chemicals & Products	2773	9.30%
Wood & Products	3908	13.10%
Metals & Products	2689	9.02%
Machinery & Electrical	1581	5.30%
Manufactured Products	4792	16.07%
Transportation	4274	14.33%
Waste & Scrap	865	2.90%
Empty Shipping Containers	1157	3.88%

The majority of the trips produced contain manufactured products, transportation, wood products and foods, with the leading commodity being manufactured products.

Trip Origin Facility

The trip facilities are critical indicators of the transshipment locations. Table 4 breaks out trips by their origin facility.

TABLE 4 Total Trips by Origin Facility

Trip Origin Facility	Total	Percent of Total Trips
Truck Terminal - Your Carrier	9317	31.48%
Truck Terminal - Another Carrier	617	2.08%
Rail Terminal	125	0.42%
Marine Terminal	121	0.41%
Airport Terminal	77	0.26%
Primary Producer	2113	7.14%
Manufacturer	10545	35.63%
Warehouse/Distribution Center	5405	18.26%
Retail Outlet	596	2.01%
Commercial/Office Building	69	0.23%
Constructions Sites	83	0.28%
Residences	139	0.47%
Home	214	0.72%
Waste Facilities	138	0.47%
Recreational Sites	36	0.12%

The leading origin facilities are the manufacturer, truck terminal (driver's carrier) and warehouse/distribution center. Among the bigger percentages, manufacturers and primary producers are not considered transshipment locations. Terminals of any sort and warehouses (at the origin end) would be considered transshipment locations. Retail outlets are technically involved in transshipment activities, but are more logically categorized as locations for production or consumption. More than 52% of all origins are transshipment locations.

Trip Destination Facility

Like the trip origin facilities, trip destination facilities are also very important in the study of transshipment location. Table 5 lists total trips by the type of destination facility.

As with the trip origin facilities, the majority (54%) of the destination facilities were terminals or warehouses, that is a probable transshipment location. A warehouse at the destination end may or may not be transshipment point, depending upon its proximity to the point of consumption.

It is important to mention that the total trips obtained in these tables are not exactly equal to the total trips made by commodity. A few trips were excluded, because some of the drivers refused to answer or did not know the answer, or trips contained commodities but were not specified by their origin facilities and their destination facilities.

TABLE 5 Total Trips by Destination Facility

Trip Destination Facility	Total	Percent of Total Trips
Truck Terminal - Your Carrier	7706	26.82%
Truck Terminal - Another Carrier	662	2.30%
Rail Terminal	143	0.50%
Marine Terminal	117	0.41%
Airport Terminal	117	0.41%
Primary Producer	745	2.59%
Manufacturer	7798	27.14%
Warehouse/Distribution Center	6860	23.88%
Retail Outlet	3280	11.42%
Commercial/Office Building	153	0.53%
Constructions Sites	410	1.43%
Residences	257	0.89%
Home	190	0.66%
Waste Facilities	230	0.80%
Recreational Sites	62	0.22%

Trip Origin-Destination Facility Connection

If more than 50% of origins and more than 50% of destinations are at transshipment points, then a very large percentage of all truck trips involve transshipment at one end or the other. An origin facility to destination facility trip matrix is essential for understanding commodity shipment behaviors. Table 6 contains this data from the Ontario CVS.

