The Transshipment Problem in Travel Forecasting: Tour Structures Model

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Abstract: The concept of transshipment of goods has not been widely incorporated into transportation planning models. A model with transshipment should recognize that a whole shipment could be transported in two or more stages, involving intermediate points (transshipment point) between the first origin and the last destination. The Ontario Commercial Vehicle Survey (CVS) is one of the few databases that contains substantial transshipment information. 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 eight tour structures could be ascertained from the database, each structure differing in the order and number of transshipment points and prior customers. A choice model of those tour structures was built. Factors such as commodity type, origin-destination facility type, truck type, distance and shipment size were significant, depending upon the structure.

Keywords: Transshipment, Freight, Tour Structure, Multinomial Logit

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INTRODUCTION AND PREVIOUS WORK

The "transportation problem" as it pertains to freight forecasting components of travel models, involves choice of destinations given that a whole shipments is transported in two or more stages. In a two-stage process, for example, the first stage might consist of transporting a product from the point of production to a transshipment point, and a second stage would then consist of transporting those goods from the transshipment point to a point of consumption. A large number of shipments pass through transshipment points during their journey until they reach their final destination. There are many reasons for transshipment; a shipment from a producer might be split into multiple, smaller shipments at a transshipment facility (e.g. terminal, warehouse or distribution center) with several ultimate destinations. Alternatively, a shipment might be taken indirectly to its consumer because other shipments in the truck must be delivered first. 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. 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. The Commercial Vehicle Survey, provided by the Ontario Ministry of Transportation, proved to have particularly useful data on transshipment.

This paper focuses on developing a tour structure model, in which shipments either pass through one or more intermediate points (transshipment point or another consumer) or go directly from the point of production to the point of consumption. The model targets the specific distinctiveness of establishments and the trip characteristics. Factors such as location, origin facility type, destination facility type, commodity type, truck type, distances and shipment size are most likely to affect the decision of how an industry might deliver its products to another establishment.

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. 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. Freight modeling is increasingly giving attention to the fact that the development of both production systems and logistics is having a fundamental influence on the amount and structure of freight demand. In this context, a trend towards experimental microscopic models on commercial transport has come up in recent years. These new models put an emphasis on the actors such as shippers and forwarders.

The lack of a transshipment component within most freight forecasting models is likely due to the extreme variety of transshipment decisions, which depend on products, markets and local economic factors. While it may be possible for a freight model to theoretically mimic a wide range of decision processes, it would be far simpler to develop transshipment relationship empirically, provided a suitably comprehensive database could be obtained. An empirical model has the additional advantages of (a) aggregating experiences across closely related products and industries, (b) providing a result that can be immediately incorporated into freight models and (c) validating existing theory and conventional wisdom.

Tour-based models, which have recently become popular for passenger travel forecasting *(1)*, are sequential models from an origin to multiple destinations taking into account the time and space constraints among the trips of the same tour. This means that the model considers the origin of the trip, then the next stop, which may be the workplace or in the case of freight it may be a warehouse, terminal or retail store. Hunt and Stefan (*2*) developed a tour-based model in the Calgary Region that accounts for truck routes involving all types of commercial vehicles as well as all sectors of the economy. They used a Monte Carlo technique to assign attributes to each of the tours which include tour purpose, vehicle type, next stop purpose, next stop location and next stop duration. Their selection of probabilities used in the microsimulation process were established using logit models estimated with choice data collected in local surveys. Donnelly (*3*) developed a model capable of representing the interactions of agents and elements for freight demand and the factors that influence those interactions. The components of the model include economic drivers, modal alternatives, transshipment, exports, imports, shipment generation, destination and vehicle choice, and finally a tour optimization. The resulting model was used in a freight simulation with traditional traffic assignment methods.

As indicated by Hunt and Stefan, a tour structure models would have particular advantages within a microsimulation. A microsimulation provides a means of modeling behavioral patterns exhibiting high degrees of variability. The interaction between shippers and carriers is an excellent example of such behavior. Boerkamps and van Binsbergen (*4*) discussed the theory and applications of GoodTrip which was one of the early commodity-based microsimulation efforts. This model estimates goods flows, urban freight traffic and its impacts. It determines logistical performance and environmental effects of alternatives for urban goods distributions, emphasizing the concentration of goods flows, destinations and routes.

Wisetjindawat, Sano, and Matsumoto (*5*) developed a commodity-based model to explain a commodity's movements as an outcome of its flow through several freight agents in a supply chain. The model reproduces each firm individually. The model covers just the steps of commodity generation and distribution. Generated commodities are linked from the point of production to the point of consumption according to the attractiveness of each production point, resulting in commodity flows from firm to firm over the entire area according to their relationships in supply chains.

