THE TRANSSHIPMENT PROBLEM IN TRAVEL FORECASTING: TOUR STRUCTURES FROM THE ONTARIO COMMERCIAL VEHICLE SURVEY

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Abstract: Transshipment has big implications for the provision of public infrastructure and the movements of goods from their point of origin to their final destination. The Ontario Commercial Vehicle Survey proves to be a database that contains substantial transshipment information applicable, indirectly, to goods movement in the United States. The analysis of the Ontario CVS first focused on commodities and their origin/destination facilities, defining terminals and warehouses as possible transshipment locations. Analysis revealed that any commodity is likely to be transshipped through either a truck terminal or a warehouse. A total of six tour structures were seen in the data. All commodity trips can have two or more segments, but most likely trips would involve three legs with two possible transshipment locations. Based on commodity/trip origin and destination coordinates it was possible to determine the distance traveled by each segment of the different tour structures. It was found that the first transshipment location or the first consumer is most likely within a short distance of the shipment's true origin. That is, the producer (P) and the first transshipment location (W or T) or the first consumer (C) are in the same municipality.   Probability distributions were determined for both shipment size and truck type showing that it is very likely a shipment would be at least 1,000 lb and truck type would be a tractor & 1 trailer.

INTRODUCTION

The transshipment problem involves the choice of routes for supplying a certain product, demanded by a set of customers (destinations), from a set of capacitated supply points (origins), by taking into account that the whole shipment is transported in two or more stages. The Ontario Commercial Vehicle Survey (CVS) is one of the few databases that contain substantial transshipment information. It involves the survey of intercity trucking activity, with the objective of obtaining information on freight flows on the provincial highway system. This data set contains more than 40,000 samples, of which 29,822 samples contained information about commodities. The Ontario CVS commodity coding is done by using the SCTG that was developed by the U.S. Department of Transportation along with Transport Canada, which means that the Ontario CVS is easily matched to freight data taken in the U.S.

A typical two-stage process of transshipment consists of transporting the product from the point of production to an intermediate point, which is the transshipment point, and then the second stage consists of transporting the product to the point of consumption. A significant amount of shipments pass through transshipment points that are split into multiple, smaller shipments with several destinations at a transshipment facility, whether it is a terminal, warehouse or a distribution center.

There are two types of urban or statewide freight forecasting models: commodity-based models and truck-based models. A commodity-based model uses the notion that the freight system is closely related to goods movement. The main focus of this model is not the movement of trucks but the movement of commodities. On the other hand, a truck-based model focuses on the movement of trucks and estimates those movements directly from data such as numbers of employees, floor areas and other related information without special concern for the amount of commodity production or consumption. Commodity-based models receive socioeconomic data

as input and give as output commodity quantity flows that can be converted into truck flows by vehicle load factors. The inputs to truck-based models are often similar but less detailed as they are able to skip commodities and provide truck flows directly as output. However, one of the most commonly seen approaches used for modeling is the synthesis of origin-destination (OD) matrices of commercial vehicle trips using one of many available expansion techniques. Commodity-based models are similar to standard four-step passenger models, with generation of shipments, distribution of shipments, mode split allocation of these shipments and the network assignment of the resulting vehicles.

Two main classes of freight movements can be identified: end-consumer and logistics. End-consumer movements are those in which the freight is moved by the customer who purchases and consumes the freight, whereas logistics movements are those in which the freight reaches the facilities where it is delivered to markets for producing other products (goods) or services (for example, a movement from the warehouse to the retail outlet). A supply chain (or tour-based) modeling might be related as follows:

- The freight is moved from the production location to where it will be consumed by the end-consumer;
- One contact point between producer and end-consumer exists in which the freight is transferred from the producer to the end-consumer;
- There are one or more additional points for consolidating or deconsolidating a shipment between the producer and end-consumer

Figure 1 shows tour-based modeling. In this structure, the supply chain exists so long as the commodity remains intact or separately identifiable. As a convenience for data analysis, once the commodity is used as a raw material in another product or process, the supply chain is terminated.
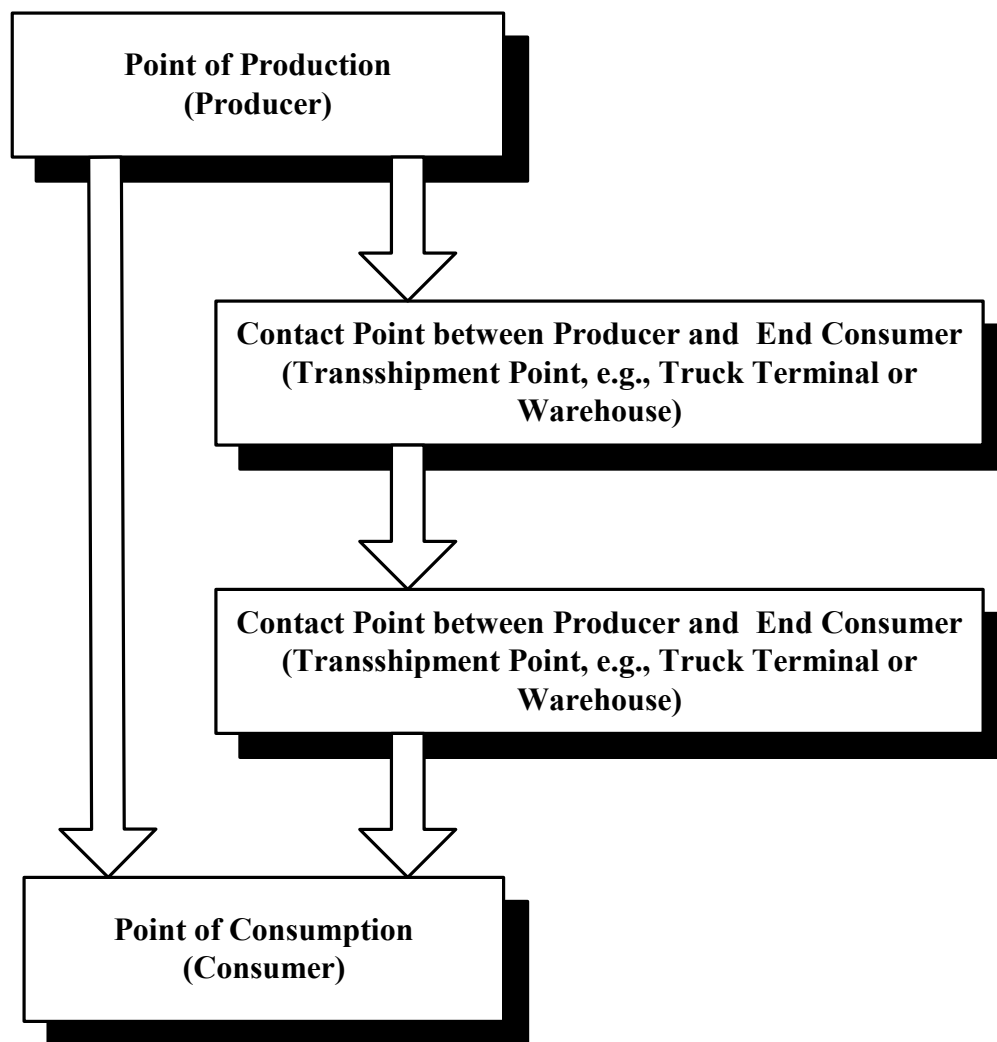
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┌─────────────────────────────┐
│     Point of Production      │
│         (Producer)           │
└─────────────────────────────┘
            │         │
            │         ▼
            │  ┌────────────────────────────────────────────┐
            │  │ Contact Point between Producer and  End Consumer │
            │  │ (Transshipment Point, e.g., Truck Terminal or │
            │  │              Warehouse)                      │
            │  └────────────────────────────────────────────┘
            │                      │
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            │  ┌────────────────────────────────────────────┐
            │  │ Contact Point between Producer and  End Consumer │
            │  │ (Transshipment Point, e.g., Truck Terminal or │
            │  │              Warehouse)                      │
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            │                      │
            ▼                      ▼
┌─────────────────────────────┐
│     Point of Consumption     │
│         (Consumer)           │
└─────────────────────────────┘
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FIGURE 1 Tour-Based Structure Modeling