TABLE 6 Trip Origin-Destination Facility Matrix

	Trip Destination Facility						
Trip Origin Facility	**Truck Terminal - Your Carrier**	**Truck Terminal - Another Carrier**	**Rail Terminal**	**Marine Terminal**	**Airport Terminal**	**Primary Producer**	**Manu-facturer**
Truck Terminal - Your Carrier	5634	250	23	23	18	120	1211
Truck Terminal - Another Carrier	143	189	4	6	4	11	83
Rail Terminal	15	1	17	3	0	1	40
Marine Terminal	19	4	2	10	0	5	29
Airport Terminal	8	1	0	0	45	0	7
Primary Producer	127	19	9	9	5	305	699
Manufacturer	1048	124	66	36	18	170	4766
Warehouse/Distribution Center	533	61	19	23	22	93	782
Retail Outlet	96	8	0	5	2	20	72
Commercial/Office Building	6	1	1	1	1	2	3
Constructions Sites	19	2	0	1	0	1	5
Residences	11	0	0	0	0	4	5
Home	10	0	0	0	1	3	16
Waste Facilities	10	1	0	0	0	4	49
Recreational Sites	10	0	0	0	0	3	1

TABLE 6 Trip Origin-Destination Facility Matrix (continuation)

	Trip Destination Facility							
Trip Origin Facility	**Ware-house/ Distri-bution Center**	**Retail Outlet**	**Commer-cial/Office Building**	**Construc-tion Sites**	**Resi-dences**	**Home**	**Waste Facilities**	**Recrea-tional Sites**
Truck Terminal - Your Carrier	1086	561	31	69	34	8	30	14
Truck Terminal - Another Carrier	100	50	0	2	0	0	7	0
Rail Terminal	20	22	0	0	1	0	3	0
Marine Terminal	31	13	1	2	0	0	2	0
Airport Terminal	7	3	1	0	0	0	0	2
Primary Producer	418	250	8	142	16	5	20	15
Manufacturer	2667	950	35	115	26	10	59	12
Warehouse/Distribution Center	2316	1181	36	43	59	17	22	3
Retail Outlet	125	202	3	10	20	6	12	3
Commercial/Office Building	13	3	31	1	1	1	2	0
Constructions Sites	13	12	1	18	1	1	6	0
Residences	14	11	0	3	76	3	2	2
Home	10	5	2	2	22	136	3	2
Waste Facilities	6	5	0	0	0	0	57	0
Recreational Sites	7	2	1	0	0	2	0	9

The pervasiveness of transshipment is also evident in Table 6. However, the most interesting result of this table is that there are many trips which have both their origin and destination at a terminal or a warehouse (36%). Given that neither end is a production location or a consumption location, these shipments must involve at least three legs, at least two of which are not (in all likelihood) captured in the dataset. It should be noted that a trip with a transshipment location at just one end could also have three or more legs, but would most likely involve just 2 legs.

Trip Facility-Commodity Connection

The analysis of possible transshipment points can also be done by looking at the interaction between the trip facilities, either origin or destination, and the type of commodity carried by the truck. In this case it is possible to identify those commodities that are most likely to be involved in transshipment. The previous analysis found that manufactured products were carried by the most trucks. Table 7 shows the number of trips originating at each facility type for each broad commodity category.

TABLE 7 Number of Truck Trips by Trip Origin Facility and Commodity

	Trip Origin Facility						
Commodity	**Truck Terminal - Your Carrier**	**Truck Terminal - Another Carrier**	**Rail Terminal**	**Marine Terminal**	**Airport Terminal**	**Primary Producer**	**Manu-facturer**
Agricultural Products	434	27	6	20	3	468	261
Food	969	62	7	6	2	253	935
Minerals & Products	462	21	5	6	0	444	690
Petroleum & Products	211	19	2	4	0	77	295
Chemicals & Products	802	48	16	10	2	112	1234
Wood & Products	1125	73	7	18	1	431	1541
Metals & Products	685	37	11	25	1	115	1322
Machinery & Electrical	483	29	11	7	9	36	611
Manufactured Products	2110	196	17	8	44	62	777
Transportation	1426	70	33	12	15	42	2062
Waste & Scrap	196	17	5	4	0	66	282
Empty Shipping Containers	414	19	5	1	0	7	535

TABLE 7 Number of Truck Trips by Trip Origin Facility and Commodity (continuation)