Ben-Akiva, de Jong, and Baak (*6*) developed a model to estimate the transport costs, shipment size frequency and mode distribution to predict the regional and interregional freight movement in Norway. The model determines the optimal transshipment location for each type or tour chain and O-D zone. Then the shipment size and tour chain are determined from all available options for a firm-to-firm flow to finally determine the one with the lowest cost which becomes the transport chain choice.

While maybe not as logistically-detailed as studies cited earlier, the multi-state regional model of the Mississippi Valley Freight Coalition (MVFC) is the stepping-off point for this research (*7*). The MVFC model is a microsimulation, where the probability of any of eight tour structures is obtained from historical percentages that vary by commodity, only. However, the tour structures allow the model to determine the number of separate trips between the producer and consumer, to find suitable transshipment locations among known warehouses and terminals, to ascertain trip lengths and to sequence the trips correctly for dynamic traffic assignments.

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 origins, 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. This study used the 2001 survey, which is the latest that Ontario was willing to share. That survey collected more than 40,000 samples.

The Ontario Commercial Vehicle Survey commodity coding is done by using the Standard Classification of Transported Goods (SCTG), so the data is consistent with databases in the U.S.

The difference between commodities is important to the analysis of the possible transshipment points made during a journey. While the Ontario 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 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

The truck types considered by the CVS are:

1. Type 1 – Tractor & Trailer
2. Type 2 – Tractor & 2 Trailers
3. Type 3 – Tractor & 3 Trailers
4. Type 4 – Straight Truck
5. Type 5 – Straight Truck
6. Type 6 – Tractor Only
7. Type 95 - Other

PRELIMINARY ANALYSIS

First Cut Data Analysis

The majority of the trucks contain manufactured products, transportation, wood products and foods, with the leading commodity being manufactured products (16.07%). The trip facilities are critical indicators of the transshipment locations. The leading origin facilities were Manufacturer, Truck Terminal (driver's carrier) and Warehouse/Distribution Center. Terminals and Warehouse/Distribution Center are considered possible transshipment locations, which resulted in 52% of origins being transshipment locations. As with the origin facilities, the majority (54%) of the destination facilities were terminals or warehouses. A warehouse at the destination end may or may not be a transshipment point, depending upon its proximity to the point of consumption. If more than 50% of origins and more than 50% of destination are at transshipment points, then a very large percentage of all truck trips involve transshipment at one end or the other. An O-D facility matrix is essential for understanding commodity shipment behaviors. Table 1 shows the O-D facility patterns found in the Ontario CVS.

The persuasiveness of transshipment is evident in this table. However, the most interesting result of this table is that there are many trips which have both their origin and their 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 explicitly 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 two legs.

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 transshipped. Table 2 shows a summary of the trips by commodity at the destination end. This table revealed that most of the commodities involve a transshipment location. 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. Agricultural products, manufactured products and transportation are those commodities that are most likely to be transshipped. It is important to mention that Table 2 only shows the trips at the destination end, and their origin could be from another transshipment location. Indeed, based on the CVS a significant amount of trips were originated at a transshipment location, either a truck terminal or a warehouse, meaning that many trips involve three legs. During this analysis it was found that manufactured goods are largely carried from or to transshipment points with a total of 83% being transshipped at the origin and a total of 72% being transshipped at the destination.

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 any other trips covering the same distance between the point of production and the point of consumption. Analysis revealed that agricultural products and manufactured products were among the commodities that have the longer trip distances. Furthermore, it was found that transshipment occurs more frequently for longer trips.

The available literature suggests there is a need for additional data analysis on transshipment that considers common behavioral mechanisms across firms within a whole economy. Furthermore, there is a potential need for models which may be conveniently incorporated into existing travel demand forecasting frameworks. The reasons for choosing logit analysis for transshipment are:

a. The Ontario CVS is a large database which contains many potentially interesting variables. There was a need for a statistical method that can find salient effects.

b. A choice model is natural, elementary and interpretable and, once calibrated, can be used for forecasting.

Tour-based Approach Development

Figure 1 illustrates some alternative tour structure. Within this rather simple diagram, there are three possible structures.

- 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 the end-consumer

For analysis purposes the supply chain exists so long as the commodity remains intact or separately identifiable. Once the commodity is used as a raw material in another product or process, the supply chain is terminated. Since the analysis is concerned with the delivery of a particular shipment, the structures do not include any trips in which the truck would be empty or on a backhaul.

The tour-based approach developed in this paper accounts for all the commodities provided in the dataset. The establishments that are used in the tour generation are segregated into three facility type categories. The facility types to be considered are: Producer (P), Consumer (C) and Warehouse (W) (also includes truck terminals). 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.

Tour Structures

The previous analysis revealed that most 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 final destination or its consumer. The next analysis involves a fuller range of possible tour structures. Figure 2 summarizes those structures that could be discerned from the Ontario CVS.

The tour structures were created 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. Long arrows (or long dashes) indicate trips that are distinctively longer in distance than any other trips in the structure. Full information was available only for trip origins and trip 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.