LITERATURE REVIEW

Transshipment is the shipment of goods through an intermediate point to a final destination. The reasons might 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. The challenge of modeling freight transportation involves very complex linkages among many freight agents including shippers, customers and carriers, and thus models are more complex when dealing with transshipment points. One of the ways to model the transshipment problem is through tour-based (or supply chain) modeling. A few recent studies have already addressed the freight modeling through a tour-based approach.

Hunt and Stefan *(1)* (2005) developed a tour-based model in the Calgary Region that accounts for truck routes involving all types of commercial vehicles including light, heavier single unit and multi-unit configurations, as well as, all sectors of the economy including retail, industrial, service and wholesaling. They used a Monte Carlo technique to assign attributes to each of the tours generated for each of the zones. The attributes included tour purpose, vehicle

type, next stop purpose, next stop location and next stop duration. Their overall framework first consisted of the number of tours based in each zone using an aggregate trip generation model. Then using a Monte Carlo process, the vehicle type and purpose for the tour were identified, followed by the specific tour start time, at which time the characteristics for the stops on the tour were identified, iterating stop by stop until the tour was finished. The tours were incrementally growing having a "return to establishment" alternative within the next stop purpose allocation. Their selection of probabilities used in the microsimulation process were established using logit models estimated using the choice data collected in the surveys for different segments of the full range commercial movements. They considered three vehicle categories: light vehicles, medium vehicles and heavy vehicles. Four stop and related trip purposes were considered: Goods, Services, Others and Return to Establishment. Five different establishments categories were considered: Industrial, Wholesale, Retail, Transport and Services. Each of these five categories were handled separately throughout the microsimulation, each with a largely unique set of coefficients throughout the process. The zones in the model were classified into five land uses types: Low Density, Residential, Retail and Commercial, Industrial and Employment Node. These types were used to differentiate coefficient values and resulting model sensitivities.

Gliebe, Cohen and Hunt *(2)* (2007) presented an activity-based model of commercial vehicle and person movements with data from Ohio. They were focused on the work done by Hunt and Stefan but enhanced the treatment of the temporal dimension within a behavioral, tour-based framework with explicit consideration of worker and vehicle movements rather than shipment movements. The model uses a dynamic discrete choice formulation that steps each simulated worker through their day, building up tours composed of stops for various purposes (Goods, Service, Meeting, Other and Return to Establishment), while tracking the elapsed time, time of day and adjusting probabilities. A tour-based location choice model selects activity stop locations, with location choices made later in the tour becoming increasingly sensitive to distance from the home establishment. All the models were then applied using Monte Carlo methods.

Wisetjindawat, Sano, Matsumoto and Raothanachonkun *(3)* (2007) developed a microsimulation model in such a way that the behavior of each freight agent is individually considered to determine the characteristics of each freight movement. The attributes of each freight agent were determined using a Monte Carlo simulation technique. They covered three of the four steps of the traditional approach including commodity production and consumption, commodity distribution, and conversion of commodity flows to truck flows through three stages: the delivery lot size and frequency, vehicle choice selection and vehicle routing models. The first step involved the amount of commodity production and consumption that were estimated using regression techniques. Then the generated commodities were linked from consumption points to production points according to the attractiveness of each production point resulting in commodity flows between consumption and production points. The commodities were then distributed over the entire area according to their relationships in supply chains, which were then converted to truck flows. The results finally were truck origin-destination matrices and the approximated distance traveled of truck by each truck type.

These three studies show that it is possible to incorporate transshipment within a microscopic simulation. However, such models require detailed statistics on tour formation and the lengths of each leg of the tour, among other important data items.

PRELIMINARY ANALISIS OF THE ONTARIO CVS

Commodities

One key way of viewing possible transshipment location is through the different commodities the trucks are shipping. The Ontario Commercial Vehicle Survey contains data from about 40,000 samples with 29,822 of them containing commodities. The Ontario CVS commodity codes are based on the SCTG, but the survey reported on more aggregated commodity categories, which are also consistent with the U.S. Commodity Flow Survey. The aggregated commodities are 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

Facilities

The facilities where the trips originate or end also has relevance in the transshipment analysis. The Ontario CVS has established the following trip facilities for their database.

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

Preliminary Data Analysis

As a matter of summary, the following tables resume the data analysis made in the previous paper *(5)* (2009). These results are further analyzed with the creation of tour structures.