Commodity	Trip Origin Facility: Ware-house/ Distri-bution Center	Retail Outlet	Commer-cial/Office Building	Construc-tion Sites	Resi-dences	Home	Waste Facilities	Recrea-tional Sites
Agricultural Products	474	55	0	0	2	4	0	4
Food	936	57	1	2	3	19	0	2
Minerals & Products	192	48	0	15	2	10	0	0
Petroleum & Products	202	8	0	0	4	3	0	0
Chemicals & Products	474	35	3	2	2	12	0	0
Wood & Products	571	48	11	4	11	37	0	4
Metals & Products	404	36	5	8	3	13	0	7
Machinery & Electrical	281	41	9	29	3	9	1	3
Manufactured Products	1202	114	24	7	88	76	1	12
Transportation	423	106	13	9	13	24	0	3
Waste & Scrap	99	23	3	7	7	4	135	1
Empty Shipping Containers	147	18	0	0	1	2	1	0

TABLE 8 Number of Truck Trips by Trip Destination Facility and Commodity

	Trip Destination Facility						
Commodity	**Truck Terminal - Your Carrier**	**Truck Terminal - Another Carrier**	**Rail Terminal**	**Marine Terminal**	**Airport Terminal**	**Primary Producer**	**Manu-facturer**
Agricultural Products	354	35	11	10	0	171	234
Food	736	59	12	8	7	97	345
Minerals & Products	381	20	4	7	4	52	570
Petroleum & Products	173	15	2	2	7	44	161
Chemicals & Products	666	54	7	18	5	60	870
Wood & Products	853	86	17	19	3	114	1235
Metals & Products	519	52	11	7	6	42	1086
Machinery & Electrical	393	27	7	11	12	31	399
Manufactured Products	1857	186	11	15	57	68	325
Transportation	1252	92	55	18	15	27	1705
Waste & Scrap	170	11	2	2	0	26	316
Empty Shipping Containers	352	25	4	0	1	13	552

TABLE 8 Number of Truck Trips by Trip Destination Facility and Commodity (continuation)

Commodity	Trip Destination Facility							
	Ware-house/ Distri-bution Center	Retail Outlet	Commer-cial/Office Building	Construc-tion Sites	Resi-dences	Home	Waste Facilities	Recrea-tional Sites
Agricultural Products	518	357	2	4	5	4	0	8
Food	1163	727	7	3	11	21	1	4
Minerals & Products	316	157	15	235	35	9	7	11
Petroleum & Products	153	214	4	21	9	3	1	0
Chemicals & Products	678	212	14	7	9	9	7	0
Wood & Products	921	321	17	32	18	38	0	3
Metals & Products	583	180	11	44	7	16	0	3
Machinery & Electrical	371	161	17	41	10	8	5	9
Manufactured Products	1287	565	51	17	138	63	2	14
Transportation	630	348	13	5	12	16	3	6
Waste & Scrap	74	22	2	1	1	0	204	4
Empty Shipping Containers	166	16	0	0	2	3	0	0

Table 7 reveals considerable differences across commodities. Agricultural products are almost entirely carried from a transshipment point. Manufactured products are largely carried from transshipment points (83%). However, there are no commodities for which transshipment is unimportant.

The same analysis, but for the trip destination facility, is shown in Table 8. Table 8 shows many of the same characteristics as the trip origin facilities for the various commodities. There seems to be a certain degree of symmetry in transshipment across most commodities, even though the reasons for transshipment at the destination would likely differ from the reasons for transshipment at the origin. Again, manufactured products are heavily transshipped at the destination (72%).

Relation of Commodities and Trip Facilities to Haul Length

According to the U.S. Bureau of Transportation Statistics, most freight shipments by value and tonnage move less than 250 miles. In 2002, more than half the value of all U.S. Commodity Flow Survey shipments ($4.5 trillion) and 80 percent of the weight (9 billion tons) moved in local and short-haul shipments, which are critical to state and metropolitan area economies using local roads, tracks and facilities. But goods that move longer distances, more than 250 miles, carried 82 percent of the ton-miles, an increase from 80 percent in 1993. During the past decade, local and short-haul shipments grew 41 percent by value, 16 percent by weight, and 19 percent by ton-miles. Shipments traveling over 250 miles grew faster: 51 percent by value; 34 percent by weight; and 36 percent by ton-miles.