As shown in Figure 2, there are a total of eight different tour structures. The tour structures analysis revealed that P-W-W-C was the structure with the largest amount of trips, followed by P-W---C. As mentioned the tour structures with long arrows (or dashes) indicate trips longer in distance than any other trips in the structure. For example, there are about one-sixth as many structures of P---W-C than P-W---C in the database. This means that transshipment is most likely to occur near the origin. 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 account for 74% of all structures. Meanwhile, agricultural products have origins at farms or elevators, and their destination are places such as 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 just 14% of shipments. The only commodity group that shows a relatively high probability of being shipped directly from its origin to their destination is minerals & products (36%). Long tour structures with multiple consumers are rare in all cases.

TOUR STRUCTURES MODEL

The Ontario Commercial Vehicle Survey contains information on origin/destinations, routes used, goods carried, weights (vehicle, axle and commodity), vehicle dimensions and driver characteristics. Among all the data obtained from the database, previous analysis (*8, 9*) revealed that commodity types, facility types, truck types, distance and shipment size were significant variables to consider in the model development.

This model should describe the choice of a specific tour structure based on selected attributes. Since there are eight discrete tour structures, a multinomial logit technique is applied.

Given the fact the commodity type, facility types, truck types, distance and shipment size were all important attributes and were significant in previous analyses they should be considered for inclusion in the deterministic utility equation of the logit model.

The model must recognize that the movement of agricultural commodities differs from the movement of manufactured commodities. All agricultural products have their origins at farms or elevators, while their destinations are other elevators, ports, other storage facilities, retail or processors. The location of these might be in the same municipality or state/province, meaning that the distances might be close, if it is an agricultural state/province. However, manufactured products might be transported into assembly locations before reaching a retail store. The distance between a manufactured location and their destination (e.g., retail store) might be somewhat larger than for agricultural products. The shipment size also plays a significant role when considering transshipment locations. Bigger shipments might point to different destinations, and those might consider a separate transshipment location to split them.

Formally, for a shipment originated at any given producer, the utility of a tour structure is specified as:

$$U_{Tour} = ASC_{tour} + \beta_{commodity} + \beta_{origin\ facility} + \beta_{destination\ facility} + \beta_{truck\ type} + \beta_1(\text{total distance}) + \beta_2(\text{shipment size}) \tag{1}$$

Where,

ASC_{tour}	alternative specific constant for tour structure;
$\beta_{commodity}$	coefficient for commodity type;
$\beta_{origin\ facility}$	coefficient for origin facility type;
$\beta_{destination\ facility}$	coefficient for destination facility type;
$\beta_{truck\ type}$	coefficient for truck type;
β_1	coefficient for distance between producer and consumer;
β_2	coefficient for shipment size;
distance	distance between producer and consumer in miles; and
shipment size	shipment size in pounds

Dummy variables for each of the attributes were used to estimate the model, except for distance and shipment size. That is, the model assigns a value for each specific commodity type, facility type, and truck type. Great circle distances between the commodity origin and destination facilities were obtained based on their coordinates (latitude and longitude), although the distance between the trip origin and destination was calculated over-the-road within the database.

Table 3 shows the estimated coefficients and their t-scores for Equation 1.

The model was re-estimated several times in order to obtain the coefficients that best predict what is happening in the database. Overall, most of the individual coefficients have t-scores indicating that the estimated values are significant for the tour structures. There are some coefficients that do not have significant values (for example, $\beta_{residences}$) for any structure. Of course, some variables were excluded because of the requirements of dummy variables. The initial log-likelihood was -36015.101 while the final log-likelihood was -23054.016. While it is not a huge drop on the log-likelihood, it is acceptable. The rho square obtained was 0.311.

For this model the alternative specific constants (ASC) vary from each other with a highest value for the tour structure P-W---C (0.06), as expected. This particular constant reflects that most of the shipments pass through transshipment points before their final destination, and that the origin and the transshipment location are within a short distance. The least ASC obtained is for tour structure P-C-C-C with a constant of -4.25 indicating that this structure is unlikely to be chosen.

There are different commodities, different O-D facility types, and different truck types; however, some of them were not significant in some of the tour structures. For example, agricultural products do not have a coefficient for tour structure P-C, meaning that these commodities will not influence the choice of this particular tour structure. That is not the case for the tour structure P-W-W-C where the coefficient for agricultural products is 0.209. The reason why the P-C alternative does not have a value, whereas, P-W-W-C does is that many agricultural products (e.g., wheat and corn) have their origins at farms or elevators and many of those products need to be stored at elevators before reaching their final destination (e.g. feedlots, ethanol plants, and food processing plants). After those agricultural products have been dried and stored, they might be split at a transshipment location into different shipments to reach their final destination.