TABLE 1 Trip O-D 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 1 Trip O-D Facility Matrix (continuation)

Trip Origin Facility	Truck Terminal - Your Carrier	Truck Terminal - Another Carrier	Rail Terminal	Marine Terminal	Airport Terminal	Primary Producer	Manufacturer
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

Trip Destination Facility

The previous analysis concluded that the majority of the trips produced contained manufactured products, transportation equipment, wood products and food, with the leading commodity being manufactured products. Also the leading origin facilities were Manufacturer, Truck Terminal (driver's carrier) and Warehouse/Distribution Center. Terminals and Warehouse/Distribution Centers are considered possible transshipment locations, which resulted in 52% of origins being transshipment locations. Meanwhile, the majority (54%) of the destination facilities were terminals and warehouses. The most interesting aspect of Table 1 is that many trips have both their origin and destination at a terminal or warehouse. Given that neither end is a production location or a consumption location, these shipments must involve at least three legs.

The same analysis revealed that agricultural products are almost entirely carried from a transshipment point.   Manufactured goods are largely carried from or to transshipment points with a total of 83% being shipped at the origin and a total of 72% being transshipped at the destination.

Trip lengths also play a role in the transshipment analysis and, thus, in the nature of tour structures. To derive average trip lengths from the unweighted trip lengths it was necessary to correct for a trip-length bias from the sampling method. The resulted average weighted trip lengths by commodity from the previous analysis are shown in Table 2.

TABLE 2 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

The preliminary analysis was developed by commodities, origin/destination facilities and the distance traveled. Weighted average trips lengths were moderately greater than shipments found in the Commodity Flow Survey, which suggests that this dataset is applicable within the U.S., with some caution.

TOUR-BASED APPROACH DEVELOPMENT

Overview

In order to develop an OD truck table to be assigned to a traffic network, a tour-based approach has been developed using the Ontario Commercial Vehicle Survey database. This tour-based approach accounts for all the commodities provided in the database, involving two preliminary steps:

1. Establishment Selection
2. Shipment Generation

Establishment Selection

The establishments which are used in the tour generation are segregated into four facility type categories. The organization of establishments is needed later to determine probabilities of various events for use in descriptive or predictive models. The facility types to be considered are:

- Producer (P)
- Consumer (C)
- Truck Terminal (T)
- Warehouse (W)

The facility types considered include those that serve as possible transshipment locations, but in this case only Truck Terminals are considered rather than the "Other Terminals" provided by the Ontario CVS. Table 3 relates the facility types considered for the tour generation with the facility types provided by the Ontario CVS.

TABLE 3 Facility Type Description

Facility Type (Tour generation)	Facility Type (Ontario CVS)
Producer	Primary Producer
	Manufacturer
Consumer	Retail Outlet
	Commercial/Office Building
	Construction Sites
	Residences
	Home
	Recreational Sites
Truck Terminal	Truck Terminal- Your Carrier
	Truck Terminal- Another Carrier
Warehouse	Warehouse/Distribution Center

TABLE 4 Probability Distribution for Facility Type

		Commodity				
		Agricultural Products	Food	Minerals & Products	Petroleum & Products	Chemicals & Products	Wood & Products
Probability	Producer of Product	0.410	0.364	0.594	0.448	0.485	0.505
	Consumer of Product	0.214	0.237	0.242	0.302	0.091	0.110
	Truck Terminal for Product (out)	0.260	0.315	0.253	0.277	0.307	0.307
	Truck Terminal for Product (in)	0.219	0.243	0.210	0.226	0.260	0.240
	Warehouse for Products (out)	0.267	0.287	0.101	0.243	0.171	0.146
	Warehouse for Products (in)	0.292	0.356	0.166	0.184	0.245	0.236

TABLE 4 Probability Distribution for Facility Type (continuation)

		Commodity				
		Metals & Products	Machinery & Electrical	Manufactured Products	Transportation	Waste & Scrap
Probability	Producer of Product	0.534	0.409	0.175	0.492	0.402
	Consumer of Product	0.097	0.156	0.177	0.094	0.035
	Truck Terminal for Product (out)	0.269	0.324	0.481	0.350	0.246
	Truck Terminal for Product (in)	0.212	0.266	0.426	0.314	0.209
	Warehouse for Products (out)	0.150	0.178	0.251	0.099	0.114
	Warehouse for Products (in)	0.217	0.235	0.269	0.147	0.086

The probability distribution was applied multiple times to each of the commodities and the facility types described above for the tour generation. Each of the establishments is assigned six different probabilities for each commodity. Probabilities are determined, such as whether the establishment is the producer of the product or whether the establishment is consumer of the product. The cases for truck terminals for product and for warehouses for product involve both shipments in and shipments out. Table 4 shows the probabilities for each of the establishments.

The probability distributions obtained reflects how likely the shipments would be transshipped, especially for manufactured products. It is interesting that the probabilities that an establishment is the producer of product or the consumer of product are relatively low compared to the probabilities that the establishment is either a truck terminal or a warehouse, both in and out. Comparatively high probabilities for the establishments being truck terminals at 0.481 and 0.426 for shipments out and in, respectively, gives a clear impression that the manufactured products will be likely be transshipped at a truck terminal. These comparatively high probabilities also give an idea of how likely it is that these transshipped products would have more than 2 legs to their supply chain. However, agricultural products have similar probabilities for both possible transshipment locations. Although these probabilities are similar, it is recognized that the low probability that an establishment is a consumer of product of 0.214 would imply that the probability of that product being transshipped is high. Overall, the majority of the commodities have a low producer of product probability, when compared to the probabilities of truck terminals and warehouses. This means that the majority of the commodities are likely to be transshipped from a truck terminal or warehouse (in the case of shipment out). On the other hand, all the commodities have a low consumer of product probability, meaning that all the commodities are very likely to be transshipped from a truck terminal or warehouse (in the case of shipment in).

To better explain these numbers, consider the case of manufactured products. Manufactured products have a probability of producer for product of 0.175, a truck terminal for product (shipment out) of 0.481, and a warehouse for product (shipment out) of 0.251. These numbers mean that the probability of a manufactured product being shipped from a transshipment location (either a truck terminal or a warehouse) is comparatively high when compared to the probability of being shipped from the producer. Meanwhile, manufactured products have a probability of consumer of product of 0.177, a truck terminal for product (shipment in) of 0.426, and a warehouse for product (shipment in) of 0.269. Manufactured products are most likely being transshipped at a terminal or a warehouse than going directly to a consumer.

These results imply that most of the commodity shipments have at least 3 legs to their supply chain. It is important to mention that the probabilities do not exactly equal 1 because the probabilities of marine terminal, airport terminal and rail terminals were not shown in the above tables, given the fact that this analysis is confined strictly to truck movements.