The distance traveled by a truck is a very important characteristic for determining specific transshipment points along its route. Distance can be analyzed in different ways. That is, trip length could vary by commodity, facility type at the origin end, facility type at the destination end or some combination. Any trip with a transshipment point is likely to have a much shorter trip length than the distance between the point of production and the point of consumption. The Ontario Commercial Vehicle Survey provides the distance traveled for each of the trips made. The trip distance categories were chosen to be consistent with the U.S. Commodity Flow Survey. Table 9 shows the distance traveled for each of the broad commodity categories.

TABLE 9 Number of Trips by Commodity and Haul Length (Unweighted Trips)

Commodity	Less than 50 miles	50-99 miles	100-249 miles	250-499 miles	500-749 miles	750-999 miles	1000-1499 miles	1500-1999 miles	2000 miles or more
Agricultural Products	128	227	353	327	162	76	144	68	291
Food	288	341	662	755	267	205	292	93	364
Minerals & Products	533	170	333	431	155	96	106	33	52
Petroleum & Products	151	148	247	172	65	11	21	4	12
Chemicals & Products	129	201	515	720	449	252	239	98	170
Wood & Products	244	271	682	903	653	375	460	105	215
Metals & Products	200	211	391	789	383	187	226	102	200
Machinery & Electrical	160	135	249	354	192	122	145	62	162
Manufactured Products	371	337	910	1055	420	341	597	141	620
Transportation	249	271	1207	1328	485	257	228	115	134
Waste & Scrap	137	113	219	236	80	40	26	5	9
Empty Shipping Containers	95	104	319	417	101	55	37	13	16

The data in Table 9 is unweighted by expansion factors. Any attempt to derive average trip lengths from this table needs to correct for a trip-length bias in the sampling method. That is, long truck trips were more likely to be sampled than short truck trips. It is readily apparent from the table that commodities differ in their trip lengths. Figure 1 shows the total distribution of trips based on the distance traveled. The average unweighted distance traveled by each of the commodities is found in Table 10.

TABLE 10 Average Unweighted Haul Length by Commodity

Commodity	Average Haul Length (miles)
Agricultural & Products	820
Food	663
Minerals & Products	385
Petroleum & Products	274
Chemicals & Products	633
Wood & Products	638
Metals & Products	643
Machinery & Electrical	697
Manufactured Products	773
Transportation	481
Waste & Scrap	321
Empty Shipping Containers	367