Another interesting result of this model relates to the coefficient for manufactured products. The P-C alternative obtained a value (-1.11) for this coefficient. However, the t-score was -16.18 which strongly indicates that manufactured products will not go directly from the producer to the consumer. The tour structure P-W-W-C obtained a coefficient of 0.246 with a t-score of 5.16 indicating that most manufactured products will have a transshipment location. The remaining tour structures did not have a significant value for manufactured products, and thus this particular commodity did not influence their choice.

A better idea of how different commodities tend toward different tour structures can be gleaned from Figure 3. The order of bars from left to right as shown in the figure are the same as the order from top to bottom shown at the right of the figure. Two commodity groups, metals and machinery, have been removed because they do not have coefficients that vary significantly according to the tour structure. The fact that some commodities have mostly odds ratios less than 1 and other commodities have odds ratios mostly greater than 1 is due to the effects of other variables in the model that interact with commodities. It is the relative heights of the bars within a single commodity that is most interesting. In this figure, tour structures have been ordered left-to-right roughly by complexity. Some relationships are immediately evident. Food, chemical and transportation products tend toward structures without warehousing but with multiple customers. Agricultural and manufactured products show an interesting tendency toward multiple warehouses (or elevators). The data suggests that any commodity could have any tour structure.

Total distance is an important factor for each of the tour structures involving transshipment locations. For example, P-C-C-C and P-C-C structures have the largest magnitude β_1 of about 0.0004, indicating that longer shipments have less chance of using these particular tour structures that do not contain any warehousing. Shipment size also has some influence on choosing to transship or not, as it can be seen that the coefficients are consistent in sign and magnitude for all structures except P-C, for which shipment size is inversely related to the probability of this structure being chosen.

The tour structure model, as is, estimates the utility function for a tour structure based on several variables which includes the commodity. However, it is entirely possible that different commodities might not follow the same patterns. To see if this is the case, separate models were estimated for food and for manufactured products. The food model was re-estimated several times to obtain the variables that best predict what is happening for this particular commodity. The model ended up being reduced to just the variables of tour structure, distance and shipment size. On the other hand, the manufactured products model included these same variables but also included some truck types. For both of the models there were an acceptable drop on the log-likelihood (e.g., -8559.902 to -3691.307 for manufactured products), however the rho square obtained did not show much of an improvement (e.g., from 0.311 for the original tour structure model to 0.335 for the manufactured products model).

The tour structure model, as opposed to the commodity models, contains more variables which makes it potentially sensitive to a wider range of inputs. For this reason, the original tour structure model, containing all commodities, would be a better approach for applications such as the MVFC Freight Model.

CONCLUSION

The transshipment model developed in this paper forecasts tour structure choice. The model was developed using the Ontario Commercial Vehicle Survey, which uses the same commodity coding used in the U.S Commodity Flow Survey. However, the model developed used aggregated commodity types, obtained from the Ontario CVS. Significant coefficients were found for commodity type, origin facility type, destination facility type, truck type, shipment size, and distance between the commodity's origin and destination, depending upon the structure.

The Ontario CVS contains information on truck trips, which could be used to develop a choice model of tour structures. However, the number of survey samples in the database is too small to build a model for highly detailed commodities. Some of the results of the model could be transferable to the United States or other countries. Particularly, the prevalent tour structures as well as some of the significant coefficients could be used to when transferring the results.

A tour structure model opens up the possibility of developing a model of transshipment location choice. Such a model would lead to an origin-destination truck table where each leg of each tour would be separately represented.

Future work should include the possibility of using other forms of logit models, such as mixed logit or nested logit, to ascertain other patterns in the database.

The tour structure model developed in this paper is suitable for both conventional and microsimulation freight forecasting models, particularly for statewide and multistate applications, such are the MVFC region. The tour structure model may not be sufficiently sensitive for inclusion, as is, in forecasting models of urban regions because of the tendency for Ontario to capture principally long-haul trips in their survey.

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TABLE 1 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 O-D 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

TABLE 2 Truck Trips by Commodity and Destination Facility

	Trip Destination Facility					
	Truck Terminal - Your Carrier	Truck Terminal - Another Carrier	Ware-house/ Distri-bution Center	Retail Outlet	Commercial/Building Office	Construction Sites
Agricultural Products	354	35	518	357	2	4
Food	736	59	1163	727	7	3
Minerals & Products	381	20	316	157	15	235
Petroleum & Products	173	15	153	214	4	21
Chemicals & Products	666	54	678	212	14	7
Wood & Products	853	86	921	321	17	32
Metals & Products	519	52	583	180	11	44
Machinery & Electrical	393	27	371	161	17	41
Manufactured Products	1857	186	1287	565	51	17
Transportation	1252	92	630	348	13	5
Waste & Scrap	170	11	74	22	2	1