Producer (P) → **Consumer (C)** → **Consumer (C)** → **Consumer (C)**

Producer (P) → **Warehouse (W)** → **Consumer (C)** → **Consumer (C)**

Producer (P) → **Warehouse (W)** → **Warehouse (W)** → **Consumer (C)**

Producer (P) → **Consumer (C)** → **Consumer (C)**

Producer (P) → **Warehouse (W)** → **Consumer (C)**
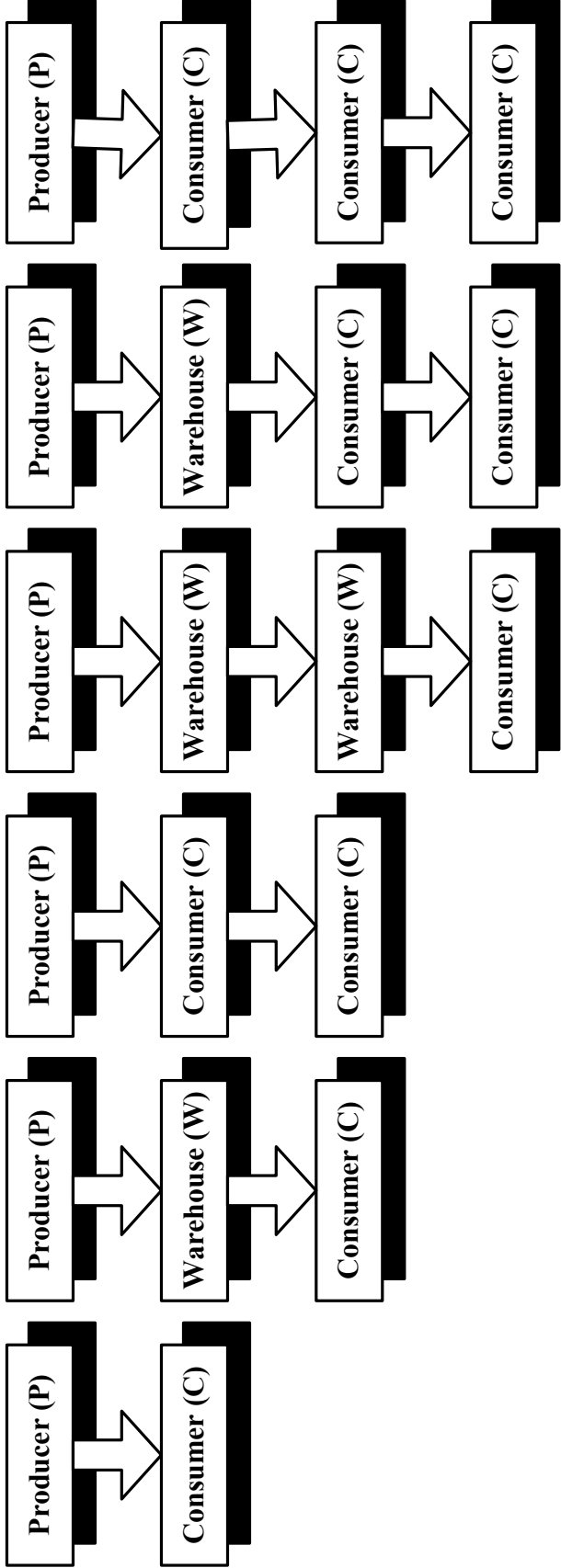
Producer (P) → **Consumer (C)**

FIGURE 2 Tour Structures

Tour Structures

The above analysis revealed that most of the commodities would likely be involved on a supply chain of at least 3 legs. This involves its point of origin (from its producer), going through at least two transshipment locations (truck terminals or warehouses), and finally to its point of destination or its consumer. The next analysis involves tour structures. Table 3 relates the facility types considered based on the Ontario CVS and the facility types organized for this analysis, but within the tour structures the "W" term includes both truck terminals and warehouses. Figure 2 summarizes those structures that could be discerned from the Ontario CVS.

The tour structures were generated based on information about commodity origin/destination and trip origin/destination on the Ontario CVS, recognizing that the trip and commodity may not travel between the same locations. Full information was available only about trip origins and destinations, so it was necessary to assume that the producer (P) was nearer the commodity origin and the last consumer (C) was nearer the commodity destination. For those tour structures that have three legs, the middle two establishments were taken to be the trip origin and the trip destination, while the outer establishments were taken to be the commodity origin and commodity destination. For those tours of exactly two legs either the commodity origin and trip origin or the commodity destination and trip destination were the same. Finally, the simplist case was P-C, where commodity origin was the same as the trip origin and commodity destination was the same as trip destination. Some trips identified multiple destinations in the database, so these were classified separately (P-C-C, P-W-C-C or P-C-C-C). Table 5 shows the number of tour structures that could be found in the database.

TABLE 5 Total Tour Structures, All Commodities

Tour Structure	Total
P-C	1960
P-W-C	2512
P-C-C	808
P-W-W-C	10580
P-W-C-C	255
P-C-C-C	48

Results in Table 5 show six different tour structures for all commodities. Once again, the total of tour structures was not equal to the total of trips carrying commodities (29,822 trips), because rail terminals, marine terminals and airport terminals were not considered in the analysis. Considering that "W" represents both warehouses and truck terminals as possible transshipment points, the vast majority of trips involve transshipment with three legs as represented by the P-W-W-C structure. Moreover, a total of 13,347 trips are involving transshipment with at least with 2 legs, as seen from P-W-C, P-W-W-C, and P-W-C-C structures. The database contained just 48 trips where a shipment was split across three consumers, so there were definite limits in the database as to the complexity of structures that were sampled or could be inferred.

To get a broader view of the tour structures by the different commodities, probabilities of each structure occurring for each commodity were determined. Such probabilities are shown in Table 6.