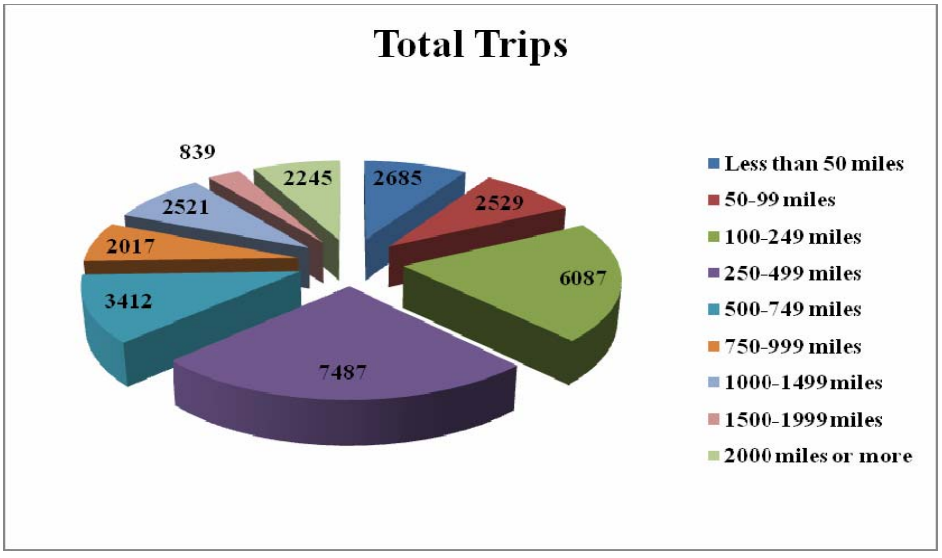

FIGURE 1 Total trips by distance traveled

Table 11 shows the distance traveled from each of the origin facilities.

TABLE 11 Number of Trips by Origin Facility and Haul Length (Unweighted Trips)

Trip Origin Facility	Less than 50 miles	50-99 miles	100-249 miles	250-499 miles	500-749 miles	750-999 miles	1000-1499 miles	1500-1999 miles	2000 miles or more
Truck Terminal - Your Carrier	804	870	2103	2052	911	630	818	302	827
Truck Terminal - Another Carrier	30	29	111	158	80	46	75	15	73
Rail Terminal	14	23	39	25	14	4	4	0	2
Marine Terminal	5	1	10	46	27	5	10	3	14
Airport Terminal	8	1	17	22	20	1	2	1	5
Primary Producer	393	257	406	376	200	110	161	48	162
Manufacturer	604	676	1956	3161	1526	859	918	316	529
Warehouse/Distribution Center	517	504	1155	1387	535	301	418	110	478
Retail Outlet	125	71	156	106	32	27	42	12	25
Commercial/Office Building	26	6	7	11	5	1	5	2	6
Constructions Sites	37	7	16	12	3	2	1	2	3
Residences	30	10	13	22	5	6	10	7	36
Home	30	18	24	24	11	10	30	14	53
Waste Facilities	21	31	32	36	10	2	5	0	1
Recreational Sites	8	6	2	7	3	1	4	1	4

Once again, there is considerable variation in trip length by origin facility. Residences have a surprisingly large number of very long trips. Table 12 gives the unweighted average haul length by each of the origin facilities.

TABLE 12 Unweighted Average Haul Length by Origin Facility

Trip Origin Facility	Average Haul Length (miles)
Truck Terminal - Your Carrier	634
Truck Terminal-Another Carrier	775
Rail Terminal	312
Marine Terminal	816
Airport Terminal	531
Primary Producer	542
Manufacturer	592
Warehouse/Distribution Center	605
Retail Outlet	416
Commercial/Office Building	515
Construction Sites	302
Residences	1042
Home	1086
Waste Facilities	266
Recreational Sites	624

Table 13 shows the distance traveled to a destination facility.

TABLE 13 Number of Trips by Destination Facility and Haul Length (Unweighted Trips)

Trip Destination Facility	Less than 50 miles	50-99 miles	100-249 miles	250-499 miles	500-749 miles	750-999 miles	1000-1499 miles	1500-1999 miles	2000 miles or more
Truck Terminal - Your Carrier	677	738	1834	1668	697	487	687	230	688
Truck Terminal - Another Carrier	31	33	124	172	77	42	81	27	75
Rail Terminal	20	20	50	20	14	3	13	1	2
Marine Terminal	3	2	9	49	24	5	9	5	11
Airport Terminal	9	5	31	27	22	4	9	1	9
Primary Producer	104	99	153	157	63	38	62	26	43
Manufacturer	574	603	1699	2428	1023	540	515	170	246
Warehouse/Distribution Center	365	448	1116	1857	916	564	662	225	707
Retail Outlet	407	399	782	685	285	150	279	76	217
Commercial/Office Building	46	19	27	19	8	4	9	6	15
Constructions Sites	222	49	45	44	14	3	6	4	23
Residences	77	28	36	27	9	9	13	11	47
Home	33	22	22	18	9	7	27	12	40
Waste Facilities	53	34	58	50	15	9	5	0	6
Recreational Sites	14	6	8	12	6	5	3	2	6

Average unweighted haul lengths by destination facility are given on Table 14.