TABLE 3 Coefficients for Tour Structure Choice Model

		Tour Structure	
	Coefficient	**P-C**	**P-W---C**
Attribute or Constant		***Value (t-score)***	***Value (t-score)***
Alternative Specific Constant	ASC	-0.232 (-4.54)	0.06 (6.22)
Commodities	$\beta_{\text{Agricultural Products}}$	-	-
	β_{Food}	0.418 (3.12)	0.561 (4.53)
	$\beta_{\text{Minerals \& Products}}$	-0.907 (-6.23)	-0.585 (-7.33)
	$\beta_{\text{Petroleum \& Products}}$	1.01 (3.68)	0.689 (3.01)
	$\beta_{\text{Chemicals \& Products}}$	0.676 (4.63)	0.348 (2.95)
	$\beta_{\text{Wood \& Products}}$	-	-
	$\beta_{\text{Metals \& Products}}$	-	-
	$\beta_{\text{Machinery \& Electricals}}$	-	-
	$\beta_{\text{Manufactured Products}}$	-1.11 (-16.18)	-
	$\beta_{\text{Transportation}}$	-	-
Origin Facility Type	$\beta_{\text{Primary Producer}}$	-	-
	$\beta_{\text{Manufacturer}}$	-0.158 (-2.65)	0.029 (2.79)
Destination Facility Type	$\beta_{\text{Retail Outlet}}$	0.281 (2.78)	0.102 (2.76)
	$\beta_{\text{Commercial/Office Building}}$	-	-
	$\beta_{\text{Construction Sites}}$	-0.461 (-2.64)	-
	$\beta_{\text{Residences}}$	-	-
Truck Type	$\beta_{\text{Tractor \& Trailer}}$	-1.15 (-3.04)	-1.11 (-3.02)
	$\beta_{\text{Tractor \& 2 Trailers}}$	-	-
	$\beta_{\text{Straight Truck}}$	-	-
	$\beta_{\text{Straight Truck \& Trailer}}$	-	-
Distance	β_1	-0.000394 (-3.4)	-0.000393 (-3.89)
Shipment Size	β_2	-0.0000202 (2.89)	0.0000187 (2.45)

TABLE 3 Coefficients for Tour Structure Choice Model (continuation)

	Tour Structure		
	Coefficient	**P---W-C**	**P-C-C**
Attribute or Constant		***Value (t-score)***	***Value (t-score)***
Alternative Specific Constant	ASC	-0.308 (8.15)	-1.31 (-15.32)
Commodities	$\beta_{\text{Agricultural Products}}$	-	-0.400 (-2.79)
	β_{Food}	0.684 (3.42)	1.062 (6.84)
	$\beta_{\text{Minerals \& Products}}$	-0.625 (-5.69)	-0.857 (-6.03)
	$\beta_{\text{Petroleum \& Products}}$	0.835 (3.69)	-
	$\beta_{\text{Chemicals \& Products}}$	0.467 (3.01)	0.963 (5.95)
	$\beta_{\text{Wood \& Products}}$	-	-
	$\beta_{\text{Metals \& Products}}$	-	-
	$\beta_{\text{Machinery \& Electricals}}$	-	-
	$\beta_{\text{Manufactured Products}}$	-	-
	$\beta_{\text{Transportation}}$	-	0.637 (2.79)
Origin Facility Type	$\beta_{\text{Primary Producer}}$	-	-
	$\beta_{\text{Manufacturer}}$	0.039 (2.55)	-0.121 (-2.32)
Destination Facility Type	$\beta_{\text{Retail Outlet}}$	0.291 (2.61)	0.265 (2.97)
	$\beta_{\text{Commercial/Office Building}}$	-	-
	$\beta_{\text{Construction Sites}}$	-	-1.486 (-2.11)
	$\beta_{\text{Residences}}$	-	-
Truck Type	$\beta_{\text{Tractor \& Trailer}}$	-1.03 (-3.16)	-1.11 (-3.03)
	$\beta_{\text{Tractor \& 2 Trailers}}$	-	-
	$\beta_{\text{Straight Truck}}$	-	-
	$\beta_{\text{Straight Truck \& Trailer}}$	-	-
Distance	β_1	-0.000471 (-3.59)	-0.000379 (-3.51)
Shipment Size	β_2	0.0000198 (2.76)	0.0000181 (2.88)

TABLE 3 Coefficients for Tour Structure Choice Model (continuation)