TABLE 6 Probability Distribution of Tour Structures by Commodity

Commodity	Tour Structure					
	P-C	P-W-C	P-C-C	P-W-W-C	P-W-C-C	P-C-C-C
Agricultural Products	0.144	0.202	0.040	0.592	0.021	0.002
Food	0.100	0.219	0.026	0.616	0.036	0.002
Minerals & Products	0.362	0.145	0.046	0.440	0.006	0.001
Petroleum & Products	0.184	0.324	0.023	0.446	0.023	0.000
Chemicals & Products	0.141	0.134	0.026	0.689	0.009	0.002
Wood & Products	0.149	0.152	0.047	0.638	0.011	0.003
Metals & Products	0.146	0.152	0.031	0.656	0.013	0.002
Machinery & Electrical	0.133	0.156	0.066	0.625	0.018	0.002
Manufactured Products	0.045	0.135	0.059	0.741	0.015	0.005
Transportation	0.081	0.100	0.066	0.741	0.008	0.003
Waste & Scrap	0.201	0.163	0.229	0.392	0.005	0.009

Table 6 demonstrates that the vast majority of commodities go through a transshipment facility on their way to the final destination. The P-W-W-C structure accounts for the largest probability for each of the commodities. For the cases of manufactured products and transportation, P-W-W-C structures have probabilities of 0.741. Meanwhile, agricultural products have origins at farms or elevators, and their destination are elevators, feedlots, ethanol plants and food processing plants; however, the probability that they reach their final destinations directly from their origin does not seems to occur often, only accounting for a probability of 0.144. The only commodity group that shows a relatively high probability of being shipped directly from their origin to their destination is minerals & products (0.362). Long tour structures with multiple consumers are rare in all cases.

Distance Traveled by Each Segment of Tour Structure

Total trip (not commodity) distances were also given by the Ontario CVS, but information on commodity distances throughout a tour could only be obtained from coordinates (latitudes and longitudes) of the commodity origin/destination and trip origin/destination. Latitudes and longitudes were sometimes imprecise, as they were constant for all origins and destinations within a single city. The next few tables show the distances that could be inferred for of each segment by tour structure.

TABLE 9 Average Weighted Distance by Segment of P-C

Commodity	Average Weighted Distance Traveled by Segment of P-C (miles)
	P-C
Agricultural Products	573.73
Food	549.60
Minerals & Products	309.53
Petroleum & Products	318.70
Chemicals & Products	727.10
Wood & Products	516.44
Metals & Products	722.31
Machinery & Electrical	769.42
Manufactured Products	693.47
Transportation	658.21
Waste & Scrap	549.83

TABLE 10 Average Weighted Distance by Segment of P-W-C

Commodity	Average Weighted Distance Traveled by Segment of P-W-C (miles)	
	P-W	W-C
Agricultural Products	0.82	621.96
Food	1.19	365.59
Minerals & Products	1.97	347.76
Petroleum & Products	0.37	272.90
Chemicals & Products	0.61	627.64
Wood & Products	0.35	218.46
Metals & Products	17.54	504.08
Machinery & Electrical	7.97	491.46
Manufactured Products	0.97	523.21
Transportation	2.05	554.71
Waste & Scrap	0.13	387.11

TABLE 11 Average Weighted Distance by Segment of P-C-C

Commodity	Average Weighted Distance Traveled by Segment of P-C-C (miles)	
	P-C	C-C
Agricultural Products	1.26	714.38
Food	0.54	334.45
Minerals & Products	5.06	261.42
Petroleum & Products	0.09	67.03
Chemicals & Products	0.14	467.86
Wood & Products	0.21	562.58
Metals & Products	0.41	577.17
Machinery & Electrical	0.27	384.43
Manufactured Products	0.59	341.40
Transportation	0.26	463.56
Waste & Scrap	0.00	351.11

TABLE 12 Average Weighted Distance by Segment of P-W-W-C

Commodity	Average Weighted Distance Traveled by Segment of P-W-W-C (miles)		
	P-W	W-W	W-C
Agricultural Products	1.95	774.23	0.74
Food	0.95	590.65	0.78
Minerals & Products	1.46	545.47	0.22
Petroleum & Products	0.99	390.80	0.10
Chemicals & Products	1.73	627.01	1.11
Wood & Products	1.35	560.23	0.71
Metals & Products	2.72	601.91	1.61
Machinery & Electrical	1.73	672.62	1.27
Manufactured Products	1.20	523.67	0.75
Transportation	1.04	614.88	0.59
Waste & Scrap	0.23	425.06	0.28

TABLE 13 Average Weighted Distance by segment of P-W-C-C

Commodity	Average Weighted Distance Traveled by Segment of P-W-C-C (miles)		
	P-W	W-C	C-C
Agricultural Products	36.91	657.63	1.18
Food	0.71	291.38	1.66
Minerals & Products	0.46	501.00	0.73
Petroleum & Products	0.23	464.60	11.59
Chemicals & Products	2.79	1053.68	3.88
Wood & Products	0.90	608.17	2.52
Metals & Products	3.98	591.98	1.36
Machinery & Electrical	0.88	1094.96	7.36
Manufactured Products	7.31	682.96	4.00
Transportation	1.71	652.21	4.57
Waste & Scrap	0.00	637.48	1.20

TABLE 14 Average Weighted Distance by Segment of P-C-C-C

Commodity	Average Weighted Distance Traveled by Segment of P-C-C-C (miles)		
	P-C	C-C	C-C
Agricultural Products	3.85	269.05	2.15
Food	1.09	517.21	10.69
Minerals & Products	0.00	40.85	0.13
Petroleum & Products	0.00	0.00	0.00
Chemicals & Products	0.00	414.85	3.06
Wood & Products	0.78	68.75	0.22
Metals & Products	0.75	711.90	1.09
Machinery & Electrical	3.76	353.80	0.55
Manufactured Products	0.57	710.16	3.48
Transportation	0.00	194.47	1.01
Waste & Scrap	0.00	801.42	5.84

From each of the tables above it can be seen that for the tour structures that have at least two segments, the distance from the producer (P) and the next establishment, whether it is a transshipment location (W) or a consumer (C) is relatively short. A frequent reason for this is that the producer of the goods is in the same municipality as the first transshipment location or the first consumer. In the case of those tour structures that involve a transshipment location (W), the fact that the location of this establishment is within a short distance from the producer and

that the second segment has a much larger distance traveled is very reasonable. If a shipment is going to be transshipped, it is very likely that the distance from the transshipment facility to its final destination (could be a final consumer or another transshipment location) will be large. The distances shown for the last segment of the P-W-W-C structure are also very reasonable because after the shipment is transshipped to any location, then the distance to its final destination would be short. Some commodities did not show any distance traveled for the first segment of some tour structure, like P-C-C-C, because both the producer and the next establishment have the same coordinates latitude and longitude.

Shipment Size by Tour Structure

The shipment size is very important when comes to determine if it might be transshipped or not. The Ontario CVS provided information on shipment size, and using the Commodity Flow Survey as a reference, the shipment size categories were subdivided. Table 15 shows the different shipment size categories that were considered.