TABLE 14 Unweighted Average Haul Lengths by Destination Facility

Trip Origin Facility	Average Haul Length (miles)
Truck Terminal - Your Carrier	628
Truck Terminal-Another Carrier	772
Rail Terminal	357
Marine Terminal	763
Airport Terminal	598
Primary Producer	531
Manufacturer	496
Warehouse/Distribution Center	726
Retail Outlet	534
Commercial/Office Building	534
Construction Sites	284
Residences	769
Home	968
Waste Facilities	301
Recreational Sites	606

Chi-Square Test

A chi-square statistical analysis found that the distributions of commodities and unweighted average haul lengths differed significantly (at the 95% confidence level) from each other. The same analyses were performed and similarly significant results were obtained from trip origin/destination facilities and unweighted average haul lengths.

Average Weighted Ontario Haul Lengths

The previous analysis was based on the unweighted average haul lengths by expansion factors. To derive average trip lengths from the unweighted trip lengths it is necessary to correct for a trip-length bias from the sampling method. The average weighted trip lengths by commodity are shown in Table 15.

TABLE 15 Average Weighted Haul Lengths by Commodity

Commodity	Average Weighted Haul Length (miles)
Agricultural & Products	351
Food	252
Mineral & Products	164
Petroleum & Products	161
Chemicals & Products	346
Wood & Products	338
Metals & Products	282
Machinery & Electrical	311
Manufactured Products	323
Transportation	300
Waste & Scrap	181
Empty Shipping Containers	241

The weighted average trip lengths using the CVS expansion factors reduces considerably (by almost half) the unweighted average trip lengths obtained in Table 10.

Average Commodity Flow Survey Trip Lengths

A way to understand the applicability of the Ontario dataset to the United States is to compare it with the Commodity Flow Survey data, provided by the U.S. Bureau of Transportation Statistics. The weighted average trip lengths obtained in Table 15 may be compared with the average trip lengths by commodity using the CFS. The 2-digit commodity average trip lengths are found on Table 16.

TABLE 16 CFS Average Trip Lengths by Commodity

Commodity	Average Distance Traveled (miles)
Agricultural & Products	329
Food	184
Minerals & Products	197
Petroleum & Products	62
Chemicals & Products	415
Wood & Products	243
Metals & Products	331
Machinery & Electrical	545
Manufactured Products	838
Transportation	735
Waste & Scrap	166
Mixed Freight	329

The average trips lengths between the CFS and the CVS are different, but the CVS tends to be somewhat larger than the CFS, except for a few commodities like manufactured products. The average weighted trip length of the CVS is about 227 miles (done with the entire dataset), while the CFS average trip lengths is about 178 miles.

CONCLUSIONS

This working paper analyzed the Ontario Commercial Vehicle Survey for its content related to transshipment. This dataset contains more than 40,000 samples, of which 29,822 samples contained information about commodities.

Transshipment analyses were developed by commodities, origin/destination facilities and the distance traveled. Linking each of these trip atributes revealed that the vast majority of the trips originated or ended at transshipment facilities.

The total distance traveled by each of the trips may be also important for establishing the location of the transshipment point. A weigthed average trip length on the Ontario Commercial Vehicle Survey revealed that trips are only moderately greater in length than shipments found in the U.S. Commodity Flow Survey, which means that this dataset may contain relationships with applicability within the U.S.

The available literature considers transshipment in logistics to improve the actions on individual firms, rather than the effects of many firms within the whole system. This working paper presented a useful dataset containing significant transshipment data, and its application to further analysis and model development of the transshipment problem in travel forecasting is appropiate.

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