		Tour Structure	
	Coefficient	**P-W-W-C**	**P-W---C-C**
Attribute or Constant		***Value (t-score)***	***Value (t-score)***
Alternative Specific Constant	ASC	0	-0.402 (-17.41)
Commodities	$\beta_{\text{Agricultural Products}}$	0.209 (3.41)	-0.332 (-2.98)
	β_{Food}	0.871 (6.87)	0.888 (6.83)
	$\beta_{\text{Minerals \& Products}}$	-0.943 (-11.29)	-0.468 (-2.85)
	$\beta_{\text{Petroleum \& Products}}$	0.674 (2.67)	1.033 (3.58)
	$\beta_{\text{Chemicals \& Products}}$	0.709 (5.07)	0.879 (5.58)
	$\beta_{\text{Wood \& Products}}$	0.086 (2.02)	-0.611 (-3.73)
	$\beta_{\text{Metals \& Products}}$	-	-
	$\beta_{\text{Machinery \& Electricals}}$	-	-
	$\beta_{\text{Manufactured Products}}$	0.246 (5.16)	-
	$\beta_{\text{Transportation}}$	0.227 (4.21)	0.451 (4.12)
Origin Facility Type	$\beta_{\text{Primary Producer}}$	-	-
	$\beta_{\text{Manufacturer}}$	-0.170 (-1.97)	-0.759 (-3.39)
Destination Facility Type	$\beta_{\text{Retail Outlet}}$	0.221 (2.57)	0.229 (2.68)
	$\beta_{\text{Commercial/Office Building}}$	-	-
	$\beta_{\text{Construction Sites}}$	-	-1.64 (-2.20)
	$\beta_{\text{Residences}}$	-	-
Truck Type	$\beta_{\text{Tractor \& Trailer}}$	-1.017 (-2.86)	-1.13 (-2.82)
	$\beta_{\text{Tractor \& 2 Trailers}}$	-	-
	$\beta_{\text{Straight Truck}}$	-	-
	$\beta_{\text{Straight Truck \& Trailer}}$	-	-
Distance	β_1	-0.000166 (-1.95)	-0.0000897 (-2.27)
Shipment Size	β_2	0.0000196 (2.98)	0.0000192 (2.09)

TABLE 3 Coefficients for Tour Structure Choice Model (continuation)

		Tour Structure	
	Coefficient	**P---W-C-C**	**P-C-C-C**
Attribute or Constant		***Value (t-score)***	***Value (t-score)***
Alternative Specific Constant	ASC	-2.088 (-13.84)	-4.25 (-12.12)
Commodities	$\beta_{\text{Agricultural Products}}$	-0.498 (-3.01)	-0.419 (-2.95)
	β_{Food}	0.859 (6.90)	1.111 (6.77)
	$\beta_{\text{Minerals \& Products}}$	-0.678 (-2.87)	-1.394 (-1.93)
	$\beta_{\text{Petroleum \& Products}}$	0.925 (3.62)	-
	$\beta_{\text{Chemicals \& Products}}$	0.579 (5.63)	1.008 (5.52)
	$\beta_{\text{Wood \& Products}}$	-0.797 (-3.77)	-
	$\beta_{\text{Metals \& Products}}$	-	-
	$\beta_{\text{Machinery \& Electricals}}$	-	-
	$\beta_{\text{Manufactured Products}}$	-	-
	$\beta_{\text{Transportation}}$	0.313 (4.04)	0.667 (2.51)
Origin Facility Type	$\beta_{\text{Primary Producer}}$	-	-
	$\beta_{\text{Manufacturer}}$	-0.909 (-3.32)	-0.888 (-3.35)
Destination Facility Type	$\beta_{\text{Retail Outlet}}$	0.201 (2.63)	0.278 (2.80)
	$\beta_{\text{Commercial/Office Building}}$	-	-
	$\beta_{\text{Construction Sites}}$	-1.72 (-2.16)	-
	$\beta_{\text{Residences}}$	-	-
Truck Type	$\beta_{\text{Tractor \& Trailer}}$	-1.17 (-2.76)	-1.162 (-3.08)
	$\beta_{\text{Tractor \& 2 Trailers}}$	-	-
	$\beta_{\text{Straight Truck}}$	-	-
	$\beta_{\text{Straight Truck \& Trailer}}$	-	-
Distance	β_1	-0.0000901 (-2.23)	-0.000397 (-3.24)
Shipment Size	β_2	0.0000191 (2.05)	0.0000190 (2.76)