TABLE 15 Shipment Size Categories

Category	Shipment Size
1	Less than 50 lbs
2	50 - 99 lbs
3	100 - 499 lbs
4	500 - 749 lbs
5	750 - 999 lbs
6	1,000 - 9,999 lbs
7	10,000 - 49,999 lbs
8	50,000 - 99,999 lbs
9	100,000 or more

Based on the shipment size and the different tour structures, probability distributions were determined for each of the tour structures. The results are shown in Tables 16 through 26.

TABLE 16 Probability Distributions of Shipment Size by Tour Structure for Agricultural Products

	Agricultural Products					
Category	P-C	P-W-C	P-C-C	P-W-W-C	P-W-C-C	P-C-C-C
1	0.000	0.000	0.024	0.000	0.000	0.000
2	0.000	0.014	0.000	0.002	0.000	0.000
3	0.013	0.033	0.048	0.029	0.000	0.000
4	0.033	0.033	0.024	0.024	0.091	0.500
5	0.053	0.051	0.024	0.065	0.000	0.000
6	0.322	0.256	0.310	0.306	0.182	0.500
7	0.250	0.256	0.262	0.239	0.364	0.000
8	0.105	0.107	0.095	0.083	0.136	0.000
9	0.224	0.251	0.214	0.252	0.227	0.000

TABLE 17 Probability Distributions of Shipment Size by Tour Structure for Food

	Food					
Category	P-C	P-W-C	P-C-C	P-W-W-C	P-W-C-C	P-C-C-C
1	0.005	0.008	0.018	0.003	0.013	0.000
2	0.014	0.011	0.000	0.003	0.000	0.000
3	0.028	0.044	0.071	0.026	0.064	0.000
4	0.019	0.030	0.000	0.031	0.051	0.250
5	0.037	0.034	0.054	0.035	0.013	0.000
6	0.292	0.294	0.518	0.304	0.308	0.000
7	0.259	0.228	0.161	0.216	0.308	0.500
8	0.088	0.110	0.107	0.100	0.090	0.000
9	0.259	0.241	0.071	0.283	0.154	0.250

TABLE 18 Probability Distributions of Shipment Size by Tour Structure for Minerals & Products

	Minerals & Products					
Category	P-C	P-W-C	P-C-C	P-W-W-C	P-W-C-C	P-C-C-C
1	0.000	0.000	0.000	0.000	0.000	0.000
2	0.003	0.000	0.000	0.002	0.000	0.000
3	0.011	0.021	0.022	0.018	0.000	0.000
4	0.003	0.007	0.022	0.009	0.000	0.000
5	0.003	0.000	0.044	0.018	0.000	0.000
6	0.168	0.287	0.200	0.180	0.333	1.000
7	0.188	0.231	0.244	0.231	0.167	0.000
8	0.073	0.154	0.067	0.083	0.167	0.000
9	0.552	0.301	0.400	0.457	0.333	0.000

TABLE 19 Probability Distributions of Shipment Size by Tour Structure for Petroleum & Products

	Petroleum & Products					
Category	P-C	P-W-C	P-C-C	P-W-W-C	P-W-C-C	P-C-C-C
1	0.011	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.091	0.005	0.000	0.000
3	0.000	0.006	0.000	0.019	0.000	0.000
4	0.011	0.000	0.000	0.009	0.000	0.000
5	0.011	0.006	0.091	0.014	0.000	0.000
6	0.125	0.213	0.455	0.230	0.000	0.000
7	0.261	0.219	0.000	0.225	0.364	0.000
8	0.125	0.123	0.182	0.080	0.091	0.000
9	0.455	0.432	0.182	0.418	0.545	0.000

TABLE 20 Probability Distributions of Shipment Size by Tour Structure for Chemicals & Products

Category	P-C	P-W-C	P-C-C	P-W-W-C	P-W-C-C	P-C-C-C
1	0.000	0.000	0.029	0.003	0.000	0.000
2	0.000	0.011	0.000	0.002	0.000	0.000
3	0.055	0.034	0.088	0.029	0.083	0.000
4	0.016	0.017	0.059	0.027	0.000	0.000
5	0.016	0.023	0.059	0.026	0.083	0.000
6	0.311	0.345	0.235	0.272	0.333	0.000
7	0.257	0.241	0.294	0.273	0.167	0.000
8	0.087	0.144	0.088	0.112	0.083	0.000
9	0.257	0.184	0.147	0.256	0.250	1.000

TABLE 21 Probability Distributions of Shipment Size by Tour Structure for Wood & Products

Category	P-C	P-W-C	P-C-C	P-W-W-C	P-W-C-C	P-C-C-C
1	0.007	0.011	0.000	0.002	0.000	0.000
2	0.000	0.000	0.024	0.004	0.000	0.000
3	0.026	0.036	0.094	0.020	0.100	0.167
4	0.007	0.018	0.012	0.016	0.000	0.000
5	0.029	0.036	0.024	0.018	0.050	0.000
6	0.333	0.307	0.329	0.262	0.200	0.333
7	0.308	0.282	0.224	0.288	0.350	0.167
8	0.117	0.087	0.071	0.111	0.000	0.167
9	0.172	0.224	0.224	0.278	0.300	0.167

TABLE 22 Probability Distributions of Shipment Size by Tour Structure for Metals & Products

Category	P-C	P-W-C	P-C-C	P-W-W-C	P-W-C-C	P-C-C-C
1	0.006	0.006	0.000	0.001	0.000	0.000
2	0.000	0.006	0.029	0.004	0.000	0.000
3	0.051	0.067	0.059	0.039	0.071	0.000
4	0.038	0.048	0.029	0.015	0.071	0.000
5	0.063	0.036	0.000	0.037	0.071	0.000
6	0.304	0.352	0.500	0.242	0.357	0.000
7	0.291	0.176	0.206	0.230	0.214	1.000
8	0.076	0.145	0.088	0.103	0.071	0.000
9	0.171	0.164	0.088	0.329	0.143	0.000

TABLE 23 Probability Distributions of Shipment Size by Tour Structure for Machinery & Electricals

Category	P-C	P-W-C	P-C-C	P-W-W-C	P-W-C-C	P-C-C-C
1	0.018	0.015	0.018	0.009	0.000	0.000
2	0.000	0.000	0.000	0.004	0.000	0.000
3	0.088	0.061	0.071	0.064	0.067	0.500
4	0.061	0.061	0.089	0.055	0.067	0.000
5	0.035	0.030	0.071	0.042	0.000	0.000
6	0.298	0.295	0.321	0.326	0.267	0.500
7	0.298	0.227	0.161	0.213	0.267	0.000
8	0.053	0.091	0.036	0.083	0.133	0.000
9	0.149	0.220	0.232	0.204	0.200	0.000

TABLE 24 Probability Distributions of Shipment Size by Tour Structure for Manufactured Products

	Manufactured Products					
Category	P-C	P-W-C	P-C-C	P-W-W-C	P-W-C-C	P-C-C-C
1	0.006	0.014	0.004	0.003	0.018	0.000
2	0.012	0.008	0.018	0.006	0.000	0.053
3	0.089	0.091	0.155	0.067	0.053	0.105
4	0.018	0.027	0.062	0.054	0.018	0.105
5	0.071	0.039	0.080	0.051	0.000	0.053
6	0.396	0.344	0.385	0.352	0.316	0.263
7	0.207	0.239	0.164	0.224	0.263	0.211
8	0.077	0.078	0.044	0.074	0.088	0.053
9	0.124	0.160	0.088	0.168	0.246	0.158

TABLE 25 Probability Distributions of Shipment Size by Tour Structure for Transportation

	Transportation					
Category	P-C	P-W-C	P-C-C	P-W-W-C	P-W-C-C	P-C-C-C
1	0.014	0.006	0.008	0.002	0.067	0.000
2	0.014	0.011	0.000	0.002	0.000	0.000
3	0.082	0.056	0.110	0.034	0.000	0.000
4	0.048	0.039	0.042	0.020	0.000	0.000
5	0.034	0.028	0.034	0.021	0.000	0.333
6	0.315	0.330	0.356	0.231	0.533	0.333
7	0.267	0.279	0.254	0.308	0.133	0.000
8	0.075	0.073	0.093	0.115	0.200	0.333
9	0.151	0.179	0.102	0.268	0.067	0.000

TABLE 26 Probability Distributions of Shipment Size by Tour Structure for Waste & Scrap

	Waste & Scrap					
Category	P-C	P-W-C	P-C-C	P-W-W-C	P-W-C-C	P-C-C-C
1	0.000	0.000	0.000	0.006	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.021	0.018	0.000	0.000
4	0.012	0.014	0.010	0.006	0.000	0.000
5	0.000	0.058	0.010	0.018	0.000	0.250
6	0.212	0.072	0.113	0.163	0.500	0.000
7	0.247	0.232	0.278	0.265	0.500	0.250
8	0.129	0.203	0.124	0.114	0.000	0.000
9	0.400	0.420	0.443	0.410	0.000	0.500

Based on the above tables it is noted that regardless of the commodity, the probabilities of a shipment being in categories 6, 7 and 9 is high compared with the other categories. This situation is seen for almost every tour structure on each commodity. Regardless of commodity or tour structure, it is very likely that the shipment size would be at least 1,000 lb.

Truck Type by Tour Structure

The type of truck used for shipment is also important in determining if a shipment would be transshipped. As part of the tour structure analysis, probability distributions were determined by each tour and each commodity. The Ontario CVS provided truck type information for each of the truck trips. Table 27 shows the different truck type configurations provided by the Ontario CVS.

TABLE 27 Truck Types

Truck Type	Configuration of Truck
Type 1	Tractor & Trailer
Type 2	Tractor & 2 Trailers
Type 3	Tractor & 3 Trailers
Type 4	Straight Truck
Type 5	Straight Truck & Trailer
Type 6	Tractor Only
Type 95	Other

A total of six specific truck types are considered, as well as Type 95, which includes any other truck configuration. Type 95 covers tractor/towing carrying other tractors, tractor towing/carrying a truck and a tractor carrying a trailer piggyback. The probability distributions for truck type are shown in Tables 28 through 38.

TABLE 28 Probability Distributions of Truck Type by Tour Structure for Agricultural Products

	Agricultural Products					
Truck Type	P-C	P-W-C	P-C-C	P-W-W-C	P-W-C-C	P-C-C-C
Type 1	0.638	0.738	0.595	0.864	0.818	1.000
Type 2	0.000	0.009	0.024	0.030	0.000	0.000
Type 3	0.000	0.000	0.000	0.000	0.000	0.000
Type 4	0.342	0.252	0.381	0.102	0.182	0.000
Type 5	0.020	0.000	0.000	0.003	0.000	0.000
Type 6	0.000	0.000	0.000	0.000	0.000	0.000
Type 95	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 29 Probability Distributions of Truck Type by Tour Structure for Food

	Food					
Truck Type	P-C	P-W-C	P-C-C	P-W-W-C	P-W-C-C	P-C-C-C
Type 1	0.704	0.642	0.661	0.898	0.513	0.500
Type 2	0.014	0.006	0.000	0.015	0.013	0.000
Type 3	0.000	0.000	0.000	0.000	0.000	0.000
Type 4	0.282	0.347	0.339	0.084	0.474	0.500
Type 5	0.000	0.004	0.000	0.003	0.000	0.000
Type 6	0.000	0.000	0.000	0.000	0.000	0.000
Type 95	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 30 Probability Distributions of Truck Type by Tour Structure for Minerals & Products

	Minerals & Products					
Truck Type	P-C	P-W-C	P-C-C	P-W-W-C	P-W-C-C	P-C-C-C
Type 1	0.622	0.510	0.378	0.723	0.333	0.000
Type 2	0.042	0.049	0.022	0.076	0.167	0.000
Type 3	0.000	0.000	0.000	0.000	0.000	0.000
Type 4	0.294	0.413	0.556	0.166	0.500	1.000
Type 5	0.042	0.028	0.044	0.035	0.000	0.000
Type 6	0.000	0.000	0.000	0.000	0.000	0.000
Type 95	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 31 Probability Distributions of Truck Type by Tour Structure for Petroleum & Products

Truck Type	P-C	P-W-C	P-C-C	P-W-W-C	P-W-C-C	P-C-C-C
Petroleum & Products						
Type 1	0.477	0.245	0.182	0.582	0.364	0.000
Type 2	0.341	0.484	0.000	0.221	0.455	0.000
Type 3	0.000	0.000	0.000	0.000	0.000	0.000
Type 4	0.170	0.258	0.818	0.197	0.182	0.000
Type 5	0.011	0.013	0.000	0.000	0.000	0.000
Type 6	0.000	0.000	0.000	0.000	0.000	0.000
Type 95	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 32 Probability Distributions of Truck Type by Tour Structure for Chemicals & Products