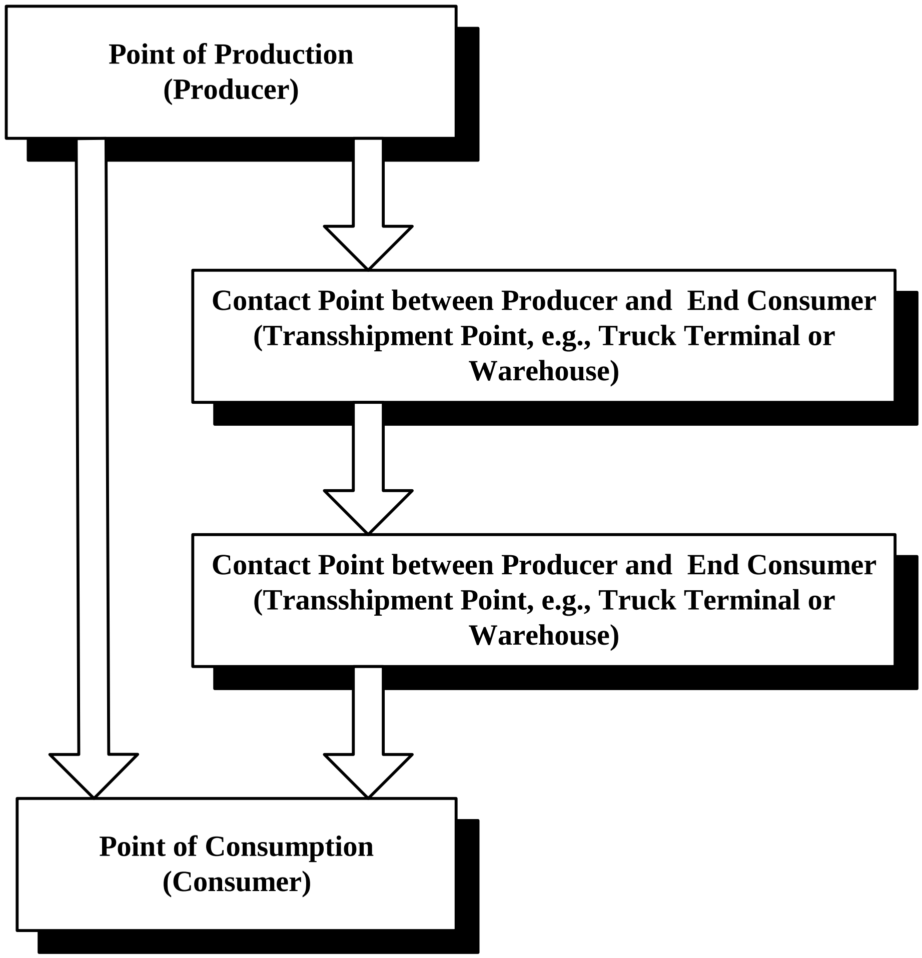

FIGURE 1 Tour-Based Structure Modeling

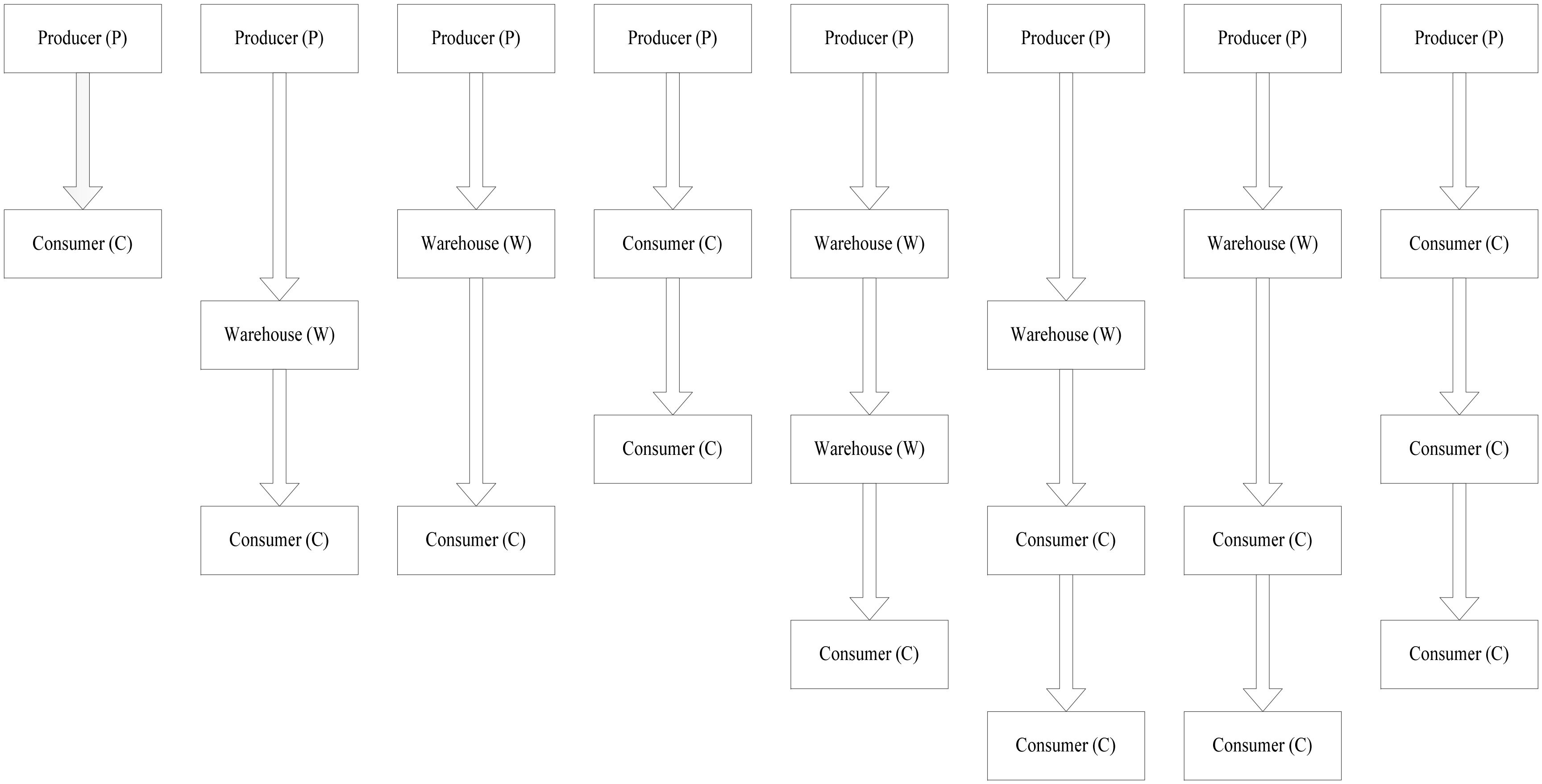

FIGURE 2 All Tour Structures Found in the Ontario CVS

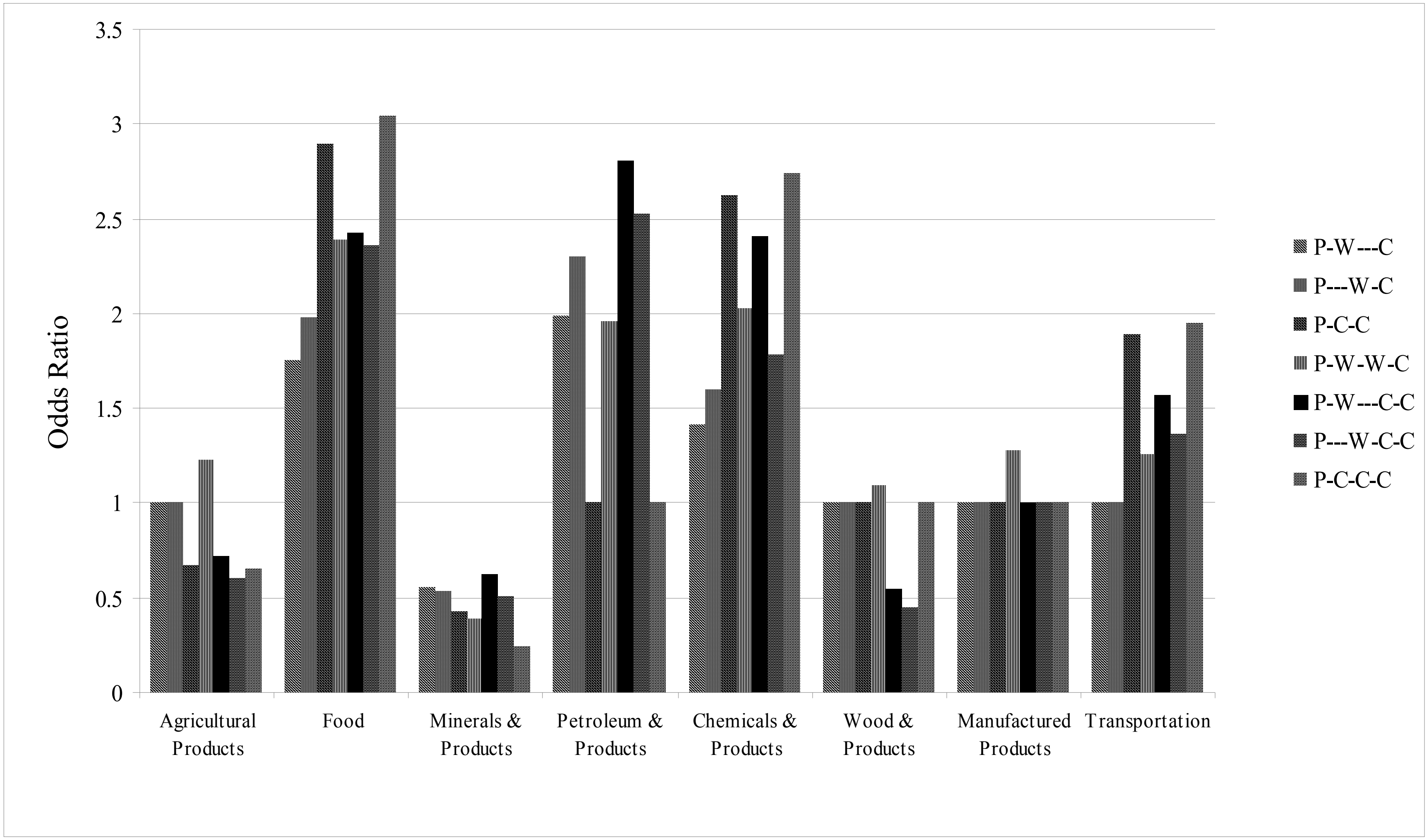

FIGURE 3 Odds Ratios of Selected Commodities