Truck Type	P-C	P-W-C	P-C-C	P-W-W-C	P-W-C-C	P-C-C-C
Chemicals & Products						
Type 1	0.891	0.690	0.706	0.891	0.833	1.000
Type 2	0.022	0.006	0.029	0.026	0.000	0.000
Type 3	0.000	0.000	0.000	0.000	0.000	0.000
Type 4	0.071	0.293	0.265	0.084	0.167	0.000
Type 5	0.016	0.011	0.000	0.000	0.000	0.000
Type 6	0.000	0.000	0.000	0.000	0.000	0.000
Type 95	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 33 Probability Distributions of Truck Type by Tour Structure for Wood & Products

Truck Type	P-C	P-W-C	P-C-C	P-W-W-C	P-W-C-C	P-C-C-C
Wood & Products						
Type 1	0.821	0.751	0.624	0.844	0.700	0.333
Type 2	0.132	0.097	0.094	0.108	0.150	0.167
Type 3	0.000	0.000	0.000	0.000	0.000	0.000
Type 4	0.044	0.144	0.282	0.041	0.150	0.500
Type 5	0.004	0.007	0.000	0.007	0.000	0.000
Type 6	0.000	0.000	0.000	0.000	0.000	0.000
Type 95	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 34 Probability Distributions of Truck Type by Tour Structure for Metals & Products

Truck Type	Metals & Products					
	P-C	**P-W-C**	**P-C-C**	**P-W-W-C**	**P-W-C-C**	**P-C-C-C**
Type 1	0.816	0.703	0.588	0.817	0.714	0.500
Type 2	0.063	0.036	0.088	0.087	0.071	0.000
Type 3	0.000	0.000	0.000	0.000	0.000	0.000
Type 4	0.114	0.242	0.265	0.086	0.214	0.500
Type 5	0.006	0.018	0.059	0.010	0.000	0.000
Type 6	0.000	0.000	0.000	0.000	0.000	0.000
Type 95	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 35 Probability Distributions of Truck Type by Tour Structure for Machinery & Electricals

Truck Type	Machinery & Electricals					
	P-C	**P-W-C**	**P-C-C**	**P-W-W-C**	**P-W-C-C**	**P-C-C-C**
Type 1	0.823	0.659	0.750	0.806	0.733	0.000
Type 2	0.009	0.000	0.018	0.023	0.000	0.000
Type 3	0.000	0.000	0.000	0.000	0.000	0.000
Type 4	0.159	0.265	0.196	0.147	0.267	1.000
Type 5	0.009	0.076	0.036	0.025	0.000	0.000
Type 6	0.000	0.000	0.000	0.000	0.000	0.000
Type 95	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 36 Probability Distributions of Truck Type by Tour Structure for Manufactured Products

Truck Type	Manufactured Products					
	P-C	**P-W-C**	**P-C-C**	**P-W-W-C**	**P-W-C-C**	**P-C-C-C**
Type 1	0.740	0.700	0.542	0.852	0.667	0.789
Type 2	0.018	0.006	0.018	0.043	0.035	0.053
Type 3	0.000	0.000	0.000	0.000	0.000	0.000
Type 4	0.231	0.286	0.409	0.095	0.281	0.158
Type 5	0.012	0.008	0.031	0.010	0.018	0.000
Type 6	0.000	0.000	0.000	0.000	0.000	0.000
Type 95	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 37 Probability Distributions of Truck Type by Tour Structure for Transportation

Truck Type	Transportation					
	P-C	P-W-C	P-C-C	P-W-W-C	P-W-C-C	P-C-C-C
Type 1	0.589	0.425	0.424	0.795	0.600	0.333
Type 2	0.021	0.022	0.017	0.015	0.067	0.000
Type 3	0.000	0.000	0.000	0.000	0.000	0.000
Type 4	0.055	0.196	0.229	0.088	0.200	0.333
Type 5	0.295	0.330	0.322	0.096	0.133	0.333
Type 6	0.000	0.000	0.000	0.000	0.000	0.000
Type 95	0.041	0.028	0.008	0.005	0.000	0.000

TABLE 38 Probability Distributions of Truck Type by Tour Structure for Waste & Scrap

Truck Type	Waste & Scrap					
	P-C	P-W-C	P-C-C	P-W-W-C	P-W-C-C	P-C-C-C
Type 1	0.706	0.826	0.629	0.855	0.500	0.750
Type 2	0.082	0.014	0.031	0.036	0.000	0.000
Type 3	0.000	0.000	0.000	0.000	0.000	0.000
Type 4	0.176	0.130	0.278	0.102	0.500	0.250
Type 5	0.035	0.029	0.062	0.006	0.000	0.000
Type 6	0.000	0.000	0.000	0.000	0.000	0.000
Type 95	0.000	0.000	0.000	0.000	0.000	0.000

The results from these tables reveals that regardless of the commodity or tour structure, it is very likely that the truck type would be a tractor & 1 trailer (Type 1). However, there might be some situations where a straight truck (Type 4) would be used, and there are a small number of situations where a straight truck & 1 trailer (Type 5) would be used. An interesting fact is that any other truck configuration (Type 95) is really only used for transportation commodities.

CONCLUSIONS

This working paper continued the analysis in further detail of the Ontario Commercial Vehicle Survey for transshipment information, which had been preliminarily analyzed by commodities, origin/destination facilities and distance traveled. The analysis presented here consisted of creating tour structures, their probability distributions and distances associated with various legs of the structures.

First, establishments were segregated into three categories (producer, consumer, or warehouse/terminal) to simplify the number of structures. Computed probabilities revealed that there is a likelihood of any shipment passing through a transshipment location, that is, either a truck terminal or a warehouse.

A total of six tour structures were ascertained from the data, and probability distributions were associated with each structure as it relates to broad commodity categories. The most likely tour structure involved two transshipment points.

Distances traveled for each segment by each tour structure were determined and showed that the producer and the first transshipment location (W) or first consumer (C) are in the same municipality for all the tour structures involving more than 2 segments. The same situation holds for the distances of the last two establishments, that is after the shipment has been transshipped then its final consumer is in the same municipality.

This working paper presented a further analysis of the Ontario CVS dataset based on tour structures and their probabilities. The results revealed the dataset contains solid information on transshipment that would be appropriate for further model development of the transshipment problem of travel forecasting.

ACKNOWLEDGEMENTS